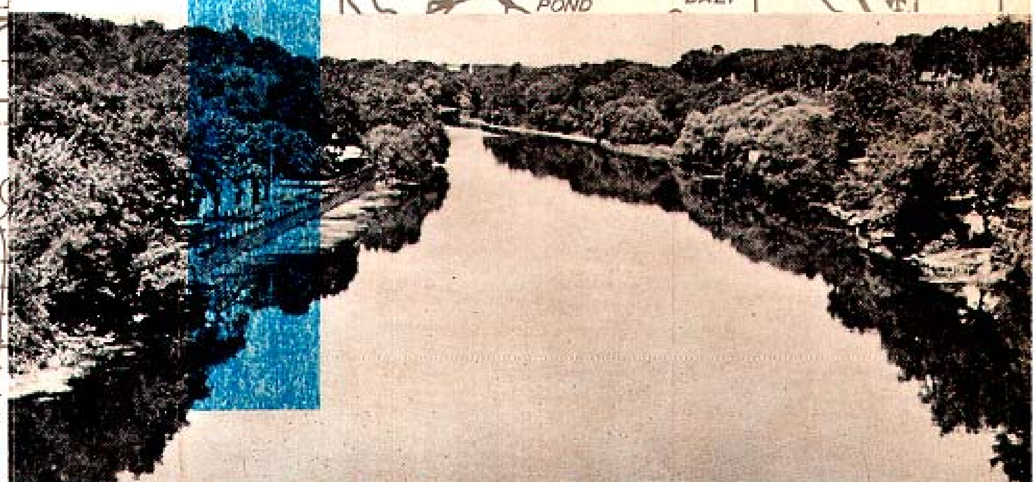
PLANNING REPORT NO. 13

A COMPREHENSIVE PLAN FOR THE MILWAUKEE RIVER WATERSHED



volume two

ALTERNATIVE PLANS AND RECOMMENDED PLAN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

COMMISSION MEMBERS

KENOSHA COUNTY
George C. Berteau, Chairman
Donald L. Klapper
Donald L. Knapp

RACINE COUNTY
Milton F. LaPour
Leonard C. Rauen
Garth R. Seehawer

MILWAUKEE COUNTY
Richard W. Cutler, Secretary
Richard C. Nowakowski
Norman C. Storck, P. E.

WALWORTH COUNTY
Eugene Hollister
Henry S. Lauterbach
John D. Voss

OZAUKEE COUNTY
Thomas H. Buestrin
James F. Egan, Vice-Chairman
Ralph J. Huiras

WASHINGTON COUNTY
Lawrence W. Hillman
Paul F. Quick
Joseph A. Schmitz, Treasurer

WAUKESHA COUNTY
Charles J. Davis
Lyle L. Link
Theodore F. Matt

MILWAUKEE RIVER WATERSHED COMMITTEE

Richard W. Cutler, Chairman . . . . Attorney, Brady, Tyrrell, Cotter & Cutler, Milwaukee; Member, Village of Fox Point Plan Commission; Commissioner, SEWRPC
Kurt W. Bauer, Secretary . . . . Executive Director, SEWRPC
Vinton W. Bacon . . . . .Professor, College of Applied Science and Engineering, University of Wisconsin-Milwaukee
Ray F. Blank. . . . . .Ozaukee County Board Supervisor
Clarence E. Boyke . . . . .Fond du Lac County Board Supervisor
Delbert J. Cook . . . . . Chairman, Cedar Creek Restoration Council
Arthur G. Degnitz . . . . Washington County Board Supervisor
Nick R. Didier. . . . . Realtor, Port Washington
Herbert A. Goetsch. . . . . .Commissioner of Public Works, City of Milwaukee
Howard W. Gregg . . . . General Manager, Milwaukee County Park Commission
LeRoy W. Grossman . . . . Director Emeritus, Capitol Marine Bank; Member, Milwaukee River Flood Control Board
Gilbert J. Howard . . . . . . .Fond du Lac County Board Supervisor
John J. Juntenen. . . . . County Planner, Sheboygan County
John T. Justen. . . . . President, Pfister & Vogel Tanning Company, Milwaukee
J. Bryan Keating. . . . . District Conservationist, U. S. Soil Conservation Service, Fond du Lac County
John L. Kratz . . . . .Citizen Member, Washington County
Thomas A. Kroehn. . . . . District Director, Southeast District, Wisconsin Department of Natural Resources
Ray D. Leary. . . . . . . Chief Engineer and General Manager, Milwaukee-Metropolitan Sewerage Commissions
Dean Livingston . . . . . District Conservationist, U. S. Soil Conservation Service, Sheboygan County
Reuben T. Lueloff . . . . .President, Village of River Hills
Dr. Darrell M. Martin . . . . Resident Manager, St. Regis Paper Company, Milwaukee
Carl Otte . . . . .Sheboygan County Board Supervisor
George Watts. . . . . . . President, George Watts & Sons, Milwaukee
Donald W. Webster . . . . . . Consulting Civil Engineer, Milwaukee

COMMISSION STAFF

Kurt W. Bauer, P.E. . . . . Executive Director

Harlan E. Clinkenbeard. . . . . Assistant Director

Philip C. Evenson . . . . Assistant to the Director

Dallas R. Behnke. . . . . Chief Planning Illustrator

William E. Creger, P.E. . . . . Chief Transportation Planning Engineer

Donald M. Drews . . . . Administrative Officer

James W. Engel. . . . . Chief of Systems Engineering and Data Processing

Robert L. Fisher . . . . Chief Land Use Planner

William D. McElwee, P.E. . . . . . Chief Natural Resources Planner

Eugene E. Molitor . . . . Chief of Planning Research

Norbert S. Theine, P.E. . . . . Chief Community Assistance Planner

PLANNING REPORT

NUMBER 13

volume two

A COMPREHENSIVE PLAN FOR THE MILWAUKEE RIVER WATERSHED

ALTERNATIVE PLANS AND RECOMMENDED PLAN

Southeastern Wisconsin Regional Planning Commission
Milwaukee River Watershed Study
Old Courthouse
Waukesha, Wisconsin
53186

The preparation of this report was financed in part through a joint planning grant from the Wisconsin Department of Natural Resources; the U. S. Department of Housing and Urban Development under the provisions of Section 701 of the Federal Housing Act of 1954, as amended; and the U. S. Environmental Protection Agency under the provisions of the Federal Water Pollution Control Act, as amended.

October 1971

Inside Region $10.00
Outside Region $15.00

(This page intentionally left blank)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

916 NO. EAST AVENUE • WAUKESHA, WISCONSIN 53186 • TELEPHONE (414) 547-6721

Serving the Counties of: KENOSHA
MILWAUKEE
OZAUKEE
RACINE
WALWORTH
WASHINGTON
WAUKESHA

October 7, 1971

STATEMENT OF THE CHAIRMAN

In August 1967 the Commission began a four-year comprehensive study of the Milwaukee River watershed in southeastern Wisconsin. The purpose of the study, as well stated in the Milwaukee River Watershed Prospectus, was to prepare a comprehensive plan for the physical development of the watershed designed to assist the federal, state, and local units of government concerned in solving the serious problems of flooding, water pollution, and changing land use which exist within the watershed. Because the headwater portions of the watershed lie outside the seven-county Southeastern Wisconsin Region in Fond du Lac and Sheboygan Counties, the Commission requested and obtained cooperation, including financial participation, from the County Boards of these two counties in the conduct of this very important watershed study.

In December 1970 the Commission published the first volume of the two-volume final planning report on the Milwaukee River watershed study. That first volume presented a summary of the factual findings of the planning and engineering inventories conducted under the study; identified and, to the extent possible, quantified the land and water resource-related problems of the watershed; and presented pertinent forecasts of anticipated growth and change within the watershed. The inventories and forecasts set forth in the first volume provided the basis for the preparation of alternative watershed plan elements and for the selection of a recommended comprehensive watershed plan from among these alternative elements.

This, the second and final volume of the planning report, presents the alternative land use, natural resource protection, park and outdoor recreation, parkway and scenic drive, flood control, stream and lake water pollution abatement, and water supply plan elements considered; describes the recommended comprehensive plan for the watershed; and sets forth detailed recommendations on the means for carrying out the plan.

The recommended watershed plan set forth in this volume represents another important element in the comprehensive plan for the physical development of the Southeastern Wisconsin Region, which the Commission is charged by statute with preparing. As is true of all of the Commission's work, the Milwaukee River watershed plan is entirely advisory to the local, state, and federal units of government concerned. The recommended plan elements and implementation devices set forth in this report are intended to provide a point of departure against which watershed development proposals can be evaluated as they arise on a day-to-day basis. Upon formal adoption of the final watershed plan by this Commission, an official copy thereof will be transmitted to all affected local, state, and federal units and agencies of government, with a request for their consideration and formal adoption and appropriate implementing action. Plan implementation must necessarily be achieved through the cooperative action of all of the governmental units and agencies operating within the watershed, with heavy emphasis, however, upon the role of the county and state levels of government.

In its continuing role of acting as a center for the coordination of planning and plan implementation activities within the Region, the Commission stands ready to provide such assistance as may be requested of it to the various units and agencies of government concerned in implementation of the Milwaukee River watershed plan.

Respectfully submitted,

George C. Berteau
Chairman

(This page intentionally left blank)

Table of Contents

	Page
Chapter I—INTRODUCTION	1
Formulation of Objectives and Standards	1
Plan Design	3
Plan Test and Evaluation	3
Plan Selection and Adoption	3
Chapter II—WATERSHED DEVELOPMENT OBJECTIVES, PRINCIPLES, AND STANDARDS	7
Basic Concepts and Definitions	7
Watershed Development Objectives	7
Engineering Design Criteria for the Milwaukee River Watershed	8
Rainfall-Frequency Relationships	8
Storm Sewer Design Criteria	20
Rainfall-Runoff Relationships	21
Water Surface Elevation-Discharge Relationships	21
Flood Routing	21
Flood Frequency	21
Overriding Considerations	22
Economic Criteria	22
Benefit-Cost Analysis	23
Time Value of Money—Interest	23
Project Benefits	24
Project Costs	24
Relationship of Economic and Financial Analysis	25
Staged Development	25
Summary	25
Chapter III—LAND USE BASE AND ALTERNATIVE NATURAL RESOURCE PROTECTION, OUTDOOR RECREATION AND RELATED OPEN SPACE, AND PARKWAY PLAN ELEMENTS	27
Introduction	27
Land Use Base	27
Design Methodology	27
Land Use Base Description	29
Residential Land Use	31
Retail and Service Land Use	31
Industrial Land Use	31
Transportation, Communication, and Utility Facility Land Use	33
Agricultural Land Use	33
Other Land Uses	33
Alternative Natural Resource Protection Plan Elements	33
Minimum Alternative Natural Resource Protection Plan Element	35
Urban Environmental Corridor Acquisition	36
High-Value Wetland Acquisition	36
High-Value Woodland Acquisition	36
Primary Environmental Corridor Zoning	38
Wetland and Woodland Resource Management	38
Concluding Remarks—Minimum Alternative Natural Resource Protection Plan Element	39
Intermediate Alternative Natural Resource Protection Plan Element	39
Optimum Alternative Natural Resource Protection Plan Element	40
Concluding Remarks—Alternative Natural Resource Protection Plan Elements	40
Alternative Outdoor Recreation and Related Open-Space Plan Elements	43
Outdoor Recreation Demand	43
Potential Park and Related Open-Space Sites	44
Recreational Land Standards in the Regional Land Use Plan	44
Minimum Alternative Outdoor Recreation Plan Element	44
Intermediate Alternative Outdoor Recreation Plan Element	47
Optimum Alternative Outdoor Recreation Plan Element	48
Concluding Remarks—Alternative Outdoor Recreation and Related Open-Space Plan Elements	48
Alternative Parkway and Scenic Drive Plan Elements	50
Alternative Parkway Drive Plan Elements	52
Milwaukee River Parkway Arterial (Regional Transportation Plan)	52
Milwaukee River Parkway Drive—Lincoln Memorial Drive to Good Hope Road	54

	Page
Milwaukee River Parkway Drive—Good Hope Road to Grafton	54
Scenic Drive Plan Elements	61
Concluding Remarks—Parkway and Scenic Drive Plan Elements	61
Summary	63
Chapter IV—ALTERNATIVE FLOOD CONTROL PLAN ELEMENTS	67
Introduction	67
Review of Previous Flood Control Investigations	68
Federal Works Progress Administration and Wisconsin Public Service Commission—1938	68
Wisconsin State Planning Board—1940	68
U. S. Soil Conservation Service—1961	68
U. S. Army Corps of Engineers—1964	69
U. S. Public Health Service—1965	69
U. S. Bureau of Outdoor Recreation—1966	69
Other Sources	69
Alternative Structural Flood Control Plan Elements	70
Reservoirs	70
Preliminary Identification of Reservoir Sites	71
Topographic and Structural Considerations	71
Recreational Evaluation	71
Proximity to Urban Population	71
Boating and Water Skiing	71
Picnicking and Sightseeing	73
Swimming	74
Fishing	74
Flood Control Potential	75
Flow Augmentation and Water Supply Potential	77
Preliminary Design of Spillways and Outlet Works	78
Selection of Reservoir Sites for Further Consideration	78
Waubeka Reservoir	80
Flood Control Operation and Resulting Benefits	82
Flow Augmentation and Water Supply Considerations	84
Recreation Development	88
Enhancement of Land Value and Local Income	88
Hydroelectric Power Evaluation	89
Land and Relocation Considerations and Costs	89
Dam and Outlet Work Design and Costs	90
Site Foundation Characteristics	90
Dam and Spillway Configuration	91
Foregone Opportunities and Costs	94
Reservoir Sedimentation Analysis	94
Water Quality Effects Attributable to Impoundment	95
Summary of Benefits and Costs	97
Horns Corners Reservoir	98
Flood Control Operation and Resulting Benefits	100
Flow Augmentation and Water Supply Consideration	101
Recreation Development	102
Enhancement of Land Value and Local Income	103
Hydroelectric Power Evaluation	103
Land and Relocation Considerations and Cost	103
Dam and Outlet Works Design and Costs	104
Site Foundation Characteristics	105
Dam and Spillway Configuration	105
Foregone Opportunities and Costs	106
Reservoir Sedimentation Analysis	107
Water Quality Effects Attributable to Impoundment	107
Summary of Benefits and Costs	110
Newburg Reservoir	111
Flood Control Operation and Resulting Benefits	112
Flow Augmentation and Water Supply Consideration	113
Recreation Development	114
Enhancement of Land Value and Local Income	115
Hydroelectric Power Evaluation	115
Land and Relocation Consideration and Cost	115
Dam and Outlet Works Design and Costs	117
Site Foundation Characteristics	117
Dam and Spillway Configuration	117
Foregone Opportunities and Costs	118
Reservoir Sedimentation Analysis	119
Water Quality Effects Attributable to Impoundment	119
Summary of Benefits and Costs	122
Horns Corners-Newburg Reservoirs Combination	123
System Storage Capability	123
Control and Conveyance Works	124

	Page
Summary of Benefits and Costs	124
Diversion Channel	127
Saukville Diversion Channel	127
Description of the Diversion System	127
Reexamination and Update	133
Dike-Floodwall Systems with Supplemental Structure Removal and Floodproofing	134
Dike-Floodwall Systems	134
Structure Removal and Floodproofing	137
Structure Removal and Costs	138
Structure Floodproofing and Costs	138
General Measures	138
Seepage Control	138
Relief from Sewer Backup	139
Protection from Overland Flow	139
Benefits Accruing from Dikes and Floodwalls with Structure Removal and Floodproofing	139
Dike-Floodwall System for the City of Glendale	139
Dike-Floodwall System for the City of Mequon	140
Dike-Floodwall System for the Village of Thiensville	149
Dike-Floodwall System for the Village of Saukville	151
Summary of Dike-Floodwall Systems	154
Alternative Nonstructural Flood Control Plan Element	155
Structure Floodproofing and Removal in the City of Glendale	157
Structure Floodproofing and Removal in the City of Mequon	157
Structure Floodproofing in the Village of Thiensville	160
Structure Floodproofing and Removal in the Village of Saukville	160
Structure Floodproofing and Removal in the Remainder of the Watershed	160
Summary of Structure Floodproofing and Removal Flood-Damage Control Alternative	162
Accessory Flood Control Plan Elements	163
Adequate Hydraulic Capacity of Bridges	163
Floodland Use Regulations	163
Extreme Flood Events on the Milwaukee River below the North Avenue Dam	172
Maintenance of Stream Gaging Stations	176
Flood Insurance	176
Major Channel Modifications	177
Engineering Investigations of Selected Dams	178
Concluding Remarks—Alternative Flood Control Plan Elements	178
Waubeka Reservoir	180
Horns Corners Reservoir	180
Newburg Reservoir	181
Horns Corners-Newburg Reservoirs Combination	182
Saukville Diversion Channel	183
Dike-Floodwall Systems with Supplemental Structure Removal and Floodproofing	183
Structure Floodproofing and Removal	184
Action of the Milwaukee Watershed Committee	184
Summary	186
Chapter V—ALTERNATIVE SURFACE WATER POLLUTION CONTROL PLAN ELEMENTS	189
Introduction	189
Alternative Stream Water Quality Management Plan Elements—Lower Watershed	191
Preliminary Identification and Rating of Combined Sewer Pollution Abatement Alternatives	191
Design Criteria	191
Tributary Area	191
System Conveyance Capacity	192
System Storage Capacity	192
Storage Requirements Based on Analysis of Milwaukee Data	194
Storage Requirements Based on Analysis of Chicago Data	196
Storage Evacuation Time	197
Rating Criteria	198
Potential for Meeting Water Quality Objectives	198
Aesthetic Characteristics	198
Disruptive Effect	198
Likelihood of Public Acceptance	198
Cost	199
Combined Sewage Storage Alternatives	199
Alternative 1—Buried Concrete Storage Tanks in Parks	199
Alternative 2—Floating Concrete Storage Tanks in Lake Michigan	203
Alternative 3—Collapsible Rubber Storage Tanks along the Milwaukee River	205

	Page
Alternative 4—Buried Concrete Storage Tanks under the Milwaukee River	207
Alternative 5—Diked Storage Lagoon in Lake Michigan	210
Alternative 6—Buried Concrete Storage Tank in Maitland Field	215
Alternative 7—Deep Tunnel Conveyance and Mined Storage Beneath the Milwaukee Harbor or Diked Surface Storage Reservoir	217
Alternative 8—Open Storage Reservoirs along the Milwaukee River Banks	219
Alternative 9—Storage under Piers and Waterfront Structures	219
Alternative 10—Conveyance of Sewage to North Avenue Dam for Release to the Milwaukee River	219
Flow-Through or In-Flow Treatment Alternatives	221
Alternative 11—Allis-Chalmers Rotating Biological Contactor	221
Alternative 12—Rex Chainbelt Screening/Dissolved-Air Flotation System	222
Alternative 13—Instream Treatment	226
Combined Sewer System Separation Alternatives (Alternatives 14 and 15)	228
Application of Separation Alternatives in the Watershed Study	235
Concluding Remarks—Preliminary Screening Process	237
Detailed Consideration of Selected Alternatives	238
Deep Tunnel Conveyance and Mined Storage Beneath the Milwaukee Harbor	239
Control Structures and Vertical Shafts	240
Conveyance Tunnels	240
Mined Storage Reservoir	242
Pumping Station	243
Treatment Facility	243
Geology, Ground Water, and Aquifer Protection	244
Seepage into the Tunnels and Chambers	244
System Operation and Performance	246
System Costs	246
Diked Storage Lagoons in Lake Michigan	248
Control Structures and Conveyance System	248
Lake Michigan Lagoons	250
Pumping Station	250
Treatment Facility	251
Geology, Foundation, and Seepage Conditions	251
System Costs	251
Screening/Dissolved-Air Flotation Treatment System Combined with Instream Aeration	252
Conveyance and Flow-Through Treatment Facilities	254
System Operation and Performance	255
System Costs	255
Concluding Remarks—Detailed Consideration of Alternatives	256
Industrial Waste Sources	259
Alternative Stream Water Quality Management Plan Elements—Upper Watershed	260
Industrial Waste Sources	260
Agricultural Runoff Control	262
Sewage Treatment Processes	263
Existing Treatment Levels and State Orders	263
Alternative Plan Elements Investigated	267
Alternative 1—Advanced Waste Treatment (85 Percent Phosphorus Removal—State Orders)	268
Alternative 1A	270
Alternative 1B	270
Alternative 1C	274
Alternative 1D	274
Concluding Remarks—Alternative 1	279
Alternative 2—Tertiary and Advanced Waste Treatment (80 Percent NOD, 95 Percent BOD, and 90 Percent Phosphorus Removal)	279
Alternative 2A	281
Alternative 2B	283
Concluding Remarks—Alternative 2	286
Alternative 3—Effluent Disposal by Land Irrigation	286
Alternative 4—Instream Aeration	288
Alternative 5—Low-Flow Augmentation	293
Concluding Remarks—Alternative Stream Water Quality Management Plan Elements—Upper Watershed	297
Alternative Lake Water Quality Management Plan Elements	302
Potential Plan Elements	307
Installation of Sanitary Sewerage Systems	307

	Page
Agricultural Runoff Control	308
Manure Storage Tanks	309
Bench Terraces	309
Other Land Management Practices	311
Weed Harvesting	312
Algae Control	312
Lake Water Mixing	312
Other Elements	313
Bottom Draw Devices	313
Water Replacement	313
Nutrient Removal	313
Dredging	313
Fish Harvesting	313
Algae Harvesting	314
Application of the Potential Plan Elements to the Major Lakes in the Watershed	314
Auburn (Fifteen) Lake	315
Big Cedar Lake	316
Crooked Lake	319
Ellen Lake	321
Forest Lake	322
Green Lake	323
Kettle Moraine Lake	324
Little Cedar Lake	326
Long Lake	329
Lucas Lake	330
Mauthe Lake	331
Mud Lake (Fond du Lac County)	332
Mud Lake (Ozaukee County)	333
Random Lake	333
Silver Lake	334
Smith Lake	335
Spring Lake	336
Twelve Lake	337
Wallace Lake	338
Concluding Remarks—Lake Water Quality Management Plan Elements	339
Chapter VI—ALTERNATIVE WATER SUPPLY PLAN ELEMENTS	343
Introduction	343
Surface Water Supply	344
Ground Water Supply	346
Sand and Gravel Aquifer	348
Dolomite Aquifer	351
Sandstone Aquifer	352
Relative Costs of Well Drilling and Aquifer Development	356
Pumping Cost	356
Alternative Water Supply Plan Elements	358
Fond du Lac County	358
Milwaukee County	358
Village of Bayside	359
Village of River Hills	359
Other Communities	360
Ozaukee County	360
City of Mequon—Village of Thiensville	360
Waubeka (Unincorporated)	361
Sheboygan County	361
Village of Cascade	361
Washington County	361
Village of Jackson	362
Newburg (Unincorporated)	362
Water Utility Alternatives for the Bayside-Mequon-River Hills-Thiensville Area	362
Other Minor Sources of Supply	367
Summary	367
Chapter VII—RECOMMENDED COMPREHENSIVE PLAN FOR THE MILWAUKEE RIVER WATERSHED	369
Introduction	369
Basis of Plan Synthesis	369
Plan Recommendations	370
Recommended Land Use Base	370
Urban Development	371
Open Space—Environmental Corridors	371
Open Space—Park and Outdoor Recreation Areas	372
Open Space—Agricultural Land Use	375
Parkway and Scenic Drives	375
Flood Control Plan Element	375
Floodplain Floodproofing	376
Floodway Clearance	377
Floodland Land Use Controls	377
Bridge Replacement	377
Reservoir Land Protection	377
Maintenance of Stream Gaging Stations	378
Water Pollution Abatement Plan Element	378
Stream Water Quality Management Plan Elements	378
Lower Watershed	378
Upper Watershed	379
Lake Water Quality Management Plan Elements	380
Water Supply Plan Elements	381
Cost Analysis	382
Summary	389

	Page
Chapter VIII—THE UNPLANNED ALTERNATIVE	391
Introduction	391
Land Use Forecast Methodology	391
Unplanned Alternative—Land Use	393
Residential Development	393
Sewer and Water Services	396
Local Park Land Use	397
Agricultural Land Use	397
The Unplanned Alternative—Flood Damages and Water Quality Management	398
Implications for Flood Control	398
Implications for Water Quality Management	398
Benefits of the Unplanned Alternative	399
Costs of the Unplanned Alternative	399
Summary	401
Chapter IX—PLAN IMPLEMENTATION	403
Introduction	403
Basic Concepts and Principles	403
Natural Resource Protection	404
Flood Control	404
Water Pollution Abatement	404
Water Supply	405
Concluding Comments—Basic Concepts and Principles	405
Plan Implementation Organizations	406
Watershed Committee	407
Local Level Agencies	407
County Park and Planning Agencies	407
County Highway Committees	408
Municipal Planning Agencies	409
Municipal Utility and Sanitary Districts	409
Soil and Water Conservation Districts	409
Harbor Commissions	410
Areawide Agencies	410
Metropolitan Sewerage Commissions	410
County Drainage Boards and Districts	411
Flood Control Boards	411
Comprehensive River Basin Districts	411
Cooperative Contract Commissions	412
Regional Planning Commission	412
State Level Agencies	412
Wisconsin Department of Natural Resources	412
Wisconsin Department of Local Affairs and Development	413
Wisconsin Department of Transportation	413
Wisconsin Department of Health and Social Services, Division of Health	413
Wisconsin Soil Conservation Board	413
Federal Level Agencies	413
U. S. Department of Housing and Urban Development	414
U. S. Environmental Protection Agency	414
U. S. Department of the Interior, Bureau of Outdoor Recreation	414
U. S. Department of the Interior, Geological Survey	414
U. S. Department of Agriculture, Farmers Home Administration	414
U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service	414
U. S. Department of Agriculture, Soil Conservation Service	414
U. S. Department of the Army, Corps of Engineers	414
Plan Adoption and Integration	415
Local Level Agencies	415
Areawide Agencies	416
State Level Agencies	416
Federal Level Agencies	417
Subsequent Adjustment of the Plan	418
Land Use, Natural Resource Protection, Park and Outdoor Recreation, and Parkway and Scenic Drive Plan Element Implementation	419
Introduction	419
Zoning Ordinances	419
Residential Areas	420
Agricultural Areas	421
Environmental Corridors	421
Other Outdoor Recreation Sites	421
Floodlands	421
Shorelands	421
Property Tax Policies	422
Greenway Tax Law Proposal	423
Woodland and Wetland Management	423
Land Acquisition—Natural Resource Protection	424
Urban Environmental Corridors	424
Milwaukee River Main Stem Corridors	426
High-Value Wetlands	426
High-Value Woodlands	426
Selected Additional Environmental Corridors	426
Land Acquisition and Development for Park and Outdoor Recreation	427
Lucas Lake-Paradise Valley Park Site	427
Hawthorne Hills Park Site	427
Selected Additional High-Value Park Sites	427

	Page
Other Additional High-Value Outdoor Recreation Sites	429
Private Park Development	429
Park Land Preservation	429
Milwaukee River Parkway Pleasure Drive	429
Milwaukee River Scenic Drives	430
Flood Control Plan Element Implementation	430
Floodland Land Use Controls	430
Floodway Clearance	432
Flood Insurance	432
Bridge Construction	432
Stream Flow Recordation	433
Reservoir Land Protection	433
Floodway Encroachment/Bulkhead Line Establishment	433
Engineering Investigations of Selected Dams	434
Water Pollution Abatement Plan Element Implementation	434
Lower Milwaukee River Watershed	435
Upper Milwaukee River Watershed	438
Establishment of Lake Sewerage Systems	440
Lake Algae Control and Weed Harvesting	441
Soil and Water Conservation Practices	441
Septic Tank Sewage Disposal Systems	442
Stream Basin Survey	442
Water Quality Monitoring Program	443
Water Supply Plan Element Implementation	443
Ground Water Supply Management	443
Municipal Water Supply Systems	444
Relationship of Watershed Plan to Report of the Milwaukee River Technical Study Committee	444
Relationship of the Watershed Plan to Environmental Impact Statements	447
Financial and Technical Assistance	447
Borrowing	448
Federal Loans	448
Special Taxes and Assessments	449
Park and Open-Space Land and Development Grants	449
State Local Park Aids Program (ORAP)	449
Federal Open-Space Land Program	449
Federal Land and Water Conservation Fund	449
Federal Cropland Adjustment Program (Greenspan)	449
Federal Urban Beautification Program	449
Water Supply and Sewerage System Grants	449
State Water Pollution Prevention and Abatement Program	449
Federal Water and Sewer Facilities Program	449
Federal Water Pollution Control Program	450
Federal Farmers Home Administration Programs	450
Soil and Water Conservation Grants	450
State Soil and Water Conservation Program	450
Federal Rural Environmental Assistance Program	450
Federal Resource Conservation and Development Program	450
Federal Cropland Adjustment Program	450
Federal Multiple-Purpose Watershed Program	450
State Water Quality Regulation Enforcement Program	450
Federal Water Resources Investigation Program	450
General Works Projects—U. S. Army Corps of Engineers	450
Gifts	451
Technical Assistance	451
Federal Agencies	451
State Agencies	451
Areawide Agencies	452
County Agencies	452
Summary	452
State Level	452
Wisconsin Department of Local Affairs and Development	454
Wisconsin Department of Transportation	454
Wisconsin Department of Health and Social Services, Division of Health	454
Wisconsin Soil Conservation Board	454
Local Level	454
Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington County Boards of Supervisors	454
Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington County Park and Planning Agencies	455
Soil and Water Conservation Districts	456
Common Councils, Village Boards, and Town Boards	456

	Page
Plan Commissions of the Cities, Villages, and Towns within the Watershed	458
Municipal Water and Sanitary Districts	458
Areawide Level	458
Metropolitan Sewerage District of the County of Milwaukee	458
Federal Level	458
U. S. Department of Housing and Urban Development	458
U. S. Environmental Protection Agency	459
U. S. Department of the Interior, Geological Survey	459
U. S. Department of Agriculture, Farmers Home Administration	459
U. S. Department of Agriculture, Soil Conservation Service	459
U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service	459
U. S. Department of the Army, Corps of Engineers	459
Chapter X—SUMMARY AND CONCLUSIONS	461
Introduction	461
Watershed Development Objectives	461
Alternative Plans	461
Recommended Watershed Plan	464
Land Use Element	464
Flood Control Element	465
Stream Water Pollution Abatement Element	466
Lake Water Pollution Abatement Element	467
Water Supply Element	468
The Unplanned Alternative	468
Cost Analysis	469
Implementation	470
Conclusion	472

List of Appendices

		Page
Appendix A—TECHNICAL ADVISORY COMMITTEE ON NATURAL RESOURCES AND ENVIRONMENTAL DESIGN		473
Appendix B—MILWAUKEE RIVER WATERSHED COMMITTEE		475
Appendix C—RAINFALL AND RUNOFF DATA FOR STORM WATER DRAINAGE AND FLOOD CONTROL FACILITY DESIGN		477
Figure C-1	Point Rainfall Intensity-Duration-Frequency for Durations of 0 to 180 Minutes, Milwaukee, Wisconsin	477
Figure C-2	Point Rainfall Intensity-Duration-Frequency for Duration of 3 to 24 Hours, Milwaukee, Wisconsin	478
Figure C-3	Point Rainfall Depth-Duration-Frequency Relationships in the Region and the Milwaukee River Watershed	479
Figure C-4	Rainfall Depth-Duration-Area Relationships in the Region and the Milwaukee River Watershed	479
Figure C-5	Seasonal Variation of Rainfall Frequency in the Region and the Milwaukee River Watershed	480
Figure C-6	Coefficient of Runoff Curves for Hydrologic Soil Groups	481
Table C-1	Weighted Runoff Coefficients for Use in the Rational Formula	482

Page

Appendix D—ECONOMIC ANALYSES OF RECREATIONAL DEVELOPMENT AND VALUE OF LAND ENHANCEMENT AT THREE PROPOSED RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED 483

Table D-1 Selected Recreational Needs in Southeastern and East Central Wisconsin for the Year 2000 483
Table D-2 Per Capita Visitation to Devils Lake State Park by Concentric Origin Zones Day Users—Summer 1968 484
Figure D-1 Summer User-Origin Curves for Existing Recreation Developments Similar to Proposed Recreation Developments at the Potential Reservoir Sites in the Milwaukee River Watershed 485
Figure D-2 Summer User-Origin Curve Developed for Potential Reservoir Sites in the Milwaukee River Watershed 485
Figure D-3 Projected Summer Recreation Visitation to Potential Reservoir Sites in the Milwaukee River Watershed 486
Table D-3 Projected Summer 1970 Visitation to the Potential Reservoir Recreation Developments in the Milwaukee River Watershed by Principal Origin Zones . . . 486
Figure D-4 Summer Demand Curves for Potential Waubeka or Newburg Reservoir Recreational Developments in the Milwaukee River Watershed 487
Table D-4 Visitation and Corresponding Benefits for Potential Reservoir Recreation Developments in the Milwaukee River Watershed 1970 and 1990 488
Table D-5 Initial Recreation Facility Requirements and Costs for the Waubeka Reservoir in the Milwaukee River Watershed. 489
Table D-6 Present Worth of Recreation and Land Enhancement Benefits and of Recreation Cost for Three Potential Reservoir Developments in the Milwaukee River Watershed 490
Table D-7 Wisconsin Reservoir Shoreline Development Guide Applicable to the Milwaukee River Watershed 490
Map D-1 Model Recreational-Residential Community Adaptable to Potential Reservoir Sites in the Milwaukee River Watershed 491
Table D-8 Model Recreation-Residential Shoreline Development Adaptable to Potential Reservoir Sites in the Milwaukee River Watershed. 492
Table D-9 Development Costs for the Model Recreation-Residential Development Proposed for Potential Reservoir Sites in the Milwaukee River Watershed 492
Table D-10 Market Value of Lots in the Model Recreation-Residential Development Adaptable to Potential Reservoir Sites in the Milwaukee River Watershed 492
Table D-11 Summary of Recreation-Residential Community Development on the Periphery of Potential Reservoir Sites in the Milwaukee River Watershed 492
Table D-12 Disbursements and Sales Over 5-Year and 20-Year Development Periods for Recreation-Residential Community at Waubeka Reservoir 493
Table D-13 Daily Expenditures Per Visitor to Wisconsin State Parks 493
Table D-14 Estimated Local Expenditures by Recreation Visitors to Reservoir Sites in the Milwaukee River Watershed and Attendant Increase in Local Income. . . . 494

Appendix E—APPLICATION OF THE NEW TOWN CONCEPT TO THE PROPOSED WAUBEKA RESERVOIR SITE IN THE MILWAUKEE RIVER WATERSHED 495

Table E-1 Alternative 'New Town' Development Proposals in the Waubeka Reservoir Site Area 496
Map E-1 Potential New Town Development at the Waubeka Reservoir in the Milwaukee River Watershed 497
Table E-2 Proposed 'New Town' Development and Other Urban Development in the Waubeka Reservoir Site Area 498

Page

Introduction to Appendices F, G, and H 499

Appendix F—HIGH WATER AND STREAM BED PROFILES AND TOPOGRAPHIC MAPS SHOWING AREAS SUBJECT TO FLOODING FOR THE MILWAUKEE RIVER AND SELECTED MAJOR TRIBUTARIES 500

Map F-1	Topographic Map Showing Areas Subject to Flooding Along Milwaukee River . . .	500
Figure F-1	High Water and Stream Bed Profiles for Milwaukee River	501
Map F-2	Topographic Map Showing Areas Subject to Flooding Along Lincoln Creek	544
Figure F-2	High Water and Stream Bed Profiles for Lincoln Creek	545
Map F-3	Topographic Map Showing Areas Subject to Flooding Along Cedar Creek.	548
Figure F-3	High Water and Stream Bed Profiles for Cedar Creek	549
Map F-4	Topographic Map Showing Areas Subject to Flooding Along North Branch Milwaukee River	568
Figure F-4	High Water and Stream Bed Profiles for North Branch Milwaukee River	569
Map F-5	Topographic Map Showing Areas Subject to Flooding Along Silver Creek (Sheboygan County)	582
Figure F-5	High Water and Stream Bed Profiles Silver Creek (Sheboygan County).	583
Map F-6	Topographic Map Showing Areas Subject to Flooding Along Silver Creek (Washington County).	588
Figure F-6	High Water and Stream Bed Profiles Silver Creek (Washington County)	589
Map F-7	Topographic Map Showing Areas Subject to Flooding Along East Branch Milwaukee River	592
Figure F-7	High Water and Stream Bed Profiles East Branch Milwaukee River	593
Map F-8	Topographic Map Showing Areas Subject to Flooding Along Crooked Lake Creek .	602
Figure F-8	High Water and Stream Bed Profiles Crooked Lake Creek	603
Map F-9	Topographic Map Showing Areas Subject to Flooding Along West Branch Milwaukee River	606
Figure F-9	High Water and Stream Bed Profiles West Branch Milwaukee River.	607
Map F-10	Index Map to Topographic Maps Showing Areas Subject to Flooding for the Milwaukee River and Selected Major Tributaries	616

Appendix G—HYDRAULIC DATA SUMMARY FOR BRIDGES OVER THE MILWAUKEE RIVER AND SELECTED MAJOR TRIBUTARIES 617

Table G-1	Hydraulic Analysis Summary Lower Milwaukee River	617
Table G-2	Hydraulic Analysis Summary Middle Milwaukee River.	617
Table G-3	Hydraulic Analysis Summary Upper Milwaukee River	617
Table G-4	Hydraulic Analysis Summary Lincoln Creek	618
Table G-5	Hydraulic Analysis Summary Cedar Creek	618
Table G-6	Hydraulic Analysis Summary North Branch Milwaukee River.	618
Table G-7	Hydraulic Analyses Summary Silver Creek (Sheboygan County)	618
Table G-8	Hydraulic Analyses Summary Silver Creek (Washington County)	619
Table G-9	Hydraulic Analyses Summary East Branch Milwaukee River	619
Table G-10	Hydraulic Analyses Summary Crooked Lake Creek	619
Table G-11	Hydraulic Analyses Summary West Branch Milwaukee River	619

Appendix H—FLOOD HAZARD MAPS. 621

Map H-1	Flood Hazard and Topographic Map Sheet Index for the Milwaukee River Watershed, October 1971	621
Map H-2	Flood Hazard Map—Portion of Milwaukee River Watershed, Ozaukee County, Wisconsin	622

Page

Appendix I—CORRESPONDENCE RELATIVE TO THE U. S. ARMY CORPS OF ENGINEERS REVIEW OF THE POTENTIAL ELIGIBILITY FOR FEDERAL PARTICIPATION IN THE DEVELOPMENT OF THE WAUBEKA RESERVOIR AND SAUKVILLE DIVERSION CHANNEL ALTERNATIVE FLOOD CONTROL PLAN ELEMENTS 623

Appendix J—MODEL RESOLUTION FOR ADOPTION OF THE COMPREHENSIVE PLAN FOR THE MILWAUKEE RIVER WATERSHED 625

List of Tables

Table | Chapter II | Page

1 Water Control Facility Development Objectives, Principles, and Standards for the Milwaukee River Watershed 9
2 Land Use Development Objectives, Principles, and Standards for the Milwaukee River Watershed 14

Chapter III

3 Existing and Proposed Land Use in the Milwaukee River Watershed—1967 and 1990 Recommended Land Use Plan 32
4 Distribution of Selected Natural Resource Elements in the Milwaukee River Watershed and in the Primary Environmental Corridor Within the Watershed—1967 35
5 Existing and Proposed Public Ownership of Selected Environmental Corridor Lands by County—1967 and 1990 Alternative Natural Resource Protection Plan Elements. 38
6 Existing and Proposed Public Ownership of Additional Milwaukee River Main Stem Environmental Corridor Lands by County—1967 and 1990 Intermediate Alternative Natural Resource Protection Plan Element 39
7 Existing and Proposed Ownership of Additional Selected Environmental Corridor Lands by County—1967 and 1990 Optimum Alternative Natural Resource Protection Plan Element 40
8 Comparison of the Relative Ability of the Alternative Natural Resource Protection Plan Elements to Meet Watershed Development Standards 41
9 Existing and Proposed Local and Regional Parks in the Milwaukee River Watershed by County—1967 and 1990 Alternative Outdoor Recreation Plan Elements. 47
10 Proposed Additional Parks and Selected Potential High-Value Park Sites in the Milwaukee River Watershed by County—1990 Intermediate Alternative Outdoor Recreation Plan Element 47
11 Proposed Additional Parks at Selected Potential High-Value Park Sites in the Milwaukee River Watershed by County—1990 Optimum Alternative Outdoor Recreation Plan Element 48
12 Comparison of the Relative Ability of the Alternative Outdoor Recreation Plan Elements to Meet Adopted Development Standards 49
13 Historic, Scenic, and Scientific Sites in Proximity to Proposed Scenic Drives in the Milwaukee River Watershed—1964 63

Table	Chapter IV	Page
14	Summary of Initial Evaluation of Potential Reservoir Sites in the Milwaukee River Watershed	73
15	Recreational Ratings of Potential Reservoir Sites in the Milwaukee River Watershed	74
16	Flood Control Rating of Potential Reservoir Sites in the Milwaukee River Watershed	76
17	Water Supply and Low-Flow Augmentation Ratings of Potential Reservoir Sites in the Milwaukee River Watershed	79
18	Estimated Land and Relocation Costs for the Waubeka Reservoir in the Milwaukee River Watershed	89
19	Schedule of Estimated Costs for the Waubeka Dam in the Milwaukee River Watershed	94
20	Estimated Costs and Benefits for the Multiple-Purpose Waubeka Reservoir Project in the Milwaukee River Watershed	98
21	Estimated Land and Relocation Costs for the Horns Corners Reservoir in the Milwaukee River Watershed	103
22	Schedule of Estimated Costs for the Horns Corners Dam in the Milwaukee River Watershed	106
23	Estimated Costs and Benefits for the Multiple-Purpose Horns Corners Reservoir Project in the Milwaukee River Watershed	110
24	Estimated Land and Relocation Costs for the Newburg Reservoir in the Milwaukee River Watershed	116
25	Schedule of Estimated Costs for the Newburg Dam in the Milwaukee River Watershed	118
26	Estimated Costs and Benefits for the Multiple-Purpose Newburg Reservoir Project in the Milwaukee River Watershed	122
27	Estimated Costs of Diversion Facilities for the Saukville Depression-Horns Corners Reservoir-Newburg Reservoir River Control System in the Milwaukee River Watershed	124
28	Estimated Costs and Benefits for the Multiple-Purpose Saukville Depression-Horns Corners Reservoir-Newburg Reservoir Project in the Milwaukee River Watershed	126
29	Costs and Benefits of a Potential Floodwater Diversion Channel From the Milwaukee River to Lake Michigan at Saukville	133
30	Estimated Costs and Benefits for Dike-Floodwall Systems with Supplemental Structure Removal and Floodproofing in the Cities of Glendale and Mequon and Villages of Thiensville and Saukville	142
31	Hydraulic Effect of the Dike-Floodwall System in the City of Glendale	143
32	Hydraulic Effect of the Dike-Floodwall System in the City of Mequon	146
33	Hydraulic Effect of the Dike-Floodwall System in the Village of Thiensville	151
34	Hydraulic Effect of the Dike-Floodwall System in the Village of Saukville	153
35	Estimated Costs and Benefits for Structure Floodproofing and Removal in the Milwaukee River Watershed	158
36	Public Bridges in the Milwaukee River Watershed Having Substandard Hydraulic Capacities	164
37	Hydraulic Effect of a Typical Designated Floodway for the City of Glendale—100-Year Recurrence Interval Flood Event and 1990 Land Use Development Conditions	167
38	Principal Features of Alternative Structural and Non-Structural River Control Plan Elements in the Milwaukee River Watershed	179
	Chapter V	
39	Summary of Alternative Combined Sewer Overflow Pollution Abatement Plan Elements for the Lower Milwaukee River Watershed	192
40	Estimated Frequency of Combined Sewer Overflow Discharge to Surface Waters for Various Storage Volumes, Milwaukee, Wisconsin	196
41	Preliminary Cost Estimates—Alternative Combined Sewer Overflow Storage Pollution Abatement Plan Elements for the Lower Milwaukee River Watershed	200
42	Preliminary Cost Estimates—Alternative Combined Sewer Overflow Flow-Through and In-Flow Treatment Pollution Abatement Plan Elements for the Lower Milwaukee River Watershed	221

Table | Page

43 Contaminant Removals in Percent by Screening and Flotation at the Hawley Road Demonstration Facility, Milwaukee, Wisconsin: May 1969-October 1969. 223
44 Nitrogen and Phosphorus Removals in Percent at the Hawley Road Demonstration Facility, Milwaukee, Wisconsin, With Utilization of Ferric Chloride—1970. 225
45 Comparison of the Effect of Overflow Rate on Removal Efficiencies at the Hawley Road Demonstration Facility, Milwaukee, Wisconsin: 1970. 225
46 Summary of Disinfection Data at the Hawley Road Demonstration Facility: 1969 and 1970 225
47 Contaminant Removals in Percent at a Combined Sewage Demonstration Facility in Fort Smith, Arkansas: 1969. 225
48 Construction Costs for Sewers in Sewer Separation Projects in Combined Sewer Areas of the City of Milwaukee 229
49 Characteristics of Study Areas for Hypothetical Application of ASCE Combined Sewer Separation Project 230
50 Estimates of Capital Costs for Hypothetical Application of ASCE Combined Sewer Separation Project 231
51 Comparison of Annual Costs for Hypothetical Application of ASCE Combined Sewer Separation Project in the North Prospect Study Area, Milwaukee, Wisconsin 231
52 Prevailing Land Uses in the North Prospect Study Area, Milwaukee, Wisconsin. 233
53 Total Separation Costs for Hypothetical Applications of ASCE Combined Sewer Separation Project in the North Prospect Avenue Study Area, Milwaukee, Wisconsin 235
54 Adjustment of Capital Costs for Separation of Combined Sewers in the North Prospect Avenue Study Area, Milwaukee, Wisconsin. 236
55 Cost Estimates—Detailed Consideration of Alternative Combined Sewer Overflow Pollution Abatement Plan Elements for the 17,200-Acre Combined Sewer Service Area in Milwaukee County. 247
56 Cost Estimates—Recommended Combined Sewer Overflow Pollution Abatement Plan Element for the 17,200-Acre Combined Sewer Service Area in Milwaukee County 259
57 Comparison of Initial and Revised Estimates of Phosphorus Contributions From Municipal Sewage Treatment Plant Effluent in the Milwaukee River Watershed—1990 267
58 Criteria Used in Application of Stream Water Quality Model to Determine if Water Use Objectives and Standards Would be Met Upon Compliance With Outstanding State Pollution Abatement Orders 269
59 Detailed Cost Estimates Alternative Stream Water Quality Management Plan Element 1A . . 272
60 Detailed Cost Estimates Alternative Stream Water Quality Management Plan Element 1B . . 275
61 Detailed Cost Estimates Alternative Stream Water Quality Management Plan Element 1C . . 277
62 Detailed Cost Estimates Alternative Stream Water Quality Management Plan Element 1D . . 280
63 Detailed Cost Estimates Alternative Stream Water Quality Management Plan Element 2A . . 284
64 Detailed Cost Estimates Alternative Stream Water Quality Management Plan Element 2B . . 287
65 Detailed Cost Estimates Alternative Stream Water Quality Management Plan Element 3 . . . 290
66 Detailed Cost Estimates Alternative Stream Water Quality Management Plan Element 4 . . . 294
67 Detailed Cost Estimates Alternative Stream Water Quality Management Plan Element 5 . . . 298
68 Summary of the Alternative Stream Water Quality Management Plan Elements for the Upper Milwaukee River Watershed 300
69 Detailed Cost Estimates Recommended Stream Water Quality Management Plan Element for the Upper Milwaukee River Watershed 306
70 Recommended Terrace Spacing 310
71 Selected Characteristics of Auburn (Fifteen) Lake, Fond du Lac County: 1967 315
72 Alternative Lake Water Quality Management Plan Elements Auburn (Fifteen) Lake, Fond du Lac County 316
73 Selected Characteristics of Big Cedar Lake, Washington County: 1967. 317
74 Alternative Lake Water Quality Management Plan Elements Big Cedar Lake, Washington County 317

Table		Page
75	Selected Characteristics of Crooked Lake, Sheboygan and Fond du Lac Counties: 1967	319
76	Alternative Lake Water Quality Management Plan Elements Crooked Lake, Sheboygan and Fond du Lac Counties	320
77	Selected Characteristics of Ellen Lake, Sheboygan County: 1967	321
78	Alternative Lake Water Quality Management Plan Elements Ellen Lake, Sheboygan County	322
79	Selected Characteristics of Forest Lake, Fond du Lac County: 1967	323
80	Alternative Lake Water Quality Management Plan Elements Forest Lake, Fond du Lac County	324
81	Selected Characteristics of Green Lake, Washington County: 1967	325
82	Alternative Lake Water Quality Management Plan Elements Green Lake, Washington County	326
83	Selected Characteristics of Kettle Moraine Lake, Fond du Lac County: 1967	326
84	Alternative Lake Water Quality Management Plan Elements Kettle Moraine Lake, Fond du Lac County	326
85	Selected Characteristics of Little Cedar Lake, Washington County: 1967	327
86	Alternative Lake Water Quality Management Plan Elements Little Cedar Lake, Washington County	328
87	Selected Characteristics of Long Lake, Fond du Lac County: 1967	329
88	Alternative Lake Water Quality Management Plan Elements Long Lake, Fond du Lac County	329
89	Selected Characteristics of Lucas Lake, Washington County: 1967	331
90	Alternative Lake Water Quality Management Plan Elements Lucas Lake, Washington County	331
91	Selected Characteristics of Mauthe Lake, Fond du Lac County: 1967	332
92	Alternative Lake Water Quality Management Plan Elements Mauthe Lake, Fond du Lac County	332
93	Selected Characteristics of Mud Lake, Fond du Lac County: 1967	333
94	Selected Characteristics of Mud Lake, Ozaukee County: 1967	333
95	Selected Characteristics of Random Lake, Sheboygan County: 1967	333
96	Alternative Water Quality Management Plan Elements Random Lake, Sheboygan County	334
97	Selected Characteristics of Silver Lake, Washington County: 1967	335
98	Alternative Lake Water Quality Management Plan Elements Silver Lake, Washington County	336
99	Selected Characteristics of Smith Lake, Washington County: 1967	336
100	Alternative Lake Water Quality Management Plan Elements Smith Lake, Washington County	337
101	Selected Characteristics of Spring Lake, Ozaukee County: 1967	337
102	Selected Characteristics of Twelve Lake, Washington County: 1967	337
103	Alternative Lake Water Quality Management Plan Elements Twelve Lake, Washington County	338
104	Selected Characteristics of Wallace Lake, Washington County: 1967	339
105	Alternative Lake Water Quality Management Plan Elements Wallace Lake, Washington County	340
106	Cost Estimates of the Recommended Lake Water Quality Management Plan Elements for the Milwaukee River Watershed	341

Chapter VI

107	Existing and Forecast Ground Water Pumpages for Selected Urban Areas in the Milwaukee River Watershed	344
108	Ground Water Availability and Estimated Hydrologic Characteristics for the Sand and Gravel Aquifer in the Milwaukee River Watershed	345
109	Ground Water Availability and Estimated Hydrologic Characteristics for the Dolomite Aquifer in the Milwaukee River Watershed	346

Table		Page
110	Ground Water Availability and Estimated Hydrologic Characteristics for the Sandstone Aquifer in the Milwaukee River Watershed	347
111	Coefficient of Permeability for Various Coarse-Grained Materials	351
112	Cost Estimates—Alternative Cooperative Water Supply Systems for the Bayside-Mequon-River Hills-Thiensville Area	363

Chapter VII

113 | Schedule of Capital and Operation and Maintenance Costs of the Recommended Milwaukee River Watershed Plan by Major Plan Element by Year: 1971-1990 | 383
114 | Expenditures for Public Sanitary Sewerage, Park and Outdoor Recreation, and Major Open Channel Drainage Purposes and Total Receipts Reported by Local Units of Government in the Milwaukee River Watershed: 1958-1968 | 386
115 | Alternative Forecasts of Expenditures for Public Sanitary Sewerage, Park and Outdoor Recreation, and Major Open Channel Drainage Purposes by the Local Units of Government in the Milwaukee River Watershed: 1969-1990 | 386

Chapter VIII

116 | Urban and Rural Land Use in the Milwaukee River Watershed: Existing 1967, 1990 Recommended Land Use Plan, and as Proposed in Community Plans and Zoning Ordinances | 393
117 | Changes in Land Use in the Milwaukee River Watershed: 1990 Recommended Land Use Plan and as Proposed in Community Plans and Zoning Ordinances | 393
118 | Urban and Rural Land Use in the Milwaukee River Watershed: Existing 1967, 1990 Recommended Land Use Plan, and 1990 Unplanned Alternative | 395
119 | Developed Area and Population Density in the Milwaukee River Watershed: Existing 1967, 1990 Recommended Land Use Plan, and 1990 Unplanned Alternative | 395
120 | Developed Urban Area and Population Served by Public Sanitary Sewer and Public Water Supply Facilities in the Milwaukee River Watershed: Existing 1967, 1990 Recommended Watershed Plan, and 1990 Unplanned Alternative | 396
121 | Comparison of the Relative Ability of the Recommended Milwaukee River Watershed Plan and the Unplanned Alternative to Meet Adopted Watershed Development Standards | 400

Chapter IX

122 | Schedule of Capital Costs of the Recommended Natural Resource Protection Plan Element of the Milwaukee River Watershed Plan by County by Year: 1971-1990 | 425
123 | Schedule of Capital and Operation and Maintenance Costs of the Recommended Outdoor Recreation Plan Element of the Milwaukee River Watershed Plan by County by Year: 1971-1990 | 428
124 | Schedule of Capital and Operation and Maintenance Costs of the Recommended Parkway and Scenic Drive Plan Elements of the Milwaukee River Watershed Plan by County by Year: 1971-1990 | 430
125 | Schedule of Capital Costs of the Recommended Site Investigations and Analysis of Stability of the North Avenue and Woolen Mills Dams in the Cities of Milwaukee and West Bend, Respectively: 1971-1990 | 434
126 | Schedule of Capital and Operation and Maintenance Costs of the Recommended Water Pollution Abatement Plan Element of the Milwaukee River Watershed for Milwaukee County by Year: 1971-1990 | 435

Table | | Page

127 Schedule of Capital and Operation and Maintenance Costs of the Recommended Water Pollution Abatement Plan Element for Ozaukee County by Year: 1971-1990 435
128 Schedule of Capital and Operation and Maintenance Costs of the Recommended Water Pollution Abatement Plan Element of the Milwaukee River Watershed Plan for Washington County by Year: 1971-1990 436
129 Schedule of Capital and Operation and Maintenance Costs of the Recommended Water Pollution Abatement Plan Element of the Milwaukee River Watershed Plan for Fond du Lac County by Year: 1971-1990 437
130 Schedule of Capital and Operation and Maintenance Costs of the Recommended Water Pollution Abatement Plan Element of the Milwaukee River Watershed Plan for Sheboygan County by Year: 1971-1990 438
131 Schedule of Capital and Operation and Maintenance Costs of the Recommended Water Resources Monitoring Program for the Milwaukee River Watershed by County by Year: 1971-1990 443
132 Schedule of Capital and Operation and Maintenance Costs of the Recommended Water Supply Plan Element of the Milwaukee River Watershed Plan by County by Year: 1971-1990 . 444

List of Figures

Figure | Chapter IV | Page

1 Profile of the Milwaukee River and Selected Tributaries Showing Existing and Potential Impoundments. 81
2 Hydrographic and Structural Features of a Potential Multiple-Purpose Waubeka Reservoir on the Milwaukee River and its North Branch 83
3 Historic Extreme Low Flows of the Milwaukee River at Estabrook Park and Relationship to the Augmentation Potential of the Waubeka Reservoir 85
4 Waubeka Reservoir Flow Augmentation Releases as a Function of Duration for Drawdowns of Three and Five Feet 86
5 Historic Low Flows of the Milwaukee River at Estabrook Park for Three Typical Years Selected From 53 Years of Record. 87
6 Topography and Borehole Locations at the Waubeka Dam Site on the Milwaukee River at River Mile 47.0 92
7 Valley Cross-Section Along the Axis of the Proposed Waubeka Dam on the Milwaukee River at River Mile 47.0 93
8 Hydrographic and Structural Features of a Potential Multiple-Purpose Horns Corners Reservoir on Cedar Creek in the Milwaukee River Watershed. 99
9 Hydrographic and Structural Features of a Potential Multiple-Purpose Newburg Reservoir on the Milwaukee River 111
10 Potential Floodwater Diversion Channel from the Milwaukee River at Saukville to Lake Michigan as Proposed by the U. S. Army Corps of Engineers 129
11 Typical Earth Dike and Concrete Floodwall and a Backwater Gate for Possible Flood Control Use in the Milwaukee River Watershed 135
12 Dike and Floodwall Cost Curves Used in the Economic Analysis of Alternate Flood Control Works in the Milwaukee River Watershed 137
13 Recorded Lake Michigan Stages in the Milwaukee Harbor: 1901-1970 175

Figure	Chapter V	Page
14	Frequency and Magnitude of Runoff From the Combined Sewer Area in Milwaukee, Wisconsin	194
15	Frequency Curves of Runoff for the Combined Sewer Area in Milwaukee, Wisconsin	195
16	Frequency and Magnitude of Runoff from the Combined Sewer Area in Chicago, Illinois	197
17	Rex Chainbelt Screening/Dissolved-Air Flotation Flow-Through Treatment System	222
18	Typical Conditions Affecting Sewer Separation in the N. Prospect Avenue Study Area, Milwaukee, Wisconsin	234
19	Stratigraphic Cross-Section Through Milwaukee and Eastern Waukesha Counties	245
20	Sewage Treatment Processes	264
21	Recommended Trunk Sewer System to Connect Existing City of Cedarburg and Village of Grafton Sewage Treatment Plants to Proposed Advanced Waste Treatment Plant	303
22	Recommended Trunk Sewer System to Connect Proposed Tri-Lakes Sewer Service Area to West Bend Sewage Treatment Plant	304
23	Recommended Trunk Sewer System to Connect Village of Thiensville to the Milwaukee-Metropolitan Sewerage System	305
24	Typical Bench Terrace Cross-Section	310
	Chapter VI	
25	Relation of Well Discharge to Drawdown in the Sand and Gravel Aquifer	348
26	Relation of Distance from Pumped Well to Drawdown in the Sand and Gravel Aquifer	349
27	Relation of Well Discharge to Drawdown in the Dolomite Aquifer	351
28	Relation of Distance from Pumped Well to Drawdown in the Dolomite Aquifer	351
29	Relation of Well Discharge to Drawdown in the Sandstone Aquifer	354
30	Relation of Distance from Pumped Well to Drawdown in the Sandstone Aquifer	354
31	Relation of Time Since Pumping Began to Drawdown in the Sandstone Aquifer	354
32	Graphs for Estimating the Cost of Drilling Wells	357
	Chapter VII	
33	Public Expenditure Trends and Alternative Forecasts for Public Sanitary Sewerage, Park and Outdoor Recreation, and Major Open Channel Drainage Purposes in the Milwaukee River Watershed: 1958-1990	387

List of Maps

Map	Chapter III	Page
1	Recommended Land Use Base for the Milwaukee River Watershed—1990	30
2	Prime Agricultural Areas in the Milwaukee River Watershed—1990	34
3	Alternative Natural Resource Protection Plan Elements for the Milwaukee River Watershed—1990	37
4	Alternative Outdoor Recreation Plan Elements for the Milwaukee River Watershed—1990	45
5	Impact of the Waubeka Reservoir on the Outdoor Recreation Sites as Proposed in the 1990 Alternative Outdoor Recreation Plan Elements	51
6	Proposed Milwaukee River Arterial Parkway	53
7	Proposed Milwaukee River Parkway Pleasure Drive, McKinley Marina to Good Hope Road	55
8	Proposed Milwaukee River Parkway Pleasure Drive, Good Hope Road to the Village of Grafton	58
9	Proposed Scenic Drives in the Milwaukee River Watershed—1990	62

Map | Chapter IV | Page

10 Potential Reservoir Sites and Diversion Channel and Tunnel Alignments in the Milwaukee River Watershed . . . 72
11 Dike-Floodwall System on the Milwaukee River, City of Glendale . . . 141
12 Dike-Floodwall System on the Milwaukee River, City of Mequon—Lac du Cours Area . . . 145
13 Dike-Floodwall System on the Milwaukee River, City of Mequon—CTH M Area . . . 148
14 Dike-Floodwall System on the Milwaukee River, Village of Thiensville. . . . 150
15 Dike-Floodwall System on the Milwaukee River, Village of Saukville. . . . 152
16 Typical Designated Floodway and Corresponding Floodplain for the City of Glendale. . . . 168
17 10- and 100-Year Recurrence Interval Floodplains in the City of Glendale . . . 169
18 Floodlands in the Milwaukee River Watershed. . . . 188

Chapter V

19 Combined Sewer Service Area Tributary to the Milwaukee River Watershed: 1970. . . . 193
20 Combined Sewage Storage Alternatives 1A and 1B . . . 202
21 Combined Sewage Storage Alternative 2A . . . 204
22 Combined Sewage Storage Alternative 2B . . . 206
23 Combined Sewage Storage Alternatives 3A and 3B . . . 208
24 Combined Sewage Storage Alternatives 4A and 4B . . . 209
25 Combined Sewage Storage Alternative 4C . . . 211
26 Combined Sewage Storage Alternative 5A . . . 213
27 Combined Sewage Storage Alternative 5B . . . 214
28 Combined Sewage Storage Alternative 6. . . . 216
29 Combined Sewage Storage Alternatives 7A and 7B . . . 218
30 Combined Sewage Storage Alternative 10 . . . 220
31 Combined Sewage Flow-Through Treatment Alternative 12 . . . 227
32 ASCE Combined Sewer Separation Project, Milwaukee, Wisconsin, Study Area . . . 232
33 Expanded Combined Sewage Storage Alternative—Deep Tunnel Conveyance and Mined Storage Beneath the Milwaukee Harbor . . . 241
34 Expanded Combined Sewage Storage Alternative—Diked Storage Lagoons In Lake Michigan . . 249
35 Detailed Combined Sewage Flow-Through Treatment Alternative—Screening/ Dissolved-Air Flotation Treatment System . . . 253
36 Recommended Combined Sewer Overflow Pollution Abatement Plan Element— Deep Tunnel Conveyance, Mined Storage, and Screening/Dissolved-Air Flotation Treatment System. . . . 258
37 Stream Water Quality Management Recommendations for Industrial Waste Sources in the Milwaukee River Watershed Downstream from the Milwaukee County Line . . . 261
38 Stream Water Quality Management Recommendations for Industrial Waste Sources in the Milwaukee River Watershed Upstream from the Milwaukee County Line . . . 262
39 Upper Milwaukee River Watershed Alternative Stream Water Quality Management Plan Element 1A: 1990 . . . 271
40 Upper Milwaukee River Watershed Alternative Stream Water Quality Management Plan Element 1B: 1990 . . . 273
41 Upper Milwaukee River Watershed Alternative Stream Water Quality Management Plan Element 1C: 1990 . . . 276
42 Upper Milwaukee River Watershed Alternative Stream Water Quality Management Plan Element 1D: 1990 . . . 278
43 Upper Milwaukee River Watershed Alternative Stream Water Quality Management Plan Element 2A: 1990 . . . 282
44 Upper Milwaukee River Watershed Alternative Stream Water Quality Management Plan Element 2B: 1990 . . . 285
45 Upper Milwaukee River Watershed Alternative Stream Water Quality Management Plan Element 3: 1990. . . . 289

Map		Page

46 Upper Milwaukee River Watershed Alternative Stream Water Quality Management Plan Element 4: 1990. 292
47 Upper Milwaukee River Watershed Alternative Stream Water Quality Management Plan Element 5: 1990. 296
48 Recommended Stream Water Quality Management Plan Element for the Upper Milwaukee River Watershed: 1990 301
49 Proposed Sanitary Sewerage System for Auburn (Fifteen) Lake 316
50 Recommended and Alternative Sanitary Sewerage Systems for Tri-Lakes—Advanced Waste Treatment at West Bend (Recommended) or at New Sewage Treatment Plant Below Little Cedar Lake (Alternative) 318
51 Proposed Sanitary Sewerage System for Crooked Lake 321
52 Recommended Sanitary Sewerage System for Ellen Lake 323
53 Recommended Sanitary Sewerage System for Forest Lake 325
54 Recommended Sanitary Sewerage System for Green Lake 325
55 Recommended Sanitary Sewerage System for Kettle Moraine Lake 327
56 Proposed Sanitary Sewerage System for Long Lake 330
57 Recommended Sanitary Sewerage System for Random Lake 335
58 Proposed Sanitary Sewerage System for Twelve Lake 339
59 Recommended Sanitary Sewerage System for Wallace Lake 341

Chapter VI

60 Structure Contour Map of the Top of the Maquoketa Shale 353
61 Structure Contour Map of the Top of the St. Peter Sandstone 355
62 Alternative Cooperative Water Supply System No. 1 for the Bayside-Mequon-River Hills-Thiensville Area 364
63 Alternative Cooperative Water Supply System No. 2 for the Bayside-Mequon-River Hills-Thiensville Area 365
64 Alternative Cooperative Water Supply System No. 3 for the Bayside-Mequon-River Hills-Thiensville Area 366

Chapter VII

65 Recommended Comprehensive Plan for the Milwaukee River Watershed: 1990 373

Chapter VIII

66 Locally Proposed Future Land Use Pattern in the Milwaukee River Watershed 392
67 The Unplanned Land Use Alternative in the Milwaukee River Watershed: 1990 394

(This page intentionally left blank)

Chapter I

INTRODUCTION

This report is the second in a series of two volumes, which together present the major findings and recommendations of the Southeastern Wisconsin Regional Planning Commission Milwaukee River watershed planning program. The first volume, published in December 1970, sets forth the basic principles and concepts underlying the study and presents in summary form the basic facts pertinent to the preparation of a comprehensive plan for the physical development of the Milwaukee River watershed, with particular emphasis upon the existing state of the land and water resources of the basin and the developmental and environmental problems associated with these resources. The first volume also contains forecasts of anticipated future growth and change within the watershed and an analysis of water law, as such law relates to watershed plan preparation and implementation, with particular emphasis upon flood control and pollution abatement.

This, the second and final volume of the series, sets forth watershed development objectives, principles, and standards; presents alternative plans for land use and water control facility development and for resource preservation and enhancement within the watershed; and recommends a comprehensive watershed development plan designed to meet the watershed development objectives under existing and probable future conditions. It proposes staging for water control facility development and recommends means for plan implementation. In addition, this volume also presents a comparative analysis of the changes which may be expected to occur within the watershed by 1990 if present development trends continue without redirection in the public interest. This latter alternative is presented not as a plan to be used to guide development within the watershed but, rather, as a forecast of unplanned development and is intended to be used as a standard of comparison for the evaluation of the recommended watershed development plan.

The recommended watershed development plan presented in this volume is the end result of a seven-step planning process developed by the Commission by which the principal functional relationships existing within the watershed can be accurately described, both graphically and numerically; the hydrologic and hydraulic characteristics of the watershed simulated; and the effect of different courses of action, with respect to land use and water control facility development, evaluated. These seven steps involved in this planning process are: 1) study design, 2) formulation of objectives and standards, 3) inventory, 4) analysis and forecast, 5) plan design, 6) plan test and evaluation, and 7) plan selection and adoption. Volume 1 of this report dealt with the first, third, and fourth steps in this planning process. This volume deals with the remaining four steps: formulation of objectives and standards, plan design, plan test and evaluation, and plan selection and adoption. Plan implementation, although beyond the initial planning process, has been considered throughout the process; and this volume contains specific recommendations for plan implementation.

A brief description of each of the seven steps comprising the planning process is contained in Chapter II, Volume 1, of this report, together with the basic principles and concepts underlying the watershed planning process and the watershed as a rational planning unit. Reconsideration of, and elaboration on, the four steps in the planning process with which this volume are concerned are warranted here.

FORMULATION OF OBJECTIVES AND STANDARDS

It is noted in Volume 1 of this report that planning is a rational process for formulating and meeting objectives; and, therefore, the formulation of objectives is an essential task which must be undertaken before plans can be prepared. The objectives chosen guide the preparation of alternative plans and, when converted to standards, provide the criteria for evaluating and selecting from among the alternatives. Since objectives provide the logical basis for plan synthesis, the formulation of sound objectives is a crucial step in the planning process. Yet, the process of formulating objectives has received relatively little attention in most planning operations. The lack of a comprehensive and tested approach to the problem of formulating objectives, however, provides no valid excuse for neglecting this fundamental task.

It is important to recognize that, because the formulation of objectives involves a formal definition of a desirable physical system by listing, in effect, the broad needs which the system aims to satisfy, the objectives implicitly reflect an underlying value system. Thus, every physical development plan is accompanied by its own unique value system. The diverse nature of value systems in a complex urban society complicates the process of goal formulation and makes it one of the most difficult tasks of the planning process. This difficulty relates, in part, to the lack of a clear-cut basis for a choice between value systems and, in part, to the reluctance of public officials to make an explicit choice of ultimate goals. Yet, it is even more important to choose the "right" objectives than to choose the "right" plan. To choose the wrong objectives is to solve the wrong problem; to choose the wrong plan is merely to choose a less efficient physical system. While, because of differing value systems, there may be no single argument to support the given choice of objectives, it is possible to state certain planning principles which provide at least some support for the choice; and this has been done herein.

Objectives cannot be intelligently chosen without knowledge of the crucial relationships existing between objectives and means. This suggests that the formulation of objectives is best done by people with prior knowledge of the social, economic, and technical means of achieving the objectives, as well as of the underlying value systems. Even so, it must be recognized that the objectives may change as a selection is attempted from among alternative means or plans. In the process of evaluating alternative plans, the various alternative plan proposals are ranked according to ability to meet objectives. If the best plan so identified nevertheless falls short of the chosen objectives, either a better plan must be synthesized or the objectives must be compromised. The plan evaluation provides the basis for deciding which objectives to compromise. The compromises may take three forms: certain objectives may be dropped because their satisfaction has been proven unrealistic; new objectives may be suggested; or conflicts between inconsistent objectives may be balanced out. Thus, formulation of objectives must proceed hand in hand with plan design and plan implementation as a part of a continuing planning process.

Concern for objectives cannot end with a mere listing of desired goals. The goals must be related in a demonstrable and, wherever possible, quantifiable manner to physical development proposals. Only through such a relationship can alternative development proposals be properly evaluated. This relationship is accomplished through a set of supporting standards for each chosen objective.

Because of the value judgments inherent in any set of development objectives and their supporting standards, soundly conceived watershed development objectives, like regional development objectives, should incorporate the combined knowledge of many people who are informed about the watershed and should be established by duly elected or appointed representatives legally assigned this responsibility rather than by planning and engineering technicians. Active participation by duly elected or appointed public officials and by citizen leaders in the regional planning program is implicit in the structure and organization of the Regional Planning Commission itself. Moreover, the Commission has provided for the establishment of advisory committees to assist it in the conduct of the regional planning program, including the necessary watershed planning studies, and to broaden the opportunities for active participation in the regional planning effort.

The use of these advisory committees appears to be the most practical and effective procedure available for involving officials, technicians, and citizens in the regional planning process and of openly arriving at decisions and action programs which can shape the future physical development of the Region and its component watersheds. Only by combining the accumulated knowledge and experience which the various advisory committee members possess can a meaningful expression of desired direction, magnitude, and quality of future regional and watershed development be attained. One of the major tasks of these advisory committees, therefore, is to assist the Commission in the formulation of development objectives, supporting principles, and standards. This chapter sets forth the watershed planning objectives, principles, and standards which have been adopted by the Commission after careful review and recommendation by the advisory committees concerned.

PLAN DESIGN

It was noted in Volume 1 of this report that plan synthesis, or design, forms the heart of the planning process and that the watershed plan design problem consists essentially of determining the allocation of scarce resources—land and water—between competing and often conflicting demands. This allocation must be accomplished so as to satisfy the aggregate needs for each use and comply with the design standards derived from the plan objectives, all at a feasible cost.

The task of designing two of the major components of an environment for life—the land use pattern and the water control facility system of a watershed—is a most complex and difficult problem. Not only does each component constitute in itself a major problem in terms of the sheer size of the system to be designed but the pattern of interaction between the components is also exceedingly complex and constantly changing. The land use pattern must enable people to live in close cooperation and yet freely pursue an enormous variety of interests. It must minimize conflicts between population growth and limited land and water resources; maintain an ecological balance of human, animal, and plant life; and avoid gross public health and welfare problems. The water control facilities must be able to carry the flood and pollution loadings generated by the land use pattern, meeting agreed-upon water use objectives while recognizing the use of existing facilities and minimizing overall costs.

The magnitude of such a design problem nearly reaches an insoluble level of complexity; yet, no substitute for intuition in plan design has so far been found, much less developed to a practical level. Means do exist, however, for reducing the gap between the necessary intuitive and integrative grasp of the problem and its growing magnitude; and these have been fully applied in the Milwaukee River watershed study. These means center primarily on the application of systems engineering techniques to the quantitative test of both the land use and water facility plans, as described below under the plan test and evaluation phase. Yet, the quantitative tests involved in these techniques, while powerful aids to the determination of the adequacy of the plan design, are of strictly limited usefulness in actual plan synthesis. Consequently, it is still necessary to develop both the land use and water facility plans by traditional graphic and analytical "cut-and-try" methods, then to quantitatively test the resulting design by application of simulation model techniques where applicable, and then make necessary adjustments in the design until a workable plan has been evolved.

Finally, and most importantly, it should be noted that, in both land use and water facility plan synthesis, the Commission had at its disposal far more definitive information bearing on the problem than has ever before been available; and this fact alone has made the traditional plan synthesis techniques applied far more powerful and useful.

PLAN TEST AND EVALUATION

It was noted in Volume 1 of this report that, if the plans developed in the design stage of the planning process are to be practical and workable and thereby realized in terms of actual land use and water control facility system development, some measures must be applied to quantitatively test the feasibility of alternative plans in advance of their adoption and implementation. Several levels of review and evaluation may be involved, including engineering performance, technical feasibility, economic feasibility, legality, and political reaction. Devices used to test and evaluate alternative plans range from mathematical models used to simulate river performance through interagency meetings and public hearings. To assist in a quantitative analysis of the engineering performance and the technical and economic feasibility of alternative plan elements, flood flow and water quality simulation models were developed and applied in the study. Test and evaluation, beyond the quantitative analyses permitted by the model application, involved qualitative evaluation of the degree to which each alternative land use or water control facility plan element met development objectives and standards and of the legal feasibility of the alternatives.

PLAN SELECTION AND ADOPTION

It was also noted in Volume 1 of this report that the general approach contemplated for the selection of one plan from among the alternatives considered was to proceed through the use of the Milwaukee River Watershed Committee structure, interagency meetings, and hearings to a final decision and plan adoption by the Commission, in accordance with the provisions of the state-enabling legislation. Because plan selection and adoption necessarily involve both technical and nontechnical policy determinations, they must be founded in the active involvement throughout the entire planning process of the various governmental bodies, technical agencies, and private interest groups concerned with watershed development. Such involvement is particularly important in light of the advisory role of the Commission in shaping regional development. The use of advisory committees and both formal and informal hearings appears to be the most practical and effective procedure available for involving public officials, technicians, and citizens in the planning process and of openly arriving at agreement among the affected governmental bodies and agencies on objectives and on plans which can be jointly implemented.

The preparation of a recommended comprehensive plan for the Milwaukee River watershed required that a selection be made from among the alternative elements which together should comprise the comprehensive plan, including a land use base and necessary supporting water control and pollution abatement facilities. Such a selection must be based upon consideration of many tangible and intangible factors but should be focused primarily upon the degree to which the agreed-upon watershed development objectives are satisfied and upon the accompanying costs. The selection of the plan elements to be included in the final plan must ultimately be made by the responsible elected and appointed public officials concerned and not by the planning technicians, although the latter may properly make recommendations based upon evaluation of technical considerations.

As an integral part of the watershed planning program, a series of informal public informational meetings and a formal public hearing were held within the watershed. The meetings and hearing were conducted by a special four-member subcommittee of the Milwaukee River Watershed Committee with the Chairman of the Watershed Committee presiding. The purpose of these meetings and hearing was to more fully inform public officials and interested citizens about the findings and recommendations of the watershed planning program and to obtain the reaction of the officials and citizens to the alternative plan elements considered and the preliminary comprehensive watershed plan recommended. The meetings and hearing were preceded by the issuance of news releases which were published in all of the daily and weekly newspapers in circulation within the watershed. A summary of the inventory, analysis, and forecast findings; of the watershed development objectives; of the alternative land use and water control facility arrangements considered; and of the recommended preliminary watershed plan was presented at each of the meetings and again at the hearing, together with data on the costs and means for implementation of the recommended plan. The public informational meetings and hearing were held in accordance with the schedule listed below, and minutes of both the informational meetings and the public hearing, totaling 225 pages in length, were published on July 21, 1971, and transmitted to both the Milwaukee River Watershed Committee and the Regional Planning Commission for review and consideration prior to final adoption of the recommended plan.

Informational Meetings

Presiding Agency	Place of Meeting	Date of Meeting
Milwaukee River Watershed Committee	City Hall Mequon, Wisconsin	June 15, 1971 9:40 a.m. - 11:50 a.m.
Milwaukee River Watershed Committee	West Bend High School West Bend, Wisconsin	June 17, 1971 7:40 p.m. - 10:35 p.m.
Milwaukee River Watershed Committee	Nicolet High School Glendale, Wisconsin	June 22, 1971 7:40 p.m. - 10:35 p.m.
Milwaukee River Watershed Committee	Cedarburg High School Cedarburg, Wisconsin	June 24, 1971 7:45 p.m. - 10:25 p.m.

Public Hearing

Presiding Agency	Place of Hearing	Date of Hearing
Milwaukee River Watershed Committee	Homestead High School Mequon, Wisconsin	June 29, 1971 7:40 p.m. - 11:20 p.m.

A total of 737 persons attended the informational meetings and public hearing. The record of the proceedings indicates that the public reaction to the recommended land use, water pollution abatement, and water supply elements was generally favorable but that a sharp division of public opinion existed over the best course of action with respect to flood control. Those citizens residing in the high potential flood damage areas of the watershed, particularly in the riverine areas through the Cities of Glendale and Mequon and the Village of Saukville, and the elected public officials who represented these citizens, strongly favored inclusion of the Waubeka Reservoir in the final watershed plan. Those citizens residing in or near the reservoir area and their elected officials vigorously opposed the inclusion of the Waubeka Reservoir in the final watershed plan, as did certain more broadly based conservation and environmental preservation organizations.

With but a single major exception, no information or arguments in either support of, or opposition to, the multiple-purpose reservoir were advanced at the hearings which had not been considered in the plan formulation and evaluation and which were not, therefore, set forth in Chapter IV of this volume. Thus, the major arguments presented in favor of the reservoir included its effectiveness as a structural flood control measure, its economic viability, its great recreational potential, its low-flow augmentation potential, and the adverse effect which a lack of positive action in the area of flood control would have on existing flood-prone land uses and land values in the lower watershed. The major arguments presented in opposition to the reservoir included the necessary attendant destruction of existing woodlands, wetlands, and wildlife habitat areas; the loss of agricultural land; the removal of land from local tax rolls; the uncertainties concerning the level of water quality within the reservoir and, hence, the recreational potential of the reservoir, if the water pollution abatement recommendations contained in the plan are not fully implemented; the possible fluctuation in the reservoir water level and the attendant creation of "mud flats" during periods of low water; and the difficulty of implementing such a major public works project given the existing institutional structure.

The only truly new information brought to light by the informational meetings and public hearing was contained in the testimony of officials of the Wisconsin Electric Power Company, who indicated that the reservoir might provide a good location for a future major electric power generating station, a station which could draw cooling water from Lake Michigan and return that water to the reservoir, thus enhancing both the quality of the reservoir and augmenting low flows in the Milwaukee River downstream from the reservoir.

Some opposition was also expressed at the public hearing to the proposals contained in the recommended natural resource protection plan element for public purchase of certain of the primary environmental corridor lands within the watershed. The opponents of such purchase, however, generally recognized the need for the preservation of the environmental corridors but suggested that the preservation be accomplished largely by zoning in order to avoid any adverse effects on the local tax base.

Finally, it should be noted that Congressman Henry S. Reuss, immediately following the public hearing, requested the U. S. Army Corps of Engineers to provide an advisory opinion as to whether or not the Waubeka Reservoir and the Saukville Diversion Channel would be eligible under existing federal guidelines for Corps funding and construction. That advisory opinion, set forth in the letter report of the Corps reproduced in Appendix I, indicated that neither project would presently qualify for federal assistance.

After careful consideration of the results of the informational meetings and public hearing and of the advisory opinion of the Corps of Engineers affecting the financial feasibility of the Waubeka Reservoir and Saukville Diversion Channel structural flood control measures, the Milwaukee River Watershed Committee, at a meeting held on October 6, 1971, voted unanimously to recommend to the Regional Planning Commission adoption of a final watershed plan which did not depart in any significant way from the preliminary plan presented at the public informational meetings and public hearing. That plan is fully documented in Chapter VII of this volume.

(This page intentionally left blank)

Chapter II

WATERSHED DEVELOPMENT OBJECTIVES, PRINCIPLES, AND STANDARDS

BASIC CONCEPTS AND DEFINITIONS

The term "objective" is subject to a wide range of interpretation and application and is closely linked to other terms often used in planning work which are equally subject to a wide range of interpretation and application. The following definitions have, therefore, been adopted by the Commission in order to provide a common frame of reference:

1. Objective; a goal or end toward the attainment of which plans and policies are directed.

2. Principle; a fundamental, primary, or generally accepted tenet used to support objectives and prepare standards and plans.

3. Standard; a criterion used as a basis of comparison to determine the adequacy of plan proposals to attain objectives.

4. Plan; a design which seeks to achieve agreed-upon objectives.

5. Policy; a rule or course of action used to ensure plan implementation.

6. Program; a coordinated series of policies and actions to carry out a plan.

Although this chapter deals only with the first three of these terms, an understanding of the interrelationship between the foregoing definitions and the basic concepts which they represent is essential to any consideration of watershed development objectives, principles, and standards.

WATERSHED DEVELOPMENT OBJECTIVES

Objectives, in order to be useful in the watershed planning process, must not only be sound logically and related in a demonstrable and measurable way to alternative physical development proposals but must also be consistent with, and grow out of, region-wide development objectives. This is essential if the watershed plans are to comprise integral elements of a comprehensive plan for the physical development of the Region and if sound coordination of regional and watershed development is to be achieved.

The Southeastern Wisconsin Regional Planning Commission has, in its planning efforts to date, adopted, after careful review and recommendation by various advisory and coordinating committees, nine general regional development objectives, eight specific regional land use development objectives, and seven specific regional transportation system development objectives. These, together with their supporting principles and standards, are set forth in SEWRPC Planning Report No. 7, Volume 2. Certain of these specific regional development objectives relating to land use are directly applicable to the watershed planning effort and are hereby recommended for adoption as development objectives for the Milwaukee River watershed. These are:

1. A balanced allocation of space to the various land use categories which meets the social, physical, and economic needs of the regional population.

2. A spatial distribution of the various land uses which will result in the protection, wise use, and development of the natural resources of the Region—soils, inland lakes and streams, ground water, wetlands, woodlands, and wildlife.

3. A spatial distribution of the various land uses which is properly related to the supporting transportation, utility, and public facility services.

4. The preservation and provision of open space to enhance the total quality of the regional environment, maximize essential natural resource availability, give form and structure to urban development, and facilitate the ultimate attainment of a balanced year-round outdoor recreational program providing a full range of facilities for all age groups.

5. The preservation of land areas for agricultural uses in order to provide for cer-

tain special types of agriculture, provide a reserve for future needs, and ensure the preservation of those rural areas which provide wildlife habitat and are essential to shape and order urban development.

In addition to the foregoing specific regional land use development objectives, the following specific land use and surface and ground water development objective is recommended for adoption as an additional development objective for the Milwaukee River watershed:

6. The attainment of good soil and water conservation practices in order to reduce storm water runoff, soil erosion, and stream and lake sedimentation, pollution, and eutrophication.

The following specific water control facility development objectives are also recommended:

1. An integrated system of drainage and flood control facilities which will effectively reduce flood damage under the existing land use pattern of the watershed and promote the implementation of the watershed land use plan, meeting the anticipated runoff loadings generated by the existing and proposed land uses.

2. An integrated system of land management and water quality control facilities and pollution abatement devices adequate to ensure a quality of stream water necessary to permit the water uses set forth in Table 1.

3. An integrated system of land management and water quality control facilities and pollution abatement devices adequate to ensure a quality of lake water necessary to permit the water uses set forth in Table 1.

4. The attainment of sound ground water resource development and protective practices to minimize the possibility for pollution and depletion of the ground water resources.

Complementing each of the foregoing specific land use and water control facility development objectives is a planning principle and a set of planning standards. These, as they apply to watershed planning and development, are set forth in Tables 1 and 2 and serve to facilitate quantitative application of the objectives in plan design, test, and evaluation.

It should be noted that the planning standards herein adopted fall into two groups: comparative and absolute. The comparative standards, by their vary nature, can be applied only through a comparison of alternative plan proposals. Absolute standards can be applied individually to each alternative plan proposal since they are expressed in terms of maximum, minimum, or desirable values. The standards set forth herein should serve not only as aids in the development, test, and evaluation of watershed land use and water control facility plans but also in the development, test, and evaluation of local land use and community facility plans and in the development of plan implementation policies and programs as well.

The foregoing watershed development objectives and their supporting principles and standards necessarily reflect certain value judgments made by the public officials, technicians, and citizen leaders who comprised the SEWRPC Milwaukee River Watershed Committee and the SEWRPC Technical Advisory Committee on Natural Resources and Environmental Design. In addition, certain engineering design criteria were utilized in the preparation of the watershed plans; and, while these are widely accepted and firmly based in current engineering practice, it was, nevertheless, felt important to document these herein. It should be noted that, while these criteria were used in the preparation of the watershed plans, they do not comprise standards as defined herein, in that they relate to the methods used in inventory, analysis, and plan synthesis, test, and evaluation rather than to specific development objectives.

ENGINEERING DESIGN CRITERIA FOR THE MILWAUKEE RIVER WATERSHED

Rainfall-Frequency Relationships

If local storm water drainage and main river flood control measures are to be compatible and function in a coordinated manner, plans for both must be based on consistent engineering design criteria. A fundamental criterion for both local and watershed drainage planning is the rainfall intensity-duration-frequency relationship representative of the watershed area. Intensity-duration-frequency curves based on a 64-year record at the Milwaukee Weather Service Station are shown in Appendix C. The curves in Figures C-1 and C-2 are directly

Table 1

WATER CONTROL FACILITY DEVELOPMENT OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE MILWAUKEE RIVER WATERSHED

OBJECTIVE NO. 1

An integrated system of drainage and flood control facilities which will effectively reduce flood damage under the existing land use pattern of the watershed and promote the implementation of the watershed land use plan, meeting the anticipated runoff loadings generated by the existing and proposed land uses.

PRINCIPLE

Reliable local municipal storm water drainage facilities cannot be properly planned, designed, or constructed except as integral parts of an areawide system of floodwater conveyance and storage facilities centered on major drainageways and perennial waterways designed so that the hydraulic capacity of each waterway opening and channel reach abets the common aim of providing for the storage, as well as the movement, of floodwaters. Not only does the land use pattern of the tributary drainage area affect the required hydraulic capacity, but the effectiveness of the floodwater conveyance and storage facilities affects the uses to which land within the tributary watershed, and particularly within the riverine areas of the watershed, may properly be put.

STANDARDS

1. All new and replacement bridges and culverts over perennial waterways shall be designed so as to accommodate, according to the categories listed below, the designated flood events without overtopping of the related roadway or railroad track and resultant disruption of traffic by floodwaters.

  a. Minor and collector streets used or intended to be used primarily for access to abutting properties: a 10-year recurrence interval flood discharge.

  b. Arterial streets and highways, other than freeways and expressways, used or intended to be used primarily to carry heavy volumes of fast, through traffic: a 50-year recurrence interval flood discharge.

  c. Freeways and expressways: a 100-year recurrence interval flood discharge.

  d. Railroads: a 100-year recurrence interval flood discharge.

2. All new and replacement bridges and culverts over perennial waterways, including pedestrian and other minor bridges, in addition to meeting the applicable above-specified requirements, shall be designed so as to accommodate the 100-year recurrence interval flood event without raising the peak stage, either upstream or downstream, more than 0.5 foot above the peak stage for the 100-year recurrence interval flood, as established in the adopted comprehensive watershed plan. Larger permissible flood stage increases may be acceptable for reaches having topographic or land use conditions which could accommodate the increased stage without creating additional flood damage potential upstream or downstream of the proposed structure.

3. The waterway opening of all new and replacement bridges shall be designed so as to readily facilitate the passage of ice floes and other floating debris and thereby avoid blockages often associated with bridge failure and with unpredictable backwater effects and flood damages. In this respect it should be recognized that clear spans and rectangular openings are more efficient than interrupted spans and curvilinear openings in allowing the passage of ice floes and other floating debris.

4. Certain new or replacement bridges and culverts over perennial waterways, including pedestrian and other minor bridges, so located with respect to the stream system that the accumulation of floating ice or other debris may cause significant backwater effects with attendant danger to life, public health, or safety or attendant serious damage to homes, industrial and commercial buildings, and important public utilities, shall be designed so as to pass the 100-year recurrence interval flood with at least 2.0 feet of freeboard between the peak stage and the low concrete or steel in the bridge span.

5. Standards 1, 3, and 4 shall also be used as the criteria for assessment of the adequacy of the hydraulic capacity and structural safety of existing bridges or culverts over perennial waterways and thereby serve, within the context of the adopted comprehensive watershed plan, as the basis for crossing modification or replacement recommendations designed to alleviate flooding and other problems.

6. Channel improvements, levees, and floodwalls should be restricted to the minimum number and extent absolutely necessary for the protection of existing and proposed land use development, which development is consistent with the land use element of the comprehensive watershed plan; and any such improvements which may significantly increase upstream or downstream peak flood discharges should be used only in conjunction with complementary facilities for the storage and movement of the incremental floodwaters through downstream reaches. The height of levees and floodwalls shall be based on the high water surface profiles for the 100-year recurrence interval flood prepared under the comprehensive watershed study and shall be capable of passing the 100-year recurrence interval flood with a freeboard of at least two feet. Channel improvements, levees, or floodwalls shall not increase the height of the 100-year recurrence interval flood by more than one-half foot in any unprotected upstream or downstream stream reaches. Increases in flood stages in excess of one-half foot resulting from any channel, levee, or floodwall improvement shall be contained within the upstream or downstream extent of the channel, levee, or floodwall improvement, except where topographic or land use conditions could accommodate the increased stage without creating additional flood damage potential.

The construction of channel improvements, levees, or floodwalls shall be deemed to change the limits and extent of the associated floodways and floodplains. However, no such change in the extent of the associated floodways and floodplains shall become effective for the purposes of land use regulation until such time as the channel improvements, levees, or floodwalls are actually constructed and operative. Any development in a former floodway or floodplain located to the landward side of any levee or floodwall shall be provided with adequate drainage so as to avoid ponding and associated damages.

7. All water control facilities, other than bridges and culverts, such as dams and diversion channels, so located on the stream system that failure would damage only agricultural lands and isolated farm buildings, shall be designed to accommodate at least the hydraulic loadings resulting from a 100-year recurrence interval flood. Water control facilities so located on the stream system that failure could jeopardize public health and safety, cause loss of life, or seriously damage homes, industrial and commercial buildings, and important public utilities or would result in closure of principal transportation routes shall be designed to accommodate a flood that approximates the standard project flood or the more severe probable maximum flood, depending on the ultimate probable consequences of failure.[a]

8. Reduced regulatory flood protection elevations and accompanying reduced floodway or floodplain areas resulting from any proposed dams or diversion channels shall not become effective for the purposes of land use regulation until the reservoirs or channels are actually constructed and operative.

9. All public land acquisitions intended to eliminate the need for water control facilities shall, in all areas not already in intensive urban use, encompass at least all of the riverine areas lying within the 100-year recurrence interval flood inundation line.

OBJECTIVE NO. 2

An integrated system of land management and water quality control facilities and pollution abatement devices adequate to ensure a quality of stream water permitting the following beneficial water uses in each of the following reaches of the stream system:

The Milwaukee River from its headwaters to the North Avenue Dam shall have a level of water quality suitable for the following water uses:[b]

a. Minimum Standards

b. Fish and Other Aquatic Life

c. Recreational Use-Full-Body Contact

d. Industrial and Cooling Water Use

The Milwaukee River from the North Avenue Dam to the Milwaukee Harbor in the City of Milwaukee:

a. Minimum Standards

b. Industrial and Cooling Water Use

c. Recreational Use-Partial-Body Contact Only

The following major tributaries of the Milwaukee River shall have a level of water quality suitable for the following water uses:

Cedar Creek except in Cedarburg
North Branch Milwaukee River
East Branch Milwaukee River
West Branch Milwaukee River
Silver Creek (Sherman Township)
Adell Tributary
Silver Creek (West Bend Township)
Pigeon Creek

a. Minimum Standards

b. Recreational Use-Full-Body Contact

c. Fish and Other Aquatic Life

The remaining three streams tributary of the Milwaukee River shall have a level of water quality suitable for the following water uses:

1. Cedar Creek in Cedarburg

   a. Minimum Standards

   b. Fish and Other Aquatic Life

   c. Recreational Use-Full-Body Contact

   d. Industrial and Cooling Water Use

2. Lincoln Creek

   a. Minimum Standards

   b. Recreational Use-Partial-Body Contact Only

3. Indian Creek

   a. Minimum Standards

PRINCIPLE

Surface water is one of the most valuable resources of southeastern Wisconsin; and, even under the effects of increasing population and economic activity levels, the potential of natural stream waters to serve a reasonable variety of beneficial uses, in addition to the single-purpose function of waste transport and assimilation, should be protected and preserved.

STANDARDS

1. Water quality levels in a stream reach shall be adequate to meet the State of Wisconsin water quality standards[c] for all water uses designated for that reach.

2. Regardless of the water uses designated for a stream reach, all reaches of all streams shall meet at least the minimum stream water quality standards set forth in the State of Wisconsin water quality standards.

3. All development except isolated residential buildings, small commercial establishments, or small industrial concerns shall be served by public sanitary sewerage facilities conveying liquid wastes to a sewage treatment plant that provides a degree of treatment adequate to meet the stated water use objectives for the stream reach involved.

OBJECTIVE NO. 3

An integrated system of land management and water quality control facilities and pollution abatement devices adequate to ensure a quality of lake water permitting the following beneficial water uses in each of the following lakes and impoundments:

For West Bend Dam Pond and Woolen Mills Dam Pond:

a. Minimum Standards

b. Industrial and Cooling Water Use

c. Recreational Use-Full-Body Contact

d. Fish and Other Aquatic Life

e. Wildlife Watering

For all remaining 19 lakes having a surface area of 50 acres or more:

a. Minimum Standards

b. Recreational Use-Full-Body Contact

c. Fish and Other Aquatic Life

d. Wildlife Watering

PRINCIPLE

Lakes are an invaluable and irreplaceable surface water resource of southeastern Wisconsin. The recreational opportunities and aesthetic value that the lakes offer the population of the Region far outweigh the value to the Region of any other potential use of the lakes and should be protected and preserved.

LAKES NOT LOCATED ON PERENNIAL TRIBUTARY STREAMS

Principle

The intermittent nature of flows in nonperennial streams does not assure that reasonable water surface levels can be maintained in lakes to support fish life and recreation nor are good aesthetic characteristics assured if fixed regular withdrawals are imposed in addition to natural water losses.

STANDARDS

1. Any lake water use other than recreation, fishing, and aesthetic enjoyment shall be considered an accessory use which is permissible only if it is compatible with recreation, fishing, and aesthetic enjoyment uses and is necessary or desirable from the standpoint of meeting watershed development objectives.

2. Lake water uses which shall not be permitted under any circumstances include industrial and cooling water use, direct livestock watering, irrigation, and waste assimilation.

3. Water quality levels in a lake shall be adequate to meet the State of Wisconsin equivalent stream water quality standards for all equivalent designated water uses.

4. Algae and aquatic weeds shall not be present in numbers sufficient to create an aesthetic nuisance or to interfere with recreational use.

LAKES LOCATED ON PERENNIAL TRIBUTARY STREAMS

Principle

Natural and man-made lakes through which perennial streams flow may be subjected to regular fixed withdrawals of water for regulated uses other than recreation, fish life, and aesthetics.

STANDARDS

1. Any lake water use other than recreation, fishing, and aesthetic enjoyment is permissible only if it is necessary from the standpoint of meeting watershed development objectives and is compatible with recreation, fishing, and aesthetic enjoyment uses.

2. Lake water uses which shall not be permitted under any circumstances include direct livestock watering and waste assimilation.

3. Lake water uses may be permitted for agricultural irrigation, lawn sprinkling, and industrial and cooling water if average monthly withdrawals do not exceed inflow equal to the one in ten-year monthly low flow and if compensating storage is available in the impoundment.

4. Lake water may be released for augmentation of low stream flow if the lake is not drawn below the predetermined conservation level based on recreational, fish life, and aesthetic requirements in the lake.

5. Water quality levels in a lake shall be adequate to meet the State of Wisconsin equivalent stream water quality standards for all equivalent designated water uses.

6. Algae and aquatic weeds shall not be present in numbers sufficient to create an aesthetic nuisance or to interfere with recreational use.

OBJECTIVE NO. 4

The attainment of sound ground water resource development and protective practices to minimize the possibility for pollution and depletion of the ground water resources.

PRINCIPLE

Sound practices in the location, installation, and operation of water supply wells and waste treatment and disposal facilities can reasonably assure a continuing supply of good quality ground water at reasonable cost.

STANDARDS

1. Ground water withdrawals should be made so as to prevent undue interference with adjacent withdrawal points, and the capacities and withdrawal rates should be related to potential yield and total demand on the aquifers penetrated.

2. Wells should be constructed so as not to permit contamination of the aquifer through the well during construction or during subsequent operation.

3. Waste conveyance, treatment, and disposal facilities, located above or below ground surface, both public and private, should be designed, constructed, and operated in a manner to prevent migration or infiltration of contaminants into sources of usable ground water. These facilities include pipes, tunnels, septic tanks, leaching areas, sanitary landfills, and injection wells.

---

[a] These flood events, which have been formulated and used by the U. S. Army Corps of Engineers, are defined and discussed in Chapter VII, SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, November 1968.

[b] For a complete listing of water uses and accompanying standards, see Chapter IX, Volume I, of this report or the Wisconsin Administrative Code.

[c] See Chapter IX, Volume I, of this report.

Table 2

LAND USE DEVELOPMENT OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE MILWAUKEE RIVER WATERSHED

OBJECTIVE NO. 1

A balanced allocation of space to the various land use categories which meets the social, physical, and economic needs of the regional and watershed populations, as well as the needs of the short-term visitors to the watershed.

PRINCIPLE

The planned supply of land set aside for any given use should approximate the known and anticipated demand for that use.

STANDARDS

1. For each additional 1,000 persons to be accommodated within the watershed at each density, the following *minimum* amounts of land should be set aside:

Residential Land	Net Area[a]	Gross Area[b]
Low Density	250 acres/1,000 persons	312 acres/1,000 persons
Medium Density	70 acres/1,000 persons	98 acres/1,000 persons
High Density	25 acres/1,000 persons	38 acres/1,000 persons

Governmental and Institutional Land	Gross Area[c]
Regional[d]	3 acres/1,000 persons
Local[e]	6 acres/1,000 persons

Park and Recreational Land[f]	Gross Area[g]
Regional[h]	4 acres/1,000 persons
Local[i]	10 acres/1,000 persons

2. For the daily use of short-term visitors to the watershed, the following amounts of land should be acquired and developed for each anticipated 100 participants[j] in each of the five major outdoor recreational activities which require intensive land development within the watershed:

Major Activity	Total Acres	Principal Development Acres	Backup Land or Secondary Development Acres
Swimming[k]	0.45	0.09	0.36
Picnicking[l]	12.50	1.25	11.25
Golfing[m]	32.79	32.79	--
Camping[n]	133.33	6.67	126.66
Skiing[o]	3.70	3.33	0.37

3. For each additional 100 commercial and industrial employees to be accommodated within the watershed, the following minimum amounts of land should be set aside:

	Gross Area[p]
Commercial Land[q]	5 acres/100 employees
Industrial Land[r]	7 acres/100 employees

OBJECTIVE NO. 2

A spatial distribution of the various land uses which will result in the protection, wise use, and development of the natural resources.

PRINCIPLE

The proper allocation of uses to land can assist in maintaining an ecological balance between the activities of man and the natural environment which supports him.

A. Soils

Principle

The proper relation of urban and rural land use development to soils can serve to avoid many environmental problems, aid in the establishment of better regional settlement patterns, and promote the wise use of an irreplaceable resource.

STANDARDS

1. Urban development, particularly for residential use, shall be located only in those areas which do not contain significant concentrations of soils rated in the regional detailed operational soil survey as poor, questionable, or very poor for such development.[s] Significant concentrations are defined as follows:

   a. In areas[t] to be developed for low-density residential use, no more than 2.5 percent of the gross area should consist of soils rated in the regional detailed operational soil survey as poor, questionable, or very poor for such development.

   b. In areas to be developed for medium-density residential use, no more than 3.5 percent of the gross area should consist of soils rated in the regional detailed operational soil survey as poor, questionable, or very poor for such development.

   c. In areas to be developed for high-density residential use, no more than 5.0 percent of the gross area should consist of soils rated in the regional detailed operational soil survey as poor, questionable, or very poor for such development.

2. Rural development, principally agricultural land uses, shall be allocated primarily to those areas covered by soils rated in the regional detailed operational soil survey as very good, good, or fair for such uses.

3. Land developed or proposed to be developed for urban use without public sanitary sewer service should be located only on areas covered by soils rated in the regional detailed operational soil survey as very good, good, or fair for such development.

B. Inland Lakes and Streams

Principle

Inland lakes and streams provide a suitable environment for desirable and sometimes unique plant and animal life; provide the population with opportunities for certain scientific, cultural, and educational pursuits; constitute prime recreational areas; provide a desirable aesthetic setting for certain types of land use development; serve to store and convey floodwaters; contribute to the atmospheric water supply through evaporation; and provide for certain water withdrawal requirements.

STANDARDS

1. A minimum of 25 percent of the perimeter or shoreline frontage of lakes having a surface area in excess of 50 acres and of both banks of all perennial streams should be maintained in a natural state.

2. A minimum of 10 percent of the shoreline of each inland lake having a surface area in excess of 50 acres should be maintained for public uses, such as a beach area, pleasure craft marina, or park.

3. Urban development, except for park and outdoor recreational use, should not be allocated to more than 50 percent of the length of the shoreline of inland lakes having a surface area in excess of 50 acres and of all perennial streams.

4. In addition, it is desirable that 25 percent of the shoreline of each inland lake having a surface area less than 50 acres be maintained in either a natural state or some low-intensity public use, such as park land.

5. Floodplain lands[u] should not be allocated to any urban development[v] which would cause or be subject to flood damage.

6. Only those structures or fills which are in conformance with the comprehensive watershed plan should be allowed to encroach upon and obstruct the flow of water in the perennial stream channels[w] and floodways.[x]

C. Wetlands

Principle

Wetlands support a wide variety of desirable and sometimes unique plant and animal life; assist in the stabilization of lake levels and streamflows; trap and store plant nutrients in runoff, thus reducing enrichment of surface waters and obnoxious weed and algae growth; contribute to the atmospheric oxygen supply; contribute to the atmospheric water supply; reduce storm water runoff by providing area for floodwater impoundment and storage; reduce stream sedimentation; and provide the population with opportunities for certain scientific, educational, and recreational pursuits.

STANDARD

All wetland area[y] adjacent to streams or lakes, all within areas having special wildlife values, and all wetlands having an area in excess of 50 acres should not be allocated to any urban development except limited recreation and should not be drained or filled. Adjacent surrounding areas should be kept in open-space use, such as agriculture or limited recreation.

D. Woodlands[z]

Principle

Woodlands assist in maintaining unique natural relationships between plants and animals; reduce storm water runoff; contribute to the atmospheric oxygen supply; contribute to the atmospheric water supply through transpiration; aid in reducing soil erosion and stream sedimentation; provide the resource base for the forest product industries; provide the population with opportunities for certain scientific, educational, and recreational pursuits; and provide a desirable aesthetic setting for certain types of land use development.

STANDARDS

1. A minimum of 10 percent of the land area of each watershed[aa] within the Region should be devoted to woodlands.

2. For demonstration and educational purposes, the woodland cover within each county should include a minimum of 40 acres devoted to each major forest type: oak-hickory, northern hardwood, pine species, and lowland forest.

3. A minimum regional aggregate of 5 acres of woodland per 1,000 population should be maintained for recreational pursuits.

E. Wildlife[bb]

Principle

Wildlife, when provided with a suitable habitat, will provide the population with opportunities for certain scientific, educational, and recreational pursuits; aid significantly in controlling harmful insects and other noxious pests; provide a food source; and provide an economic resource for the fur and fishing industries.

STANDARD

The most suitable habitat for wildlife, that is, the area wherein fish and game can best be fed, sheltered, and reproduced, is a natural habitat. Since the natural habitat for fish and game can best be obtained by preserving or maintaining other resources in a wholesome state, such as soil, air, water, wetlands, and woodlands, the standards for each of these other resources, if met, would ensure the preservation of a suitable wildlife habitat and population.

OBJECTIVE NO. 3

A spatial distribution of the various land uses which is properly related to the supporting transportation and public utility systems to assure the economical provision of utility and municipal services.

PRINCIPLE

The transportation and public utility facilities and the land use pattern which these facilities serve and support are mutually interdependent in that the land use pattern determines the demand for, and loadings upon, transportation and utility facilities; and these facilities, in turn, are essential to, and form a basic framework for, land use development.

STANDARDS

1. The transportation system should be located and designed to avoid the penetration of prime natural resource areas by through traffic.

2. The transportation system should be located and designed to provide access not only to all land presently devoted to urban development but also to all land well suited for urban development.

3. Land developed or proposed to be developed for medium- and high-density residential use should be located in a gravity drainage area tributary to an existing or proposed public sanitary sewerage system.

4. Land developed or proposed to be developed for medium- and high-density residential use should be located in areas serviceable by an existing or proposed public water supply system.

5. Urban development should be located so as to maximize the use of existing transportation and utility systems.

OBJECTIVE NO. 4

The preservation and provision of open space[cc] to enhance the total quality of the regional environment, maximize essential natural resource availability, give form and structure to urban development, and provide the basis for the ultimate attainment of a balanced year-round outdoor recreational program providing a full range of facilities for all age groups.

PRINCIPLE

Open space is the fundamental element required for the preservation, wise use, and development of such natural resources as soil, water, woodlands, wetlands, and wildlife; it provides the opportunity to add to the physical, intellectual, and spiritual growth of the population; it enhances the economic and aesthetic value of certain types of development; and it is essential to outdoor recreational pursuits.

STANDARDS[dd]

1. Local park and recreation open spaces should be provided within a maximum service radius of one-half mile of every dwelling unit in an urban area, and each site should be of sufficient size to accommodate the maximum tributary service area population at a use intensity of 675 persons per acre.

2. Regional park and recreation open spaces should be provided within an approximately one hour travel time of every dwelling unit of the Region and should have a minimum site area of 250 acres.

3. Areas having unique scientific, cultural, scenic, or educational value should not be allocated to any urban or agricultural land uses; and adjacent surrounding areas should be retained in open-space use, such as agriculture or limited recreation.

OBJECTIVE NO. 5

The preservation of land areas for agricultural uses in order to provide for certain special types of agriculture, provide a reserve for future needs, and ensure the preservation of those unique rural areas which provide wildlife habitat and which are essential to shape and order urban development.

PRINCIPLE

Agricultural areas, in addition to providing food and fiber, contribute significantly to maintaining the ecological balance between plants and animals; provide locations proximal to urban centers for the production of certain food commodities which may require nearby population concentrations for an efficient production-distribution relationship; and provide open spaces which give form and structure to urban development.

STANDARDS

1. All prime agricultural areas[ee] should be preserved.

2. All agricultural lands surrounding adjacent high-value scientific, educational, or recreational resources and covered by soils rated in the regional detailed operational soil survey as very good, good, or fair for agricultural use should be preserved.

In addition to the above, attempts should be made to preserve agricultural areas which are covered by soils rated in the regional detailed operational soil survey as fair if these soils: a) occur in concentrations greater than five square miles and surround or lie adjacent to areas which qualify under either of the above standards, or b) occur in areas which may be designated as desirable open spaces for shaping urban development.

OBJECTIVE NO. 6

The attainment of good soil and water conservation practices in order to reduce storm water runoff, soil erosion, and stream and lake sedimentation, pollution, and eutrophication.

PRINCIPLE

Good soil and water conservation practices, including mulch tillage, terracing, grass in waterways, contour strip cropping, and suitable crop rotation in rural areas; seeding; sodding; erosion control structures for drainageways; erosion control structures at storm sewer outlets; and proper land development and construction methods and practices, particularly in urban areas, including maximum possible delay in stripping of vegetation, construction of sediment basins, and mulching and revegetating as soon as possible, can assist in reducing storm water runoff, soil erosion, and stream and lake siltation, pollution, and eutrophication.

STANDARDS

1. The area of the watershed in cultivated agricultural use, which has general land slopes greater than 2 percent, should be under district cooperative soil and water conservation agreements and planned conservation treatment.

2. Drainageways should be controlled to eliminate channel erosion both through stabilization of bank and bed materials and by reduction of the channel gradient.

3. All urban and structural plans and developments, where soil and vegetative cover is removed, should include soil and water conservation practices to control erosion on critical areas.

4. Runoff through and from areas with exposed soil should be trapped and stored or retarded to less than critical erosive velocities.

---

[a]Net land use area is defined as the actual site area devoted to a given use and consists of the ground floor site area occupied by any buildings plus the required yards and open spaces.

[b]Gross residential land use area is defined as the net area devoted to this use plus the area devoted to all supporting land uses, including streets, neighborhood parks and playgrounds, elementary schools, and neighborhood institutional and commercial uses, but not including freeways and expressways.

[c]Gross governmental and institutional area is defined as the new area devoted to this use plus the area devoted to supporting land uses, including streets and off-street parking.

[d]Includes federal, state, and county governmental uses; hospitals; cemeteries; colleges and universities; and large region-serving, semipublic institutional uses, such as central YMCA facilities. Presently approximates 3 acres per 1,000 persons.

[e]Includes schools and churches. Approximately one-half of this standard is met implicitly if the gross acreage standard for residential use is met. Presently approximates 6 acres per 1,000 persons.

[f]This category does not include regional or local open spaces other than those actively used for public park or outdoor recreational purposes; that is, such uses as boulevards, parkways, stadia, environmental corridors, arboreta, zoological gardens, and botanical gardens are not included unless they are a part of, or adjacent to, an active recreational area.

[g]Gross park and recreation area is defined as equal to net area.

[h]Presently (1967) includes 23 existing parks developed and undeveloped within the Region classified as being of regional significance, which combined contain 6,741 acres, or 3.7 acres per 1,000 persons. These are: seven of the Milwaukee County Park Commission Metropolitan parks--Brown Deer Park, Grant Park, Greenfield Park, Lake-Juneau Park, Lincoln Park, Oakwood Park, and Whitnall Park; Hawthorne Hills Park in Ozaukee County; the Brighton Dale Park, Fox River Park, and Petrifying Springs Park in Kenosha County; Cliffside Park and Johnson Park in Racine County; Big Foot Park and Whitewater Lake Recreation Area in Walworth County; Pike Lake Recreation Area and Ridge Run Park in Washington County; and Menomonee Park, Minooka Park, Mukwonago Park, Nagawaukee Park, and Ottawa Lake Recreation Area in Waukesha County.

[i]Presently (1967) includes 379 neighborhood and community parks, which combined contain 5,698 acres, or 3.4 acres per 1,000 persons. A portion of this standard is met implicitly if the gross acreage standard for residential use is met. This implicit portion totals: 1.3 acres per 1,000 persons in a one-half mile square high-density neighborhood; 2.5 acres per 1,000 persons in a one-mile square medium-density neighborhood; and 4.5 acres per 1,000 persons in a two-mile square low-density neighborhood.

[j]A participant is defined as a person 12 years of age or older who actively participates in a particular recreational activity on a given day.

[k]Swimming--One acre of developed beach area can accommodate approximately 370 people at any one time. With a daily turnover rate of 3.0, the maximum capacity of one acre of developed beach is 1,110 people per acre per day. In addition, for every one acre of developed beach area, four (4) acres of back-up lands are required to provide necessary parking area (approximately one and one-half acres), concession services, and dressing room area (approximately one acre) and other activity area, such as picnic area (approximately one and one-half acres).

[l]Picnicking--One acre of developed picnic area with a maximum of 16 tables can accommodate approximately 50 people at any one time. With a daily turnover rate of 1.6, the maximum capacity of one acre of developed picnic area is 80 people per acre per day. In addition, for every one acre of developed picnic area, nine (9) acres of back-up land are required to provide necessary parking area and additional secondary facilities.

[m]Golfing--A minimum of 10 acres of land per hole is required to develop a regulation 9- or 18-hole golf course, including area for clubhouse and parking, and will accommodate approximately one golfer per acre at any one time. With a daily turnover rate of 3.0, the maximum capacity of each golf course is 3.0 golfers per acre per day, or 30 golfers per hole per day.

[n]Camping--One acre of developed camp area with a maximum of five camp units can accommodate approximately 15 people per day. There is no daily turnover rate for camping. In addition, for every one acre of developed camp area, nineteen (19) acres of back-up land are required to provide necessary supporting activities or facilities, such as central convenience facilities, hiking and nature trails, picnic areas, boat and canoe launching sites, and horseback trails.

[o]Skiing--One acre of developed ski slope can accommodate approximately 10 people at any one time. With a daily turnover rate of 3.0, the maximum capacity of one acre of developed ski slope is 30 people per acre per day. In addition, for every 10 acres of developed ski slope, one acre of back-up land is required to provide parking and concession facilities. The recommended minimum site area is 100 acres.

[p]Gross commercial and industrial area is defined as the net area devoted to this use plus the area devoted to supporting land uses, including streets and off-street parking.

[q]Includes all regional, local, and highway-oriented commercial activities plus adjacent streets and on-site parking. Presently approximates 3.4 acres per 100 employees.

[r]Includes all manufacturing and wholesaling activities plus adjacent streets and on-site parking. Presently approximates 4.1 acres per 100 employees.

[s]See SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin, June 1966.

[t]Areas, as used in this context, refer to any land unit, 160 acres or more in areal extent, which is subject to development.

[u]Floodplain lands are herein defined as those lands inundated by a flood having a recurrence interval of 100 years where hydrologic and hydraulic engineering data are available and, where such data are not available, as those lands inundated by the maximum flood of record as indicated by high water marks.

[v]Urban development, as used herein, refers to all land uses except agriculture, water, woodlands, wetlands, and open lands.

[w]A stream channel is herein defined as that area of the floodplain lying either within legally established bulkhead lines or within sharp and pronounced banks marked by an identifiable change in flora and normally occupied by the stream under average annual high-flow conditions.

[x]Floodway lands are herein defined as those floodlands, including the channel, required to carry and discharge the 100-year recurrence interval flood. If development and fill are to be prohibited in the floodplain, the floodway may be delineated as that area subject to inundation by the 10-year recurrence interval flood.

[y]Wetland areas are defined as those lands which are partially covered by marshland flora and generally covered with shallow standing water, open lands intermittently covered with water, or lands which are wet and spongy due to a high water table or character of the soil.

[z]The term woodlands, as used herein, is defined as a dense, concentrated stand of trees and underbrush covering a minimum area of 20 acres.

[aa]A watershed, as used herein, is defined as a portion of the surface of the earth occupied by a surface drainage system discharging all surface water runoff to a common outlet and which is 25 square miles or larger in areal extent.

[bb]Includes all fish and game.

[cc]Open space is defined as land or water areas which are generally undeveloped for residential, commercial, or industrial uses and are or can be considered relatively permanent in character; it includes areas devoted to park and recreation uses and to large land-consuming institutional uses, as well as areas devoted to agricultural use and to resource conservation, whether publicly or privately owned.

[dd]It was thought impractical to establish spatial distribution standards for open space, per se; therefore, only the park and recreation component of the open-space land use category is listed in the standards, according to its local or regional orientation. These local park and recreation spaces may include playlots, playgrounds, playfields, and neighborhood parks. Regional park and recreation spaces include large county or state parks. Other open spaces which are not included in this spatial distribution standard are: forest preserves and arboreta; major river valleys; lakes; zoological and botanical gardens; stadia; woodland, wetland, and wildlife areas; scientific areas; and agricultural lands whose location must be related to, and determined by, the natural resource base.

[ee]Prime agricultural areas are defined as those areas which a) contain soils rated in the regional detailed operational soil survey as very good or good for agriculture and b) occur in concentrated areas over five square miles in extent which have been designated as exceptionally good for agriculture production by agricultural specialists.

applicable to urban storm water drainage system design using the rational formula,[1] while the curves in Figure C-3, which relate total rainfall to duration and frequency, are more convenient for use in basin-wide hydrologic simulation. These curves are applicable to the Southeastern Wisconsin Region and to the Milwaukee River watershed. The variation of rainfall depth with area of consideration and the seasonal variation of rainfall probability are described in Figure C-4 and C-5, respectively.

[1]*For a full discussion of the application of the rational formula to urban storm water drainage design, see "Determination of Runoff for Urban Storm Water Drainage System Design," by K. W. Bauer, SEWRPC Technical Record, Vol. 2, No. 4, April-May 1965. The rainfall intensity-duration-frequency curves set forth in Figures C-1 and C-2, Appendix C, of this report are intended to update and replace the curves set forth in Figure 2 of the cited Technical Record article.*

Storm Sewer Design Criteria

Revised rainfall criteria and newly available soil survey data make possible a more detailed consideration of rainfall-runoff relationships in the design of storm sewers for urban areas in the Southeastern Wisconsin Region and in the watershed. Recommended values for the coefficient of runoff, C, which are based on land use, land slope, and soil type, are presented in Appendix C, Figure C-6 and Table C-1.[2] Soils which occur in the watershed and the Southeastern Wisconsin Region are categorized in hydrologic groups according to their infiltration capability in Appendix C of SEWRPC Planning Guide No. 6, Soils Development Guide.

[2] *Ibid.*

Rainfall-Runoff Relationships

The rainfall-runoff criteria adopted for storm sewer design are not adequate for hydrologic simulation of basin-wide floods. For this purpose, U. S. Soil Conservation Service rainfall-runoff relationships were adopted. These relationships, and adjustments made to them for the specific conditions existing in the Milwaukee River watershed, are described in Chapter XII, Volume 1, of this report.

Water Surface Elevation-Discharge Relationships

Water surface elevation-discharge relationships for dams were computed with standard weir formulas after obtaining data describing the structural and hydraulic characteristics of each dam. Stage-discharge relationships at all other points of interest in the stream system were determined using a computer program, identified in Chapter XII, Volume 1, of this report as the backwater submodel, which applies the "standard step method" of backwater calculation for river reaches and a U. S. Army Corps of Engineers computational procedure for backwater analysis through bridges and culverts.

Starting with known hydraulic conditions at the downstream end of a river reach, the "standard-step" method determines the hydraulic conditions at the upstream end of the reach by an iterative procedure, the object of which is to satisfy the conservation of energy law. During this iterative process, the energy loss attributed to friction in the reach is computed with the empirical Manning open-channel flow equation. The principal aspects of the "standard step method," including the use of the Manning equation, are presented in Chapter XII, Volume 1, of this report, while the method is treated in detail in hydraulics texts, such as Open Channel Flow by Ven Te Chow, McGraw-Hill Book Co., New York, New York, 1959. The U. S. Army Corps of Engineers backwater computational procedure for bridges and culverts incorporates various combinations of open-channel flow, orifice flow, and weir flow, depending on the structural and hydraulic conditions of each particular bridge or culvert. For example, orifice flow may occur through the opening of a submerged bridge, while weir flow exists over the top of the structure. This computational procedure is described briefly and referenced in Chapter XII, Volume 1, of this report.

Flood Routing

The convex or coefficient method of routing, employing an empirical velocity-routing coefficient relation developed by the Soil Conservation Service, was selected for flood-routing computations in the nonimpounded portions of the stream system, while flood routing through the impounded reaches of the river system was accomplished by application of the storage-indication method, a reservoir routing technique. These two flood-routing procedures were applied as an integral part of a computer program referred to in Chapter XII, Volume 1, of this report as the flood-routing submodel and are explained in detail in that chapter.

Flood Frequency

Flood frequency relationships were developed, as described in Chapter VI, Volume 1, of this report for two locations in the watershed, using the log Pearson Type III method of analysis for peak discharge frequencies and for runoff volume frequencies. At the Estabrook Park gaging station, on the Milwaukee River, and the Cedarburg gaging station on Cedar Creek, records of discharge have been kept since 1914 and 1930, respectively. These actual measured discharges were analyzed statistically to establish flood frequency relationships for both peaks and volumes of flows at these locations. The discharge-frequency relationship developed for the Estabrook Park gaging station was determined to be applicable to that reach of the Milwaukee River extending from a point approximately midway between the North Avenue Dam and Estabrook Park Dam upstream to a point about midway between the Estabrook Park Dam and Brown Deer Road. Similarly, the discharge-frequency relationship developed for the Cedarburg gaging station is applicable to that reach of Cedar Creek extending from approximately midway between Hamilton Road and the gaging station upstream to a point approximately 2 miles above STH 60.

In the remainder of the watershed, discharge-frequency relationships were established synthetically utilizing the flood-flow simulation model. For this purpose the model was operated so as to reproduce the discharge-frequency and volume-frequency relationships previously developed for the two gaging stations. The resulting peak flood stages were further verified by comparison to historic high water marks available for various locations along the lower reaches of the Milwaukee River system. This method was judged to be the best procedure for use in the Milwaukee River watershed study, considering the limited number of stream gaging stations in the watershed and the relatively short period of record at these stations. As streamflow data collection continues within the watershed, flood frequency relationships should be reviewed and revised, if necessary.

On the basis of the analyses made, it was concluded that the peak flood flows recorded within the watershed during March 1918 and August 1924 at the Estabrook Park gage of 15,100 cfs were both equivalent to a 77-year recurrence interval flood flow. At Cedarburg a maximum recorded flood peak of 3,600 cfs occurred during March 1960 and was equivalent to a 14-year recurrence interval flood flow.

The maximum flood volume of 3.85 inches of runoff over the watershed recorded during the August 1924 flood at the Estabrook Park gage was equivalent to a 100-year recurrence interval flood volume. At Cedarburg the maximum recorded flood volume occurred during March and April 1959 and was equivalent to a 20-year recurrence interval flood volume.

A flood event with both a 100-year recurrence interval peak discharge and runoff volume was selected as the plan design flood and was used to delineate the outer limits of the floodplains of the watershed. Analysis indicates that urbanization within the watershed will not appreciably change the peak discharge of this design flood.

OVERRIDING CONSIDERATIONS

In the application of the watershed development objectives, principles, and standards in the preparation, test, and evaluation of the watershed plans, several overriding considerations must be recognized. First, it must be recognized that any proposed water control and water quality management facilities must constitute integral parts of a total system. It is not possible from an application of the standards alone, however, to assure such a system integration, since the standards cannot be used to determine the effect of individual facilities and controls on each other or on the system as a whole. This requires the application of hydrologic, hydraulic, and water quality simulation models to quantitatively test the proposed facilities as part of a system, thereby permitting adjustment of the spatial distribution and capacities of the facilities and system to the existing and future runoff and waste loadings as derived from the land use plan. Second, it must be recognized that it is unlikely that any one plan proposal will meet all the standards completely; and the extent to which each standard is met, exceeded, or violated must serve as a measure of the ability of each alternative plan proposal to achieve the specific objectives which the given standard complements. Third, it must be recognized that certain objectives and standards may be in conflict and require resolution through compromise. Finally, it must be recognized that an overall evaluation of each combination of land use and water control facility plans must be made on the basis of cost. This concept is so important that it warrants special attention herein.

Economic Criteria

The concepts of economic analysis and economic selection are vital to the public planning process. Sound economic analysis of benefits and costs should be an important guide to planners and decision-makers in the selection of the most suitable plan from an array of alternatives. All decisions concerning monetary expenditures, either private or public, are implicitly based on an evaluation of benefits and costs. This is not to imply that a formal economic analysis is made before every expenditure. The process of decision itself, however, consists of a consideration of whether the benefit received would be worth the amount paid. Benefits are not necessarily accountable in monetary terms and may be purely intangible, but the very act of expending money (or resources) for an intangible benefit implies that the benefit is worth to the purchaser at least the amount spent.

In addition to the consideration involved in deciding that a potential benefit is worth its cost, consideration is also given to possible alternative benefits that could be received for alternative expenditures within the limits of available resources. Alternative benefits are compared, either objectively or subjectively; and the one which is considered to give the greatest value for its cost is selected. Again, the benefits may be purely intangible; but the decision-making process itself implies an evaluation of which alternative is considered to be worth the most. When consideration is made of investment for future benefits, one alternative that should always be considered is the benefit which could be received from investment in the money market. This benefit is expressed in the prevailing interest rate.

Personal and private decisions, while implying at least subjective consideration of benefits and costs, broadly defined, are not necessarily based upon either formal or objective evaluation of monetary benefits and costs. Public officials, however, have a responsibility to evaluate objectively and explicitly the monetary benefits and costs of alternative investments to assure that the public will receive the greatest possible benefits from limited monetary resources.

It is then a fundamental principle that every public expenditure should desirably return to the public a value at least equal to the amount expended plus the interest income foregone from the ever-present alternative of private investment. This principle may also be stated that the public should receive a value return from its tax investment at least equal to what it could receive from private investment.

Therefore, economic analysis is a fundamental requirement of responsible public planning; and all plans should desirably promise a return to the public at least equal to the expenditure plus interest. It is emphasized that public expenditures should not be expected to "make money" but that they should be expected to return a value in goods and services which is worth to the public the amount expended plus interest.

Benefit-Cost Analysis

The benefit-cost analysis method of evaluating government investments in public works came into general use after the adoption of the Federal Flood Control Act of 1936. The Act stated that waterways should be improved "if the benefits to whomsoever they may accrue are in excess of the estimated costs." Monetary value of benefits has since been defined as the amount of money which an individual would pay for that benefit if he were given the market choice of purchase. Monetary costs are taken as the total value of resources used in the construction of the project.

Benefits, including intangible values, must exceed costs in order for a project to be justified, but this criterion alone is not sufficient to justify the investment. Although a project may have a benefit-cost ratio greater than 1.0, the ratio may be less than the benefit-cost ratio of an alternative project which would accomplish the same objectives. Therefore, in order to assure that public funds are invested most profitably, alternative plans or projects should be investigated and analyzed; and, in such analyses, incremental, as well as total, benefit-cost ratios, may have to be considered. Implementation of comprehensive plans for the Milwaukee River watershed could include benefits of flood control, recreation, efficient community utilities and facilities, enhancement of property values, and an aesthetically pleasing community environment. Costs which could be incurred in implementation of watershed plans include construction, land acquisition, and income foregone as a result of regulation of land use.

There may be situations in which a local community affected by an alternative plan proposal subjectively evaluates the costs and benefits of that proposal in a manner differing significantly from an objective, economically sound analysis of the costs and benefits. The community may, for example, because of its subjective interpretation of benefits and costs, strongly favor an alternative plan proposal that has an objectively determined benefit-cost ratio of less than one; or, conversely, the affected community may oppose an alternative with a favorable benefit-cost ratio. Adoption and implementation of areawide plan elements with objectively determined benefit-cost ratios of less than one should be discouraged, except possibly in situations where the costs are borne entirely and equitably by, and with the full knowledge and understanding of, the local beneficiaries.

Time Value of Money—Interest

The benefits and often the costs of construction projects accrue over long periods of time. Each project or alternative, public and private, is likely to have a different time flow of benefits and costs. Benefits of one project may be realized earlier than those of another, while the time flow of costs may vary from one large initial investment for one project to small but continuously recurrent expenditures for another. In order to place these projects with varying time flows of benefits and costs on a comparable basis, the concept of the time value of money must be introduced.

A dollar has a greater value to the consumer today than does the prospect of a dollar in the future. Because of this time preference for money, a consumer will agree to pay more than one dollar in the future for one dollar today. Conversely, to an investor one dollar in the future is worth less than one dollar today because he can obtain one dollar in the future from the investment of less than one dollar today. By the same reasoning, for public projects a one-dollar cost or a one-dollar benefit at some time in the future has a value of less than one dollar today. The variation of value of capital, benefits, and costs with respect to time is expressed through the mathematics of compound interest.

Use of an interest rate automatically incorporates consideration of the ever-present possibility of private investment as an alternative. A project, to be economical, should return to the public at least as great a benefit as it might obtain through private investment. Money invested privately is expected to return generally from 4 to 10 percent interest. Since implementation of the watershed plan should return benefits to the public equal to, or greater than could be attained through, private investment, an interest rate of 6 percent is recommended for use in the economic evaluation of plans.

The benefit-cost analysis for a project must be based on a specified number of years, usually equal to the physical or economic life of the project. Most of the improvements proposed in the Milwaukee River watershed plans, however, will continue to furnish benefits for an indefinite time, particularly the land use control and park reservation elements. In indefinite situations, such as this, government agencies have generally selected 50 years for the period of analysis; and this period is recommended for the Milwaukee River watershed plans. Using 6 percent interest, benefits accrued after 50 years, when discounted to the present, are very small. For example, given a uniform annual benefit of one dollar, the total present worth of the entire 50-year period, from year 51 through year 100, would be only one dollar. The total present worth of the benefits for the 50-year period, from year 1 through year 50, however, would be almost $16. A final reason for using a 50-year period as a basis for benefit-cost analysis is the inability to anticipate the social, economic, and technological changes which may occur in the more distant future and which may influence project benefits and costs.

Project Benefits

The benefits from a project can be classified as direct, or measurable in monetary terms, and as intangible. Intangible benefits either are of such a nature that no monetary value can be assigned to them or are so obscure that calculation of the monetary value is impracticable. In the Milwaukee River watershed planning studies, direct benefits include flood-damage reduction, enhancement of property values, and those parts of recreation and water quality management to which a monetary value can be assigned. Intangible benefits include aesthetic factors deriving from natural beauty and a pleasant environment. Intangibles also include benefits, such as improved efficiencies in community utilities and facilities, that have monetary values but which are impracticable to calculate.

Direct benefits attributable to flood control were calculated by subtracting annual flood-damage risk for each plan alternative from annual flood damage in an unplanned situation. Annual flood-damage risk was calculated for each alternative by means of the damage-frequency curves prepared for the study, as described in Chapter VIII, Volume 1, of this report.

The direct benefits from land use controls, water quality management, and the provision of recreational opportunities are more difficult to establish but were determined in monetary terms for specific developments. Benefits for individual recreational developments were calculated for each alternative by means of demand curves, as described in Chapter XIV, Volume 1, of this report and Chapter IV, Volume 2, of this report.

Benefits from water quality management through augmentation of low stream flows were quantified on the basis of costs for an existing alternative facility, as described in Chapter IV, Volume 2, of this report.

A partial account of the benefits resulting from the implementation of sound land use plans was made in terms of increased land values for housing sites adjacent to attractive natural environments. The remainder of the benefits of the land use plans were considered to be intangible. These intangibles include benefits from the provision of a more attractive and pleasant environment for living and working and benefits to communities and individuals because community facilities, such as drainage, water supply, roads, schools, and waste disposal, cost less per capita in a well-planned land use situation.

Project Costs

The direct costs of water resource development include the construction costs of physical elements of the plan and the cost of acquiring land. Costs of structural facilities were calculated using 1969 unit prices which reflect the magnitude of work, the location in the urban region, and regional labor costs.

The cost of land acquisition was based on 1969 market prices for urban improved, urban unimproved, and rural agricultural land in the Milwaukee River watershed.

Relationship of Economic and Financial Analysis

The distinction between economic feasibility and financial feasibility is of particular importance in the consideration of the costs of land already under public ownership. A financial analysis involves an examination of the liquidating characteristics of the project from the point of view of the particular government agency undertaking the project. The relevant matters are the monetary disbursements and monetary receipts of the project. The financial analysis determines whether or not the prospective available funds are adequate to cover all of the costs.

On the other hand, an economic analysis by a government body determines if the project benefits to whomsoever they accrue exceed the costs to whomsoever they accrue. Since one of the legitimate objectives of government is to promote the general welfare, it is necessary to consider the effect of a proposed project on all of the people who may be affected, not just on the income and expenditures of a particular agency. The economic valuation of the benefits and costs may differ considerably from the actual income and expenditures of a government agency. The present market value of publicly owned but uncommitted land, such as the undeveloped holdings of a park commission, is counted on the cost side of the economic analysis. Under the economic criterion of benefits and costs to whomsoever they accrue, this land must be considered to have an economic value for alternative uses which are foregone when the land is committed to another use, such as open space or recreation. The costs of public lands already developed with facilities for recreation are considered as sunk costs and are not included in the economic analysis because alternative uses of the land can no longer be reasonably considered because costs of land under public ownership, undeveloped or developed, are not considered in the financial analysis since no monetary outlay is required.

Staged Development

An attractive feature of many water resource developments is their divisibility into several individual projects which may be financed and built at different times. Staged construction requires lesser initial capital investments, reduces interest costs, and allows for flexibility of continued planning. Staging developments may also allow deferring an element until increased demands raise its benefit-cost ratio. In planning for staged development, however, consideration must be given to possibilities of higher costs in the future and the possible unavailability of land. In any development staging also serves to lower risks incurred through inavailability of data during preparation and partial implementation of initial plans.

SUMMARY

The process of formulating objectives and standards to be used in plan design and evaluation is a difficult but necessary part of the planning process. It is readily conceded that regional and watershed development plans must advance development proposals which are physically feasible, economically sound, aesthetically pleasing, and conducive to the promotion of public health and safety. Agreement on development objectives beyond such generalities, however, becomes more difficult to achieve because the definition of specific development objectives and supporting standards inevitably involves value judgments. Nevertheless, it is essential to state such objectives for watershed development and to quantify them insofar as possible through standards in order to provide the framework within which watershed plans can be prepared. Moreover, so that the watershed plans will form an integral part of the overall long-range plans for the physical development of the Region, the watershed development objectives must be compatible with, and dependent upon, regional development objectives while meeting the primary watershed development objectives. Therefore, the watershed development objectives and supporting principles and standards set forth herein are based upon, and incorporated in, previously adopted regional development objectives, supplementing these only as required to meet the specific needs of the Milwaukee River watershed planning program.

(This page intentionally left blank)

Chapter III

LAND USE BASE AND ALTERNATIVE NATURAL RESOURCE PROTECTION, OUTDOOR RECREATION AND RELATED OPEN SPACE, AND PARKWAY PLAN ELEMENTS

INTRODUCTION

The economic and demographic base and the existing land use pattern of the Milwaukee River watershed were described in Chapter III, Volume 1, of this report. Forecasts of probable future population and economic activity levels, together with accompanying demands for various land uses within the watershed, were set forth in Chapter VII, Volume 1, of this report. The population of the watershed was forecast to increase from the 1967 level of 544,000 to a 1990 level of 678,000 persons, an increase of about 25 percent in approximately 23 years. Employment within the watershed was forecast to increase from the present (1967) total of 289,900 jobs to a 1990 total of 346,100 jobs, an increase of about 19 percent.

In the face of this growth in population and employment, the amount of land devoted to urban use within the watershed was forecast to increase from the present (1967) total of 102 square miles, or about 15 percent of the total area of the watershed, to 133 square miles, or about 19 percent of the total area of the watershed, by 1990. This demand for urban land will have to be satisfied primarily through the conversion from rural to urban uses of the remaining agricultural lands, woodlands, and wetlands of the watershed. Such rural land uses may be expected to decline collectively from 593 square miles in 1967 to 562 square miles in 1990, a decrease of about 5 percent. It is extremely important that this new urban development be related sensibly to soil capabilities; to long-established utility systems; to the floodlands of the Milwaukee River system; and to the wetlands, woodlands, and surface water resources of the watershed. If such new urban development is not so related, the already severe developmental and environmental problems of the watershed, as documented in Volume 1 of this report, may be expected to continue to intensify.

If such intensification of developmental and environmental problems is to be avoided and the serious problems of flooding and water pollution already existing within the Milwaukee River watershed are to be abated, new urban development within the watershed must be directed into a more orderly and efficient pattern, a pattern carefully adjusted to the ability of the underlying and sustaining natural resource base to support further urban development. A land use plan must, therefore, constitute a major element of any comprehensive plan for the development of the Milwaukee River watershed. This land use plan element, although emphasizing the protection of the riverine areas and of the recreational resource base of the watershed, must cover the entire watershed and must represent the major basic approach to the resolution of the growing environmental and developmental problems of the watershed. Structural water control facility plan elements for flood control and pollution abatement must be subordinate to and support the land use plan element in that the structural water control facility plan elements do not affect the entire watershed and cannot alone offer sound solutions to the developmental and environmental problems of the watershed.

This chapter presents a brief description of the necessary basic land use plan element, with particular attention to the alternatives available in terms of preservation of the natural resource base of, and the overall quality of the environment within, the watershed as a whole. In addition, this chapter presents a description of the alternatives available with regard to wise development and use of the recreation-related resource base of the watershed, including park, parkway, and scenic drive development within the watershed.

LAND USE BASE

Design Methodology

As noted above, the land use plan element forms the basic element of the comprehensive watershed plan. With respect to that portion of the Milwaukee River watershed lying within the Southeastern Wisconsin Region, the watershed land use plan is set within the context of, and reflects the concepts and recommendations contained in, the adopted regional land use plan. With respect to that portion of the Milwaukee River watershed lying outside the Southeastern Wisconsin Region in Dodge, Fond du Lac, and Sheboygan Counties, the watershed land use plan is an entirely new plan element prepared under the Milwaukee River watershed study. As such, it represents both an extension of the adopted regional land use plan and the concepts and development objectives embodied in that plan to those areas of the Milwaukee River watershed adjacent to the seven-county Region and an integration of those concepts and development objectives with the concepts and development objectives expressed in planning work currently being conducted at the county level by the Fond du Lac and Sheboygan County Planning Departments.

The regional land use plan was designed to meet sound regional development objectives and standards and was selected after careful consideration of three alternative regional land use plans—a corridor, a satellite city, and a controlled existing trend plan—and after comparing these three alternative plans to an unplanned alternative. The regional land use plan and the alternatives considered in its adoption are fully described in SEWRPC Planning Report No. 7, Volume 2, Chapters V and VI.

The methodology applied in the preparation of the land use plan is described in SEWRPC Planning Report No. 7, Volume 2, Forecasts and Alternative Plans—1990, Chapter V, and consists of a combination of design-oriented mapping activities concerned primarily with the spatial distribution of the various land uses, relating these to existing development and to the natural resources and public utility base through application of physical planning and engineering principles and a socioeconomic-oriented land use demand projection and allocation process, employing both traditional and mathematical simulation model techniques.

Thus, the general land use base for that portion of the Milwaukee River watershed within the Region was basically established through the preparation of a regional land use plan, a plan adopted by the Regional Planning Commission, as well as by two of the three counties in the Southeastern Wisconsin Region within which the Milwaukee River watershed lies; namely, Milwaukee and Washington Counties. Of the seven counties within the Region, and the three counties concerned within the watershed, only Ozaukee County to date has not adopted the regional land use plan.

The regional land use development objectives, which the regional land use plan is designed to meet, as set forth in Chapter II, Volume 2, SEWRPC Planning Report No. 7, Forecasts and Alternative Plans—1990, remain valid and applicable to the land use element of the more detailed watershed development plan. Therefore, these regional development objectives and the supporting principles and standards were made the basis of the watershed land use development objectives, principles, and standards set forth in Chapter II of this volume.

The same general techniques used in preparing the regional land use plan were used in the preparation of a complementary controlled existing trend land use plan for that portion of the Milwaukee River watershed lying outside the Southeastern Wisconsin Region. This area of the Milwaukee River watershed is composed of several small urban centers set in a large rural area rich in high-value natural resources, including a substantial portion of the Northern Unit of the Kettle Moraine State Forest. The population of the out-of-Region portion of the watershed was forecast to increase modestly from its present (1967) level of about 12,000 persons to a 1990 level of about 13,000 persons, an increase of about 8 percent. Employment within the out-of-Region portion of the watershed was forecast to increase from the present (1967) total of about 4,000 jobs to a 1990 total of about 4,500 jobs, an increase of about 11 percent. Based upon these population and employment forecasts for the out-of-Region portion of the watershed, it was estimated that only about 126 acres, or about 0.2 square mile of land, would have to be converted from rural to urban land use within the plan design period. This modest amount of urban growth was allocated in the preparation of a controlled existing trend plan for the out-of-Region portion of the watershed to areas adjacent to the existing urban centers. In addition, all primary environmental corridors were identified and mapped. By combining this controlled existing trend land use plan for the out-of-Region portion of the watershed with the adopted regional land use plan for the in-Region portion of the watershed, a general land use base for the Milwaukee River watershed plan was established.

The adopted regional land use plan set forth broad recommendations for areawide land use development designed to meet the social, physical, and economic needs of the Region while protecting and enhancing the natural resource base. Similarly, the controlled existing trend land use plan recommended for the out-of-Region portion of the Milwaukee River watershed is also designed to meet social, physical, and economic needs while protecting and enhancing the natural resource base. The resolution of the natural resource-related problems existing within the Milwaukee River watershed, as set forth in Chapter XIII of Volume 1 of this report, however, requires more intensive land use investigation, more detailed land use plan design, and more specific land use plan implementation recommendations. This is particularly true with respect to the riverine areas of the watershed. In this way the natural resource-related problems may be abated through appropriate private, as well as local, state, and federal governmental actions. Therefore, this chapter, in addition to describing the already adopted regional land use plan as it applies to the Milwaukee River watershed and the recommended controlled existing trend plan for the out-of-Region portion of the watershed, sets forth 1) detailed alternative proposals for the protection and wise use of the natural resources of the watershed in order to achieve a favorable natural environment, 2) alternative proposals for the preservation and proper development of the recreation-related resource base of the watershed in order to meet the growing demand for outdoor recreation within the watershed, and 3) alternative proposals for the development of parkway and scenic drives within the watershed.

Two important and interrelated elements of the natural resource base requiring protection through sound land use development and management have been identified in the inventories and analyses made as a part of the watershed study: the primary environmental corridors and the remaining prime outdoor recreation and related open-space sites within the watershed. Accordingly, specific alternative plans for the preservation of these two elements are explored in this chapter. In these alternative plans, specific attention is given to the preservation of the following subelements of the primary environmental corridors: lakes and streams and the associated shorelands and floodlands, wetlands, woodlands, and wildlife habitat areas. It should be noted in this respect that, unless specified to the contrary, the areal extent of the woodland, wetland, and wildlife habitat areas proposed to be protected and preserved under the various alternative plans are based upon the detailed land use data compiled in the SEWRPC land use inventories rather than on the natural resource inventories conducted under the watershed study. This was done in order to avoid any potential confusion with respect to acreage figures because of the multiple counting of certain acreages under the natural resource inventories (see Chapter XIII of Volume 1 of this report).

Land Use Base Description

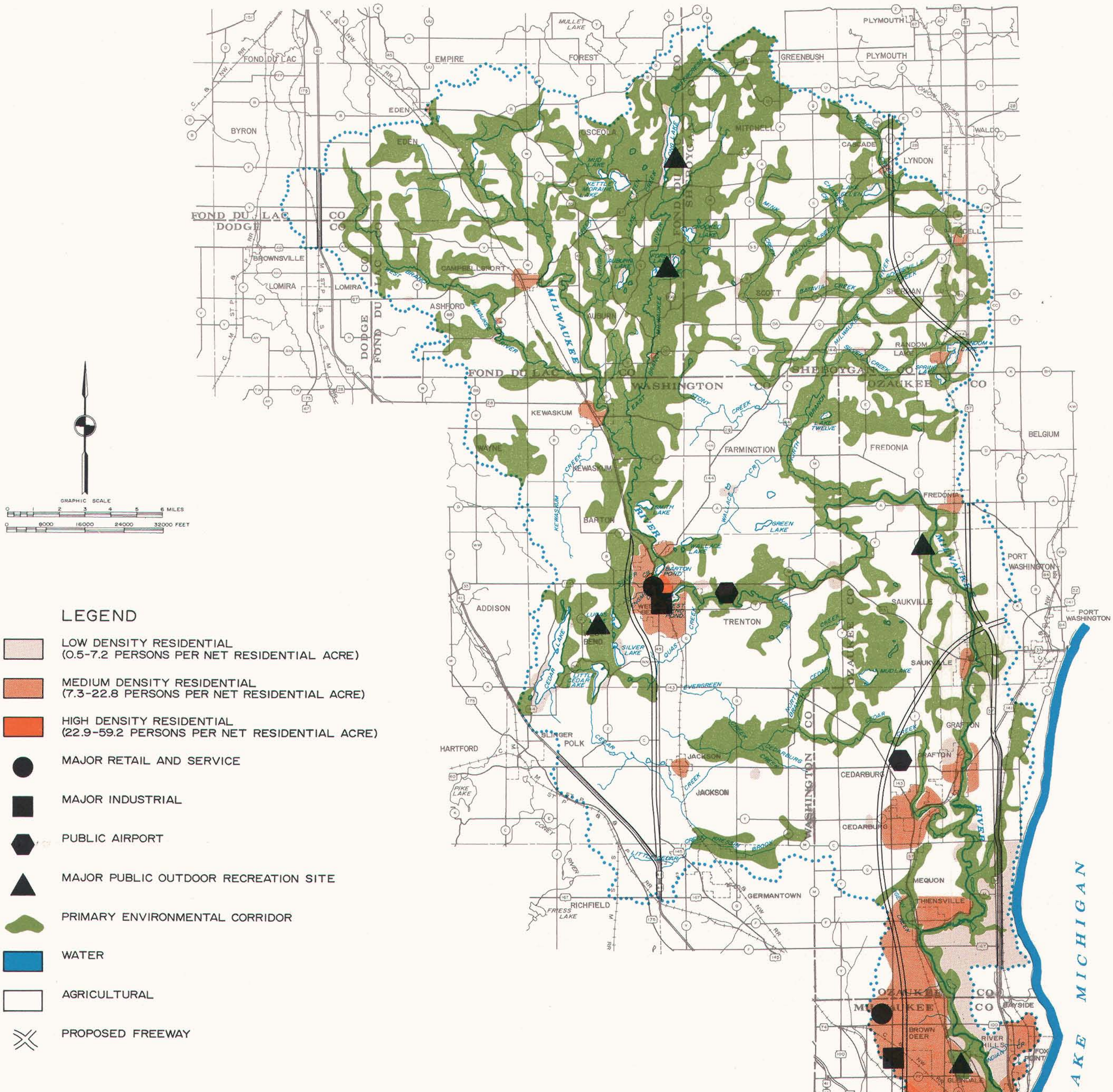
As noted above, the adopted regional land use plan and a recommended controlled existing trend plan for the out-of-Region portion of the watershed together form the recommended land use base for the Milwaukee River watershed plan. The recommended land use base would meet the social, physical, and economic needs of the future watershed population by allocating sufficient land to each of the various major land use categories to satisfy the known and anticipated demand for each use, meeting both the demands of the urban land market and the adopted land use design standards. The allocation of the anticipated future urban land use development within each county of the watershed is designed to meet the demand for land expected to be created by the forecast population growth occurring within each county through the plan design year 1990. To the extent possible, the proposals contained in existing community development plans and ordinances are accommodated in the land use base. The land use base seeks to protect and enhance the natural resource base of the watershed and allocates new urban development only to those areas of the watershed that are covered by soils well-suited to such development. It further seeks to encourage urban development in those areas of the watershed that can be readily provided with gravity drainage sanitary sewer service and public water supply.

The land use base emphasizes continued reliance on the urban land market to determine the location, intensity, and character of future development within the Region and within the watershed outside the Region for residential, commercial, and industrial land uses. It does, however, propose to regulate in the public interest the effect of this market on development in order to provide for a more orderly and economical land use pattern and in order to avoid intensification of developmental and environmental problems within the Region and the watershed. The land use base for the Milwaukee River watershed is shown in graphic summary form on Map 1 and is more specifically described in the following paragraphs and subsequent sections of this chapter.

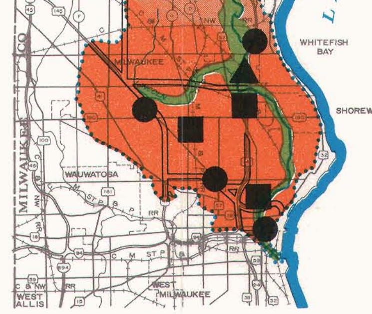
The land use base proposes the conversion of approximately 21 square miles of land within the watershed from rural to urban use over the next

Map I

RECOMMENDED LAND USE BASE
FOR THE MILWAUKEE RIVER WATERSHED
1990



A sound land use plan must constitute the basic element of any watershed plan. This is true because the misuse of land is a major cause of water pollution, flood damage, inadequate water supply, and the deterioration and destruction of the natural resource base. The misuse of land, particularly through the widespread dispersion of urban development, is also a major contributor to inefficiencies in the provision of public services and facilities of all kinds and to the increasing cost of local government. The recommended land use plan seeks to concentrate the new urban development which will be required to meet the forecast population growth in those areas of the watershed that are covered by soils well suited to healthy and economical urban development and that can be readily served by public sewer and water supply facilities--the orange shaded areas on the plan map. Most importantly, the plan proposes the preservation in essentially natural open uses of all of the environmental corridors of the watershed--the green areas on this map--and the preservation in essentially rural uses of the remaining agricultural areas of the watershed--the white areas on this map.



Source: SEWRPC.

two decades, or about 10 square miles less than the forecast conversion of 31 square miles of land noted earlier in this chapter. The forecast conversion was based upon forecast population levels and an assumed continuation of recent trends in land development within the watershed, as fostered by adopted local land use plans and local zoning ordinances and as discussed in Chapter VIII of this volume. The planned conversion recommended in the land use base is thus less than the forecast land use conversion under the unplanned alternative. The planned conversion, while relying on the continued effect of the urban land market, assumes the imposition of greater public constraints in the form of land use controls in order to regulate in the public interest the effect of the urban land market on development. In essence, the planned land use conversion represents a more efficient urban land development process and one which is better adjusted to the underlying and sustaining natural resource base.

It is important to note that the land use base, as shown on Map 1, represents a refinement of the adopted regional land use plan in the riverine areas of the watershed. This plan refinement was primarily directed at delineation of the boundaries of the primary environmental corridors within the watershed and was made possible by the natural resource inventories and hydrological investigations and floodland delineations carried out as a part of the Milwaukee River watershed study. Because floodlands can be an important determinant of environmental corridor boundaries, the floodland information provided by the Milwaukee River study affected and was used to refine the corridor boundaries as those boundaries were originally delineated in the adopted regional land use plan.

Residential Land Use: As indicated in Table 3, the land use base proposes to add 7,869 acres to the existing stock of residential land in the watershed in order to supply land to meet the housing needs of the anticipated population increase. Approximately 297 acres, or about 2 percent of this new residential land, are proposed to be developed at low population densities, with lot sizes ranging from approximately one-half acre to five acres per dwelling unit and with gross residential population densities ranging from 350 to 3,499 persons per square mile. About 6,337 acres, or about 82 percent of this new residential land, are proposed to be developed at medium population densities, with lot sizes ranging from approximately 6,000 square feet to approximately one-half acre per dwelling unit and with gross residential population densities ranging from 3,500 to 9,999 persons per square mile. The remaining 1,235 acres, or about 16 percent of this new residential land, are proposed to be developed at high population densities, with lot sizes ranging from approximately 2,400 to 6,000 square feet per dwelling unit and with gross residential population densities ranging from 10,000 to 25,000 persons per square mile.

All of the new medium- and high-density residential development is proposed to be served by public sanitary sewer and public water supply facilities, so that by 1990, 76 percent of the total urban area within the watershed and 94 percent of the total watershed population would be served by public sanitary sewerage facilities, as compared to 64 and 92 percent, respectively, in 1967. Similarly, 71 percent of the total urban area and 93 percent of the total watershed population would be served by public water supply facilities, as compared to 60 percent and 91 percent, respectively, in 1967.

Retail and Service Land Use: Six major multipurpose commercial centers are proposed in the watershed land use base for 1990, including five existing centers—three in the City of Milwaukee, including the Milwaukee Central Business District; one in the City of Glendale; and one in the City of West Bend—and one new major commercial center in the City of Milwaukee near the Milwaukee-Ozaukee County line. The one new major commercial center would add approximately 95 acres of retail and service land to the existing 1,368 acres of retail and service land to the watershed. In addition, approximately 528 acres of new community and local retail and service land would be added during the plan design period. As shown in Table 3, these additions to the existing stock of retail and service land in the watershed would total 623 acres, or an increase of about 45 percent over the existing supply.

Industrial Land Use: Based on the employment forecast, five major industrial centers are proposed in the land use base, including two existing centers in the City of Milwaukee, one existing center in the City of Glendale, and one existing center in the City of West Bend. One new major industrial center is proposed to be added in the City of Milwaukee in the former Town of Granville area. This new major industrial center would

Table 3

EXISTING AND PROPOSED LAND USE IN THE MILWAUKEE RIVER WATERSHED- 1967 AND 1990 RECOMMENDED LAND USE PLAN

LAND USE CATEGORY	EXISTING (1967)								
	IN REGION			OUTSIDE REGION			TOTAL		
	ACRES	SQUARE MILES	PERCENT OF MAJOR CATEGORY	ACRES	SQUARE MILES	PERCENT OF MAJOR CATEGORY	ACRES	SQUARE MILES	PERCENT OF MAJOR CATEGORY
URBAN LAND USE									
RESIDENTIAL............	25,398	39.68	44.1	1,622	2.53	21.0	27,020	42.22	41.3
LOW-DENSITY..........	11,217	17.52	19.5	1,041	1.63	13.4	12,258	19.15	18.7
MEDIUM-DENSITY.......	5,433	8.49	9.4	581	0.91	7.5	6,014	9.40	9.2
HIGH-DENSITY.........	8,748	13.67	15.2	0	0.00	0.0	8,748	13.67	13.4
COMMERCIAL.............	1,267	1.98	2.2	101	0.16	1.3	1,368	2.14	2.1
INDUSTRIAL.............	1,700	2.66	2.9	63	0.10	0.8	1,763	2.76	2.7
MINING.................	866	1.35	1.5	247	0.38	3.2	1,113	1.74	1.7
TRANSPORTATION.........	20,839	32.56	36.2	4,672	7.30	60.4	25,511	39.86	39.1
GOVERNMENTAL...........	3,129	4.89	5.4	323	0.50	4.2	3,452	5.39	5.3
RECREATIONAL...........	4,371	6.83	7.6	710	1.11	9.2	5,081	7.94	7.8
TOTAL URBAN LAND USE.....	57,570	89.95	100.0	7,738	12.10	100.0	65,308	102.05	100.0
RURAL LAND USE									
AGRICULTURAL AND OPEN LAND...............	218,704	341.72	100.0	160,939	251.47	100.0	379,643	593.19	100.0
TOTAL RURAL LAND USE.....	218,704	341.72	100.0	160,939	251.47	100.0	379,643	593.19	100.0
TOTAL	276,274	431.67	100.0	168,677	263.57	100.0	444,951	695.24	100.0

LAND USE CATEGORY	PLANNED INCREMENT (1967-1990)								
	IN REGION			OUTSIDE REGION			TOTAL		
	ACRES	SQUARE MILES	PERCENT OF MAJOR CATEGORY	ACRES	SQUARE MILES	PERCENT OF MAJOR CATEGORY	ACRES	SQUARE MILES	PERCENT OF MAJOR CATEGORY
URBAN LAND USE									
RESIDENTIAL............	7,795	12.18	59.9	74	0.12	58.7	7,869	12.29	59.9
LOW-DENSITY..........	297	0.46	2.3	0	0.00	0.0	297	0.46	2.2
MEDIUM-DENSITY.......	6,263	9.78	48.1	74	0.12	58.7	6,337	9.90	48.2
HIGH-DENSITY.........	1,235	1.93	9.5	0	0.00	0.0	1,235	1.93	9.4
COMMERCIAL.............	618	0.96	4.7	5	0.01	4.0	623	0.97	4.7
INDUSTRIAL.............	633	0.99	4.9	3	0.01	2.4	636	0.99	4.8
MINING.................	0	0.00	0.0	0	0.00	0.0	0	0.00	0.0
TRANSPORTATION.........	2,346	3.66	18.0	32	0.05	25.4	2,378	3.72	18.1
GOVERNMENTAL...........	733	1.14	5.6	9	0.01	7.1	742	1.16	5.6
RECREATIONAL...........	893	1.40	6.8	3	0.01	2.4	896	1.40	6.8
TOTAL URBAN LAND USE.....	13,018	20.34	100.0	126	0.20	100.0	13,144	20.53	100.0
RURAL LAND USE									
AGRICULTURAL AND OPEN LAND..............	-13,018	-20.34	--	-126	-0.20	--	-13,144	-20.53	--
TOTAL RURAL LAND USE	-13,018	-20.34	--	-126	-0.20	--	-13,144	-20.53	--
TOTAL	--	--	--	--	--	--	--	--	--

LAND USE CATEGORY	TOTAL (1990)								
	IN REGION			OUTSIDE REGION			TOTAL		
	ACRES	SQUARE MILES	PERCENT OF MAJOR CATEGORY	ACRES	SQUARE MILES	PERCENT OF MAJOR CATEGORY	ACRES	SQUARE MILES	PERCENT OF MAJOR CATEGORY
URBAN LAND USE									
RESIDENTIAL............	33,193	51.86	47.0	1,696	2.65	21.6	34,889	54.51	44.5
LOW-DENSITY..........	11,514	17.99	16.3	1,041	1.63	13.2	12,555	19.61	16.0
MEDIUM-DENSITY.......	11,696	18.28	16.6	655	1.02	8.3	12,351	19.30	15.8
HIGH-DENSITY.........	9,983	15.60	14.1	0	0.00	0.0	9,983	15.60	12.7
COMMERCIAL.............	1,885	2.94	2.7	106	0.16	1.3	1,991	3.11	2.5
INDUSTRIAL.............	2,333	3.64	3.3	66	0.10	0.8	2,399	3.75	3.1
MINING.................	866	1.35	1.2	247	0.38	3.1	1,113	1.74	1.4
TRANSPORTATION.........	23,185	36.23	32.8	4,704	7.35	59.8	27,889	43.58	35.6
GOVERNMENTAL...........	3,862	6.03	5.5	332	0.52	4.2	4,194	6.55	5.3
RECREATIONAL...........	5,264	8.22	7.4	713	1.11	9.1	5,977	9.34	7.6
TOTAL URBAN LAND USE.....	70,588	110.29	100.0	7,864	12.30	100.0	78,452	122.59	100.0
RURAL LAND USE									
AGRICULTURAL AND OPEN LAND..............	205,686	321.38	100.0	160,813	251.27	100.0	366,499	572.65	100.0
TOTAL RURAL LAND USE.....	205,686	321.38	100.0	160,813	251.27	100.0	366,499	572.65	100.0
TOTAL	276,274	431.67	100.0	168,677	263.57	100.0	444,951	695.24	100.0

SOURCE- SEWRPC.

add approximately 400 acres to the existing 1,763 acres of industrial land in the watershed. In addition, approximately 236 acres of new community and local industrial land would be added during the plan design period. As shown in Table 3, these additions to the existing stock of industrial land would total 636 acres, or an increase of about 36 percent over the existing supply.

Transportation, Communication, and Utility Facility Land Use: As indicated in Table 3, the land use base proposes to add approximately 2,378 acres of transportation, communication, and utility facility land use to the existing stock of such land uses within the watershed, or an increase of about 9 percent.

Agricultural Land Use: The previously described increases in urban land uses in the watershed by 1990 would result in a corresponding decrease in agricultural and other rural and related open-space uses. The stock of rural land within the watershed could, therefore, be expected to decrease from about 380,000 acres in 1967 to 366,000 acres in 1990, a decrease of nearly 4 percent. Of this agricultural and related open-space land which is proposed to be converted to urban uses, 1,866 acres, or about 13 percent, would be prime agricultural land; that is, land which has a relatively high potential crop yield capability, which has consistently produced higher than average yields, and in which the farm sizes and capital investments in agricultural improvements are relatively large (see Map 2).

Other Land Uses: The land use base also includes proposals for the reservation and development of outdoor recreation and related open-space land uses and for reservation of the primary environmental corridors. These land uses will be described in greater detail in the following sections of this chapter.

ALTERNATIVE NATURAL RESOURCE PROTECTION PLAN ELEMENTS

The concept of the environmental corridor was set forth in Chapters IV and XIII of Volume 1 of this report. In addition, these chapters discussed the importance of the preservation of the primary environmental corridors to the protection of the best remaining elements of the natural resource base, including the surface waters and associated shorelands and floodlands, woodlands, wetlands, and wildlife habitat areas, as well as the best remaining potential park and related open-space sites, including high-value historic, scientific, and scenic sites within the watershed. The primary environmental corridors encompass about 157 square miles, or approximately 23 percent of the total watershed area of 694 square miles. These primary environmental corridors, however, contain about 85 percent of the perennial stream channel length, about 88 percent of the shoreline of the 21 major lakes within the watershed, about 77 percent of all remaining wetlands, about 59 percent of all remaining woodlands, about 47 percent of all unused lands, about 72 percent of all remaining wildlife habitat area, and about 66 percent of all potential park and related open-space sites remaining within the watershed (see Table 4).[1] Any plan for the preservation, protection, and wise use of the natural resource base within the watershed must, therefore, be centered on the preservation and protection of the primary environmental corridors.

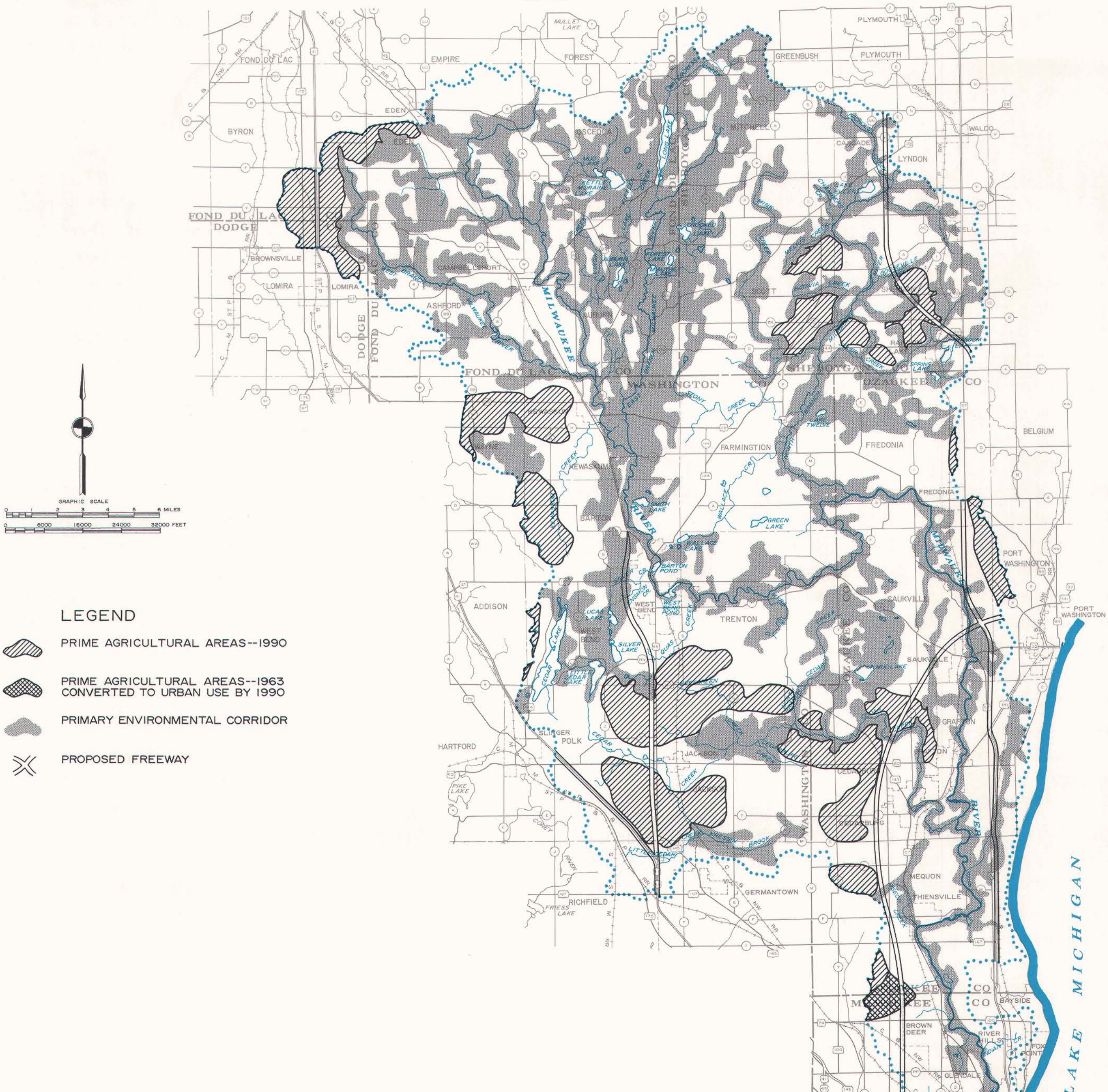
The complex of resource elements contained within the primary environmental corridors, as determined by the detailed watershed land use inventory, includes 6,554 acres of water area; 45,160 acres of wetland area; 20,774 acres of woodland area; 3,851 acres of unused land area; and 23,934 acres of agricultural and agricultural-related land area. Any plan for the preservation, protection, and wise use of the primary environmental corridors of the Milwaukee River watershed must, in turn, consist of a carefully selected mosaic of proposals for the protection and maintenance of the complex of individual resource elements comprising these corridors.

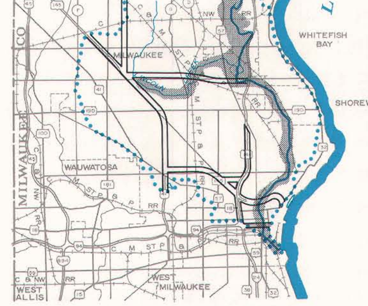
Three alternative natural resource protection plan elements were developed in the process of detailing and refining the regional land use plan for the Milwaukee River watershed and of preparing the recommended controlled existing trend land use plan for the out-of-Region portion of the watershed, using sound land use development objectives relating directly to the underlying and sustaining natural resource base. Each of these three alternative plan elements was designed to provide for

[1] *It is important to note that the indicated percentage distribution of wetlands, woodlands, and wildlife habitat area in the primary environmental corridor represents such resource elements as determined in the SEWRPC land use inventories rather than the watershed natural resource inventories, in order to avoid the multiple counting of certain acreages under the latter inventories.*

Map 2

PRIME AGRICULTURAL AREAS IN THE MILWAUKEE RIVER WATERSHED 1990





The recommended land use plan proposes to preserve in essentially open rural use a total of approximately 366,000 acres of agricultural land within the watershed--the white and black cross-hatched areas on this map. Of this total, approximately 51,000 acres--the black cross-hatched areas on this map--constitute prime agricultural areas. These areas are not only covered by highly fertile soils, but are areas in which the farm sizes are large enough so as to constitute efficient operations, in which relatively large amounts of capital have been invested in increasing productivity, and areas which have consistently produced higher than average crop yields. The preservation of these areas is not only important to the economy of the watershed but to the preservation of the overall quality of the environment in the watershed.

Source: SEWRPC.

Table 4

DISTRIBUTION OF LAND USE RESOURCE ELEMENTS IN THE MILWAUKEE RIVER WATERSHED AND IN THE PRIMARY ENVIRONMENTAL CORRIDOR WITHIN THE WATERSHED--1967

RESOURCE ELEMENT[a]	AMOUNT IN WATERSHED			AMOUNT IN CORRIDOR			PERCENT IN CORRIDOR		
	IN REGION	OUTSIDE REGION	TOTAL	IN REGION	OUTSIDE REGION	TOTAL	IN REGION	OUTSIDE REGION	TOTAL
STREAMS (MILES)........................	206	124	330	161	121	282	78.2	97.6	85.4
(ACRES)........................	2,044	641	2,685	1,965	600	2,565	96.1	93.6	95.5
LAKES (ACRES)..........................	2,491	1,679	4,170	2,310	1,679	3,989	92.7	100.0	95.7
WETLANDS (ACRES).......................	26,406	32,050	58,456	17,477	27,683	45,160	66.2	86.4	77.3
WOODLANDS (ACRES)......................	19,624	15,408	35,032	8,617	12,175	20,774	43.9	79.0	59.3
AGRICULTURAL AND RELATED LAND (ACRES)...	161,292	110,078	271,370	10,579	13,355	23,934	6.6	12.1	8.8
UNUSED LAND (ACRES)....................	4,693	3,498	8,191	1,030	2,821	3,851	21.9	80.6	47.0
WILDLIFE HABITAT (ACRES)...............	50,565	49,778	100,343	30,318	42,170	72,488	59.2	84.7	72.2
EXISTING OUTDOOR RECREATIONAL SITES (ACRES)........................	11,313	17,752	29,065	8,126	16,552	24,678	71.8	93.2	84.9
POTENTIAL OUTDOOR RECREATIONAL SITES (ACRES)........................	17,606	4,329	21,935	11,414	3,153	14,567	64.8	72.8	66.4
TOTAL AREA (ACRES).....................	275,373	168,678	444,051	42,505	57,767	100,272	15.5	34.3	22.5

[a]THE AREAS INDICATED FOR THE NATURAL RESOURCE ELEMENTS SET FORTH IN THIS TABLE WILL NOT TOTAL TO THE AREA OF THE WATERSHED SINCE THESE ELEMENTS ARE NOT MUTUALLY EXCLUSIVE IN NATURE; THAT IS, FOR EXAMPLE, SUCH ELEMENTS AS WOODLANDS AND WETLANDS ALSO CONSTITUTE AREA DELINEATED AS WILDLIFE HABITAT AND POTENTIAL OUTDOOR RECREATIONAL SITES.

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND SEWRPC.

the preservation, protection, and wise use of the best remaining elements of the natural resource base, with emphasis on protecting and preserving the regenerative qualities of that base, including the soils, surface and ground water, wetlands, woodlands, and wildlife. All of the alternatives are centered on the preservation of the primary environmental corridors, with each alternative plan including all the elements of the preceding alternative, thereby more completely attaining the watershed land use development objectives as these objectives relate to the protection and enhancement of the natural resource base. The major objective of these watershed plan elements and, indeed, of the concept of environmental corridors, is the preservation, protection, balanced use, and proper management of the biota and thereby maintenance of resource diversity within the watershed for all time.

Minimum Alternative Natural Resource Protection Plan Element

The first alternative natural resource protection plan element considered was a minimum design intended to protect through public acquisition, zoning, and management the primary environmental corridor of the watershed, as delineated in the adopted regional land use plan, which plan was subsequently refined under the Milwaukee River watershed planning program and in the recommended controlled existing land use plan for the out-of-Region portion of the watershed. This alternative plan element consists of five specific subelements:

1. Public acquisition of all remaining undeveloped primary environmental corridor lands lying in, and adjacent to, those areas of the watershed expected to be in urban use by 1990. These lands total 9,847 acres, or about 2 percent of the total watershed area and nearly 10 percent of the total primary environmental corridor area.

2. Public acquisition of selected remaining high-value wetland areas located in the primary environmental corridors adjacent to existing publicly owned and leased woodland, wetland, and wildlife areas. These areas total 16,040 acres, or about 4 percent of the total watershed area and 16 percent of the total primary environmental corridor area.

3. Public acquisition of selected remaining high-value woodland areas located in the primary environmental corridors adjacent to existing publicly owned woodland, wetland, and wildlife areas. These areas total 3,401 acres, or about 1 percent of the total watershed area and 3 percent of the total primary environmental corridor area.

4. Protection of all remaining environmental corridor areas not now in public ownership and not proposed for future public ownership in rural portions of the watershed, through appropriate agricultural, floodland, shoreland, conservancy, and low-

density residential zoning. These areas total 46,632 acres, or about 12 percent of the total watershed area and nearly 47 percent of the total primary environmental corridor area.

5. Promotion of good management of all remaining woodland and wetland resources of the watershed.

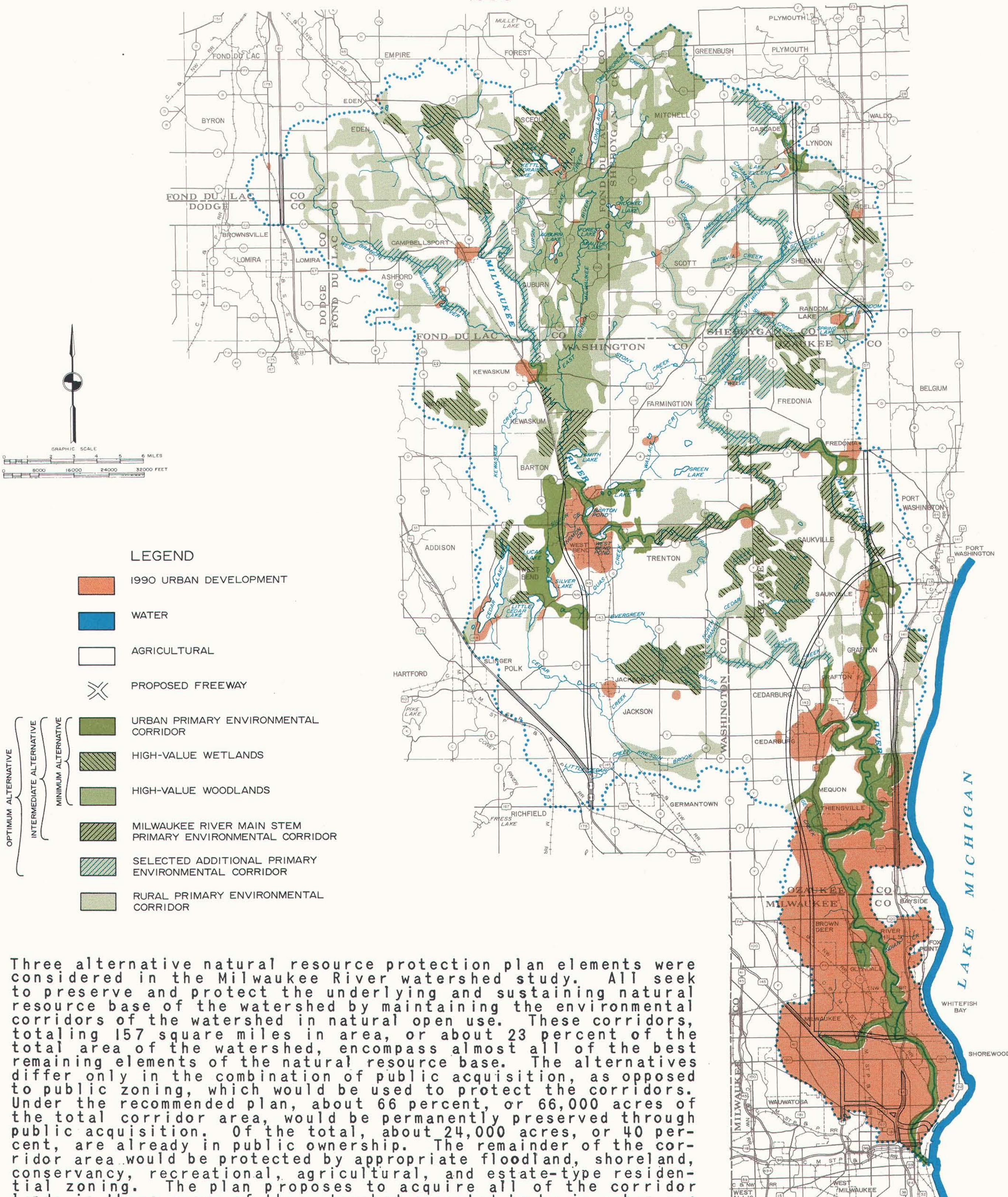
Urban Environmental Corridor Acquisition: This proposal consists of the acquisition for public use and protection of all remaining undeveloped primary environmental corridors lying in, and adjacent to, areas of the watershed expected to be in urban use by 1990 (see Map 3). This would require the staged acquisition of a total of 9,847 acres of urban environmental corridor lands within the watershed in addition to the 1,801 acres of urban corridor land presently in public ownership (see Table 5). As shown on Map 3, urban environmental corridor lands are located in the Cities of Glendale and Milwaukee and the Villages of Brown Deer, River Hills, and Shorewood in Milwaukee County; the Cities of Cedarburg and Mequon, the Villages of Fredonia, Grafton, Saukville, and Thiensville, and the Towns of Cedarburg, Fredonia, Grafton, and Saukville in Ozaukee County; the City of West Bend, the Village of Kewaskum, and the Towns of Barton, Trenton, and West Bend in Washington County; and the Villages of Cascade and Random Lake and the Towns of Lyndon and Sherman in Sheboygan County. The acquisition of these urban environmental corridor lands would permanently protect 2,690 acres of wetland, 3,500 acres of woodland, and 2,801 acres of potential park site within the watershed. These urban environmental corridor lands also comprise almost 10 percent of the total environmental corridor acreage proposed to be utilized for park and open-space uses in the recommended outdoor recreation plan element. The total cost of acquiring the urban environmental corridors is estimated at $20,438,000 over a 20-year plan implementation period. It is important to stress that this public land acquisition proposal includes only undeveloped lands within the delineated primary environmental corridors and does not, therefore, include any lands already developed for urban uses.

High-Value Wetland Acquisition: Continued acquisition of selected high resource value wetland areas within the primary environmental corridors of the watershed is proposed in this plan element in order to protect and enhance the existing public ownership, which now totals about 7,170 acres (see Map 3). Additional wetland acreage proposed to be acquired includes the best remaining wetlands within the watershed adjacent to existing wildlife-wetland conservancy areas of the watershed. Acquisition of these areas would total about 16,040 acres, which includes 9,933 acres inventoried as wetland and 6,107 acres inventoried as woodland, unused land, or agricultural land (see Table 5). The proposed acquisition represents 27 percent of the wetlands within the watershed. Areas proposed for additional high-value wetland acquisition include the Jackson Marsh and Wayne Marsh areas in Washington County, the Cedarburg Bog and Hurias Lake areas in Ozaukee County, the Kettle Moraine Lake area in Fond du Lac County, and the Adell Swamp area in Sheboygan County. The total cost of acquiring these high-value wetlands is estimated at $4,857,400.

High-Value Woodland Acquisition: Continued acquisition of selected high resource value woodland areas within the primary environmental corridors of the watershed is also recommended to meet woodland preservation objectives (see Map 3). Acquisition of high-value woodlands within the watershed should be continued in order to assist in completing the acquisition of the Northern Unit of the Kettle Moraine State Forest. In this respect, it should be noted that the acquisition recommendation being made here includes some areas not now included within the project boundaries as determined by the Wisconsin Department of Natural Resources for the Kettle Moraine State Forest. These areas, as well as certain lands lying outside the primary environmental corridors but within the project boundaries of the Kettle Moraine State Forest, are needed to fully protect the natural resource base and provide continuity for the proper management of state-owned lands. It is extremely important that certain large, key natural resource areas of the watershed, such as the Kettle Moraine area, remain in open space and woodland cover for all time. The total woodland area recommended for acquisition is 3,401 acres, in addition to the 13,865 woodland acres presently in public ownership (see Table 5). These 3,401 acres include 1,393 acres inventoried as woodland and 2,008 acres inventoried as wetland, unused land, and agricultural land. The proposed acquisition represents about 9 percent of the total woodlands inventoried in the watershed. The total cost of acquiring these high-value woodlands is estimated at $2,380,700.

Map 3

ALTERNATIVE NATURAL RESOURCE PROTECTION PLAN ELEMENTS FOR THE MILWAUKEE RIVER WATERSHED 1990



Three alternative natural resource protection plan elements were considered in the Milwaukee River watershed study. All seek to preserve and protect the underlying and sustaining natural resource base of the watershed by maintaining the environmental corridors of the watershed in natural open use. These corridors, totaling 157 square miles in area, or about 23 percent of the total area of the watershed, encompass almost all of the best remaining elements of the natural resource base. The alternatives differ only in the combination of public acquisition, as opposed to public zoning, which would be used to protect the corridors. Under the recommended plan, about 66 percent, or 66,000 acres of the total corridor area, would be permanently preserved through public acquisition. Of the total, about 24,000 acres, or 40 percent, are already in public ownership. The remainder of the corridor area would be protected by appropriate floodland, shoreland, conservancy, recreational, agricultural, and estate-type residential zoning. The plan proposes to acquire all of the corridor lands in those areas of the watershed expected to be in urban use by 1990, totaling about 9,800 acres, and all of the corridor along the main stem of the Milwaukee River from Milwaukee through West Bend, totaling an additional 3,400 acres.

Source: SEWRPC.

Table 5

EXISTING AND PROPOSED PUBLIC OWNERSHIP OF SELECTED ENVIRONMENTAL CORRIDOR LANDS BY COUNTY-- 1967 AND 1990 ALTERNATIVE NATURAL RESOURCES PROTECTION PLAN ELEMENTS[a]

	Urban Environmental Corridor						High Value Wetland Areas					
	Existing Public Ownership (1967)		Proposed Public Acquisition		Total (1990)		Existing Public Ownership (1967)		Proposed Public Acquisition		Total (1990)	
County	Acres	Percent of Watershed	Acres	Percent Change	Acres	Percent of Watershed	Acres	Percent of Watershed	Acres	Percent Change	Acres	Percent of Watershed
Fond du Lac	--	--	--	--	--	--	2,895	40.4	5,470	--	8,365	36.0
Milwaukee	1,276	70.1	248	19.4	1,524	13.1	--	--	--	--	--	--
Ozaukee	160	8.8	4,468	2,792.5	4,628	39.7	1,070	14.9	4,112	5,152.5	5,182	22.4
Sheboygan	10	1.4	1,098	10,980.0	1,108	9.5	1,555	21.7	775	--	2,330	10.0
Washington	355	19.7	4,033	1,136.0	4,388	37.7	1,650	23.0	5,683	463.9	7,333	31.6
Total	1,801	100.0	9,847	462.5	11,648	100.0	7,170	100.0	16,040	792.0	23,210	100.0

	High-Value Woodland Areas						Total					
	Existing Public Ownership (1967)		Proposed Public Acquisition		Total (1990)		Existing Public Ownership (1967)		Proposed Public Acquisition		Total (1990)	
County	Acres	Percent of Watershed	Acres	Percent Change	Acres	Percent of Watershed	Acres	Percent of Watershed	Acres	Percent Change	Acres	Percent of Watershed
Fond du Lac	6,728	48.5	2,369	24.8	9,097	52.7	9,543	39.8	7,839	82.1	17,382	32.6
Milwaukee	--	--	--	--	--	--	1,276	5.3	248	19.4	1,524	2.9
Ozaukee	--	--	--	--	--	--	1,230	5.1	8,580	893.7	9,810	18.4
Sheboygan	6,084	43.9	856	11.2	6,940	40.2	7,649	31.9	2,729	35.6	10,378	19.5
Washington	1,053	7.6	176	6.5	1,229	7.1	4,283	17.9	9,892	230.9	14,175	26.6
Total	13,865	100.0	3,401	17.1	17,266	100.0	23,981	100.0	29,288	117.1	53,269	100.0

[a] The proposed public acquisition of various environmental corridor lands as set forth in this table is included in the minimum, intermediate, and optimum natural resources protection plan elements, as described in this chapter.

Source- Wisconsin Department of Natural Resources and SEWRPC.

Primary Environmental Corridor Zoning: Public acquisition of the primary environmental corridor lands within the watershed is the best means of protecting and enhancing the natural resource base of the watershed, providing needed park and open spaces, protecting floodlands from incompatible urban uses, and lending form and structure to urban development. Those areas of the primary environmental corridors which are not actually acquired for public use, however, should be kept in compatible, essentially natural open-space uses. This can largely be achieved through the use of agricultural, floodland, shoreland, conservancy, and very low-density residential zoning within the watershed. This zoning should, at a minimum, encompass all of the riverine areas of the watershed lying within the 100-year recurrence flood hazard line and all areas within 1,000 feet of the shoreline of the 21 major lakes within the watershed. Such zoning will assist in protecting the remaining woodlands, wetlands, and wildlife habitat areas, as well as the floodlands and water quality, within the watershed from continued deterioration and destruction by fragmented urban development. These zoning measures will also serve to prevent intensification of flood problems within the watershed. It is proposed that 46,632 acres, or about 47 percent of the primary environmental corridors within the watershed, be zoned in a manner appropriate to the preservation of the natural resource element. In addition, those areas of the corridors proposed to be acquired for public use should also be initially zoned as exclusive agricultural, floodland, park land, or conservancy districts in order to achieve immediate protection from urban encroachment pending acquisition.

Wetland and Woodland Resource Management: In addition to the foregoing environmental corridor acquisition and zoning proposals, it is recommended that adequate management practices be instituted for all remaining natural resource base elements within the watershed. These management practices should be extended to the 14,258 acres of woodlands and 13,336 acres of wetlands in the watershed which lie outside the environmental corridor boundaries. In addition, such management practices should be applied to the wetlands and woodlands lying within the primary environmental corridor. The continued function of these areas in sustaining a varied biota, in the production of wildlife, in the protection and enhancement of water quality, and in the maintenance of a naturally well-regulated streamflow regimen within the watershed can only be ensured by applying good forestry and wetland management measures.

Concluding Remarks—Minimum Alternative Natural Resource Protection Plan Element: The total primary environmental corridor acreage to be acquired for public use under this minimum alternative plan element is 29,288 acres, including 9,847 acres of urban environmental corridor lands, 16,040 acres of high-value wetland areas, and 3,401 acres of high-value woodland areas for environmental protection and preservation of wildlife, open space, recreation, and natural biotic functions (see Table 5). The total cost of acquiring this corridor land is estimated at $27,676,100. Including the 24,352 acres of the primary environmental corridor presently in public ownership, a total of 53,640 acres of corridor lands would be held in public trust with the implementation of the minimum alternative natural resource protection plan element. This total area of 53,640 acres constitutes 53 percent of the primary environmental corridor area delineated within the Milwaukee River watershed and 12 percent of the total area of the watershed. In addition, under this alternative a total of 46,632 acres, or about 47 percent of primary environmental corridor land, would be protected by appropriate agricultural, floodland, shoreland, conservancy, and low-density residential zoning.

This natural resource protection plan alternative would provide a minimum program for preservation of the resource base of the watershed through public acquisition of selected primary environmental corridor areas subject to urbanization, zoning of the remaining environmental corridor area, and application of good management practices to all woodlands and wetlands lying both within and outside the primary environmental corridors. It would result in an integrated system of public greenways and resource protection districts within the watershed which would ensure the provision of needed park and open-space lands within the watershed and the rapidly urbanizing Southeastern Wisconsin Region, lend form and structure to urban development, and prevent intensification of flooding and water pollution within the watershed. About one-half of the primary environmental corridors in the watershed, however, would not be permanently protected from urban encroachment through public acquisition.

Intermediate Alternative Natural Resource Protection Plan Element

A second alternative natural resource protection plan element considered included all of the subelements proposed in the first alternative natural resource protection plan element and, in addition, public acquisition of all other undeveloped primary environmental corridor lands remaining along the main stem of the Milwaukee River in Ozaukee and Washington Counties. This proposal would entail the acquisition of 3,420 acres of primary environmental corridor along the main stem of the Milwaukee River not previously proposed for acquisition under the first alternative natural resource protection plan element and not already in public ownership (see Map 3 and Table 6). Such acquisition would include the preservation and protection of an additional 1,917 acres of wetland and 892 acres of woodland encompassed within the primary environmental corridors of the watershed. The total cost of acquiring this additional environmental corridor land is estimated at $2,394,000.

Table 6

EXISTING AND PROPOSED PUBLIC OWNERSHIP OF ADDITIONAL MILWAUKEE RIVER MAIN STEM ENVIRONMENTAL CORRIDOR LANDS BY COUNTY--1967 AND 1990 INTERMEDIATE ALTERNATIVE NATURAL RESOURCE PROTECTION PLAN ELEMENT

	MILWAUKEE RIVER MAIN STEM ENVIRONMENTAL CORRIDOR[a]					
	EXISTING PUBLIC OWNERSHIP (1967)		PROPOSED PUBLIC ACQUISITION		TOTAL (1990)	
COUNTY	ACRES	PERCENT OF WATERSHED	ACRES	PERCENT CHANGE	ACRES	PERCENT OF WATERSHED
FOND DU LAC....	--	--	--	--	--	--
MILWAUKEE......	--	--	--	--	--	--
OZAUKEE........	287	100.0	898	312.9	1,185	32.0
SHEBOYGAN......	--	--	--	--	--	--
WASHINGTON.....	--	--	2,522	--	2,522	68.0
TOTAL	287	100.0	3,420	1,191.6	3,707	100.0

[a]DOES NOT INCLUDE ENVIRONMENTAL CORRIDOR LANDS ALONG THE MAIN STEM OF THE MILWAUKEE RIVER PROPOSED FOR PUBLIC ACQUISITION AS URBAN ENVIRONMENTAL CORRIDOR IN TABLE 5.

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND SEWRPC.

The adoption and implementation of this second alternative natural resource protection plan element would place a total of 57,060 acres, or 57 percent of the primary environmental corridor lands within the watershed and 13 percent of the total area of the watershed, in public ownership. Of the total acreage recommended for public ownership, 24,352 acres, or 43 percent, are presently publicly owned. A total of 18,158 acres of woodlands, or 52 percent of the remaining woodlands and 4.1 percent of the total watershed area, and 25,127 acres of wetland, or 40 percent of the remaining wetlands and 5.6 percent of the total watershed area, would be protected through public ownership under this plan alternative.

The second alternative natural resource protection plan element differs from the first alternative only in proposing public acquisition of additional primary environmental corridor land along the main stem of the Milwaukee River from Kewaskum in Washington County to the Saukville area in Ozaukee County. Thus, through existing public ownership, proposed public acquisition, zoning, and management, the total of 100,272 acres of primary environmental corridor area within the watershed would be protected. In addition, a total of 27,594 acres of high-value wetlands and woodlands would be protected through existing public ownership and proposed zoning and management outside the primary environmental corridors. This second alternative would better meet the natural resource-related development objectives and standards set forth in this volume than would the first alternative resource protection plan element since more high-value environmental corridor land would be permanently protected and preserved through public acquisition.

Optimum Alternative Natural Resource Protection Plan Element

The third alternative natural resource protection plan element considered included all of the subelements proposed in the first and second alternative plan elements and, in addition, public acquisition of additional selected undeveloped primary environmental corridor lands throughout the watershed. Additional environmental corridors recommended for acquisition include the following: a portion of the Campbellsport Corridor in the Town of Auburn, Fond du Lac County; a portion of the Cedarburg Corridor along Cedar Creek in the Towns of Cedarburg and Jackson, Ozaukee County; a portion of the West Branch Corridor along the Milwaukee River in the Town of Ashford, Fond du Lac County; portions of the Cascade, Mink Creek, Random Lake, and Waubeka Corridors in the Town of Farmington, Washington County; the Town of Fredonia, Ozaukee County; and the Towns of Lyndon, Mitchell, Scott, and Sherman in Sheboygan County (see Map 3). These additional primary environmental corridor acquisitions would encompass a total of 8,876 acres and account for about 9 percent of the total primary environmental corridor in the watershed (see Table 7). Included in these additional acres would be 4,646 acres of wetland and 2,976 acres of woodland. The total cost of acquiring this additional environmental corridor land is estimated at $4,438,000.

This alternative plan element would provide optimum protection not only of the primary environmental corridors but, in addition, other high-value woodlands, wetlands, and adjacent undeveloped areas remaining within the Milwaukee River watershed. Through existing public ownership, proposed public acquisition, zoning, and management, a total of 127,866 acres of primary environmental corridor area and related high-value woodlands and wetlands outside the primary environmental corridor but within the watershed would be protected. Of this total of 127,866 acres, 100,272 acres constitute the primary environmental corridor lands. Of the total primary environmental corridor acreage, 24,352 acres, or about 24 percent, are presently in public ownership; and an additional 41,584 acres are proposed to be acquired, resulting in a total of 65,936 acres, or about 66 percent of the total primary environmental corridor area within the watershed, being permanently preserved and maintained through public ownership. The total cost of acquiring all of the environmental corridor land proposed in this alternative is estimated at $34,508,100.

Concluding Remarks—Alternative Natural Resource Protection Plan Elements

The relative effectiveness of the three alternative natural resource protection plan elements in meeting the watershed development objectives and standards relating to lakes and streams, woodlands, wetlands, and wildlife habitat area is summarized in Table 8. All three plan elements perform well with respect to these objectives and standards. The second alternative would better meet the natural resource objectives and standards than the first alternative because more woodlands and wetlands would be publicly acquired, thus providing greater assurance of permanent protection and preservation of a larger amount of such area. Similarly, the third alternative would better meet the objectives and standards than either the first

Table 7

EXISTING AND PROPOSED OWNERSHIP OF ADDITIONAL SELECTED ENVIRONMENTAL CORRIDOR LANDS BY COUNTY--1967 AND 1990 OPTIMUM ALTERNATIVE NATURAL RESOURCE PROTECTION PLAN ELEMENT

COUNTY	SELECTED PRIMARY ENVIRONMENTAL CORRIDOR					
	EXISTING PUBLIC OWNERSHIP (1967)		PROPOSED PUBLIC ACQUISITION		TOTAL (1990)	
	ACRES	PERCENT OF WATERSHED	ACRES	PERCENT CHANGE	ACRES	PERCENT OF WATERSHED
FOND DU LAC....	--	--	2,190	--	2,190	23.7
MILWAUKEE.......	--	--	--	--	--	--
OZAUKEE.........	--	--	1,660	--	1,660	18.0
SHEBOYGAN.......	354	100.0	3,152	890.3	3,506	38.0
WASHINGTON.....	--	--	1,874	--	1,874	20.3
TOTAL	354	100.0	8,876	2,507.3	9,230	100.0

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND SEWRPC.

Table 8

COMPARISON OF THE RELATIVE ABILITY OF THE ALTERNATIVE NATURAL RESOURCE PROTECTION PLAN ELEMENTS TO MEET WATERSHED DEVELOPMENT STANDARDS

OBJECTIVE	MINIMUM ALTERNATIVE NATURAL RESOURCE PROTECTION PLAN ELEMENT	INTERMEDIATE ALTERNATIVE NATURAL RESOURCE PROTECTION PLAN ELEMENT	OPTIMUM ALTERNATIVE NATURAL RESOURCE PROTECTION PLAN ELEMENT
NATURAL RESOURCES RELATED STANDARDS[a]			
INLAND LAKES AND STREAMS			
1. LARGE INLAND LAKES OVER 50 ACRES (21 LAKES)			
A. 25% OF SHORE IN NATURAL STATE	MET FOR 14 OF 21 LAKES	MET FOR 14 OF 21 LAKES	MET FOR 14 OF 21 LAKES
B. 10% OF SHORE IN PUBLIC USE	MET FOR 8 OF 21 LAKES	MET FOR 8 OF 21 LAKES	MET FOR 8 OF 21 LAKES
C. 50% OF SHORE IN NONURBAN USES	MET FOR 13 OF 21 LAKES	MET FOR 13 OF 21 LAKES	MET FOR 13 OF 21 LAKES
2. SMALL INLAND LAKES--UNDER 50 ACRES (50 LAKES)			
A. 25% SHORE IN NATURAL STATE[b]	COULD BE MET	COULD BE MET	COULD BE MET
3. PERENNIAL STREAMS (30 STREAMS)			
A. 25% OF SHORE IN NATURAL STATE[c]	MET FOR 26 OF 30 STREAMS	MET FOR 26 OF 30 STREAMS	MET FOR 26 OF 30 STREAMS
B. 50% OF SHORE IN NONURBAN USES[c]	MET FOR 26 OF 30 STREAMS	MET FOR 26 OF 30 STREAMS	MET FOR 26 OF 30 STREAMS
C. RESTRICT URBAN USES IN FLOODPLAINS[d]	MET	MET	MET
D. RESTRICT DEVELOPMENT IN CHANNELS AND FLOODWAYS[d]	MET	MET	MET
WETLANDS			
1. PROTECT WETLANDS OVER 50 ACRES AND THOSE WITH HIGH RESOURCE VALUES[d]	MET	MET	MET
WOODLANDS			
1. 10% OF THE WATERSHED[c]	MET	MET	MET
2. 40 ACRES OF EACH FOREST TYPE[b]	COULD BE MET	COULD BE MET	COULD BE MET
3. 5 ACRES/1,000 POPULATION FOR RECREATIONAL PURSUITS[e]	COULD BE MET	COULD BE MET	COULD BE MET
WILDLIFE			
1. MAINTAIN A WHOLESOME HABITAT	COULD BE MET	COULD BE MET	COULD BE MET

[a]THE INDICATED STANDARDS AND THE DEVELOPMENT OBJECTIVES WHICH THEY SUPPORT ARE SET FORTH IN FULL IN CHAPTER II OF THIS VOLUME.

[b]THIS STANDARD COULD BE MET BY LOCAL COMMUNITY ACTION.

[c]THIS STANDARD IS MET UNDER EACH ALTERNATIVE PLAN ELEMENT BECAUSE ALL OF THE PRIMARY ENVIRONMENTAL CORRIDORS ARE PROPOSED TO BE PROTECTED THROUGH PUBLIC ACQUISITION OR EFFECTIVE LOCAL ZONING.

[d]THIS STANDARD IS MET UNDER EACH ALTERNATIVE PLAN ELEMENT BECAUSE IT SERVED AS AN INPUT TO THE PLAN DESIGN PROCESS.

[e]ONLY THAT WOODLAND WITHIN THE PRIMARY ENVIRONMENTAL CORRIDORS WAS ASSUMED TO BE PRESERVED.

SOURCE- SEWRPC.

or second alternative because, again, there would be greater public acquisition of primary environmental lands. All three alternative plan elements require the use of sound floodland, shoreland, and conservancy zoning techniques to supplement public land acquisition.

It is apparent that the adoption and implementation of any one of the three alternative natural resource protection plan elements would have a desirable and far-reaching effect on the quality of life within the Milwaukee River watershed, particularly in those areas of the watershed which will be urbanized by 1990. The basic difference between the three alternatives is the amount of public land acquisition and, hence, the degree of assurance of the permanent protection and preservation of the primary environmental corridor areas of the watershed.

It is recommended that the third, or optimum, alternative natural resource protection plan element be included in the recommended comprehensive plan for the Milwaukee River watershed. This alternative, while more costly than the minimum and intermediate alternatives, provides the greatest degree of permanent preservation of the primary environmental corridors of the watershed, with existing and proposed public ownership of these important lands totaling nearly 66 percent of the total primary environmental corridor land in the watershed.

Implementation of the optimum alternative natural resource protection plan element will, as noted above, result in greater assurance that the adopted watershed planning standards relating to woodlands and wetlands will be met. The woodland standard requires that a minimum of 10 percent of the total watershed area be maintained in permanent woodland cover. A total of 44,405 acres of woodland area must, therefore, be maintained within the Milwaukee River watershed to meet this adopted standard. The total number of woodland acres proposed to be preserved and maintained through public ownership under the recommended alternative natural resource protection plan element is 19,126 acres. This means that an additional 25,279 acres of woodlands will have to be maintained and managed on private lands throughout the watershed in order to meet the adopted woodland standard. The detailed woodland natural resource inventory conducted during the watershed study by the Wisconsin Department of Natural Resources identified a total of 70,885 acres of woodland areas within the watershed which would be available for such maintenance and management and which could be used to assist in meeting the recommended woodland standard.

The adopted wetland standards require that all wetland units 50 acres or larger in area be protected, maintained, and managed as permanent wetland areas. The total wetland area to be preserved and maintained through public ownership under the recommended alternative natural resources protection plan element is 29,823 acres. This means that an additional 9,729 acres of wetlands in units 50 acres or larger in area will have to be maintained and managed on private lands throughout the watershed in order to meet the adopted wetland standard. The detailed wetland natural resource inventory conducted in the watershed study by the Wisconsin Department of Natural Resources identified a total of 39,652 acres of wetland areas in units 50 acres or larger in area within the watershed which would be available for such maintenance and management and which could be used to assist in meeting the recommended wetland standard.

It is also important to note that woodlands and wetlands are not mutually exclusive natural resource base elements. There is an overlap of such resource areas, particularly in the lowland conifer woodland area and the tamarack wetland area throughout the watershed. Through a combination of public land acquisition, zoning, and management practices, therefore, there is an excellent opportunity in the Milwaukee River watershed to provide the preservation and protection necessary to meet the recommended natural resource planning standards and to maintain the environmental diversity afforded the watershed by these remaining natural resource base elements.

Of great significance in the recommendation that the optimum alternative natural resource protection plan element be included in the recommended comprehensive plan for the Milwaukee River watershed is the permanent preservation through acquisition of the primary undeveloped riverine areas of the watershed—along the main stem of the Milwaukee River—where potential flood damages would be greatest if urban development is further allowed to encroach and where many of the high-value resources are concentrated. It should be noted that proposals for acquisition of the land along the main stem of the Milwaukee River and the development of a continuous Milwaukee River parkway date back as far as 1939.[2] Implementation of the optimum alternative would also provide permanent protection against urban encroachment into the significant upland resource areas of the watershed. To a large degree, this recommendation continues the very excellent and long-established program of the State of Wisconsin for the public acquisition and permanent preservation of Kettle Moraine State Forest lands, while expanding that program to include the equally important riverine areas of the watershed.[3] It is further recommended that special attention be given in the implementation of this plan element to roadside conservation and stabilization measures along roadways in, and adjacent to, primary environmental corridors in order to stabilize and maintain the roadside areas and reduce erosion and siltation into the streams, wetlands, and lakes of the watershed. In addition, the roadside areas provide protective cover for wildlife species native to the area, as well as a flora diversity, thus assuring a biotic mix within the primary environmental corridors of the area.

It is important to note that, if the Waubeka multipurpose reservoir alternative flood control plan element, as presented in Chapter IV of this volume, is included in the recommended comprehensive plan for the Milwaukee River watershed, it will affect the intermediate and optimum, but not the minimum, alternative natural resources protection plan elements described in this chap-

---

[2]*Wisconsin State Planning Board and Conservation Commission Bulletin No. 8, A Park, Parkway, and Recreational Area Plan, January 1939, Madison, Wisconsin.*

[3]*It should be noted also that recent federal and state efforts have resulted in the establishment of a publicly owned "Ice Age Reserve" within Wisconsin, including not only portions of the existing Kettle Moraine State Forest in Sheboygan County within the Milwaukee River watershed, but also the approximately 3,870 acre Campbellsport drumlin area in the Fond du Lac County portion of the watershed. While acquisition of these drumlin lands is not currently planned, except for two small parcels to provide scenic overlooks along highways, the protection of these lands through appropriate zoning measures is essential to maintain the significant glacial characteristics of the landscape.*

ter. With respect to the intermediate natural resource plan element, the Waubeka multi-purpose flood control reservoir would eliminate the need to purchase for public use about 700 acres of Milwaukee River main stem primary environmental corridor in Ozaukee and Washington Counties, thus reducing the total Milwaukee River main stem corridor to be acquired to 2,720 acres and reducing the total cost of acquiring the main stem environmental corridor by $490,000. With respect to the optimum natural resources protection plan element, implementation of the Waubeka multi-purpose flood control reservoir would eliminate the need to purchase for public use a total of about 3,600 acres of selected environmental corridor areas in Ozaukee, Sheboygan, and Washington Counties, reducing the total selected environmental corridor areas to be acquired to 5,276 acres and reducing the total cost of acquiring the selected additional environmental corridor areas by $1,800,000.

ALTERNATIVE OUTDOOR RECREATION AND RELATED OPEN-SPACE PLAN ELEMENTS

Three alternative outdoor recreation and related open-space plan elements were prepared under the Milwaukee River watershed planning program, all based upon, and constituting refinements of, the adopted regional land use plan and the recommended controlled existing trend plan for the out-of-Region portion of the watershed. Each of these three alternative plan elements was designed to provide areas for the expansion of existing outdoor recreation facilities, as well as to provide areas for the development of new outdoor recreation facilities, while, at the same time, protecting and preserving selected high-value elements of the natural resource base encompassed by each of the specific outdoor recreation sites under consideration. As was true of the three alternative natural resource protection plan elements considered, the three alternative outdoor recreation plan elements are cumulative in nature; that is, the second plan element includes all subelements of the first, and the third includes all subelements of the first and second. The three alternative plan elements differ only in their relative ability to meet, through public acquisition and development of park and outdoor recreation sites, the forecast 1990 demand for recreational land for each of the major outdoor recreational activities.

Outdoor Recreation Demand

The rapidly increasing demand within the Milwaukee River watershed for land and water for outdoor recreational activities was described in Chapter XIV of Volume 1 of this report. A total of 16 outdoor recreational activities were examined in terms of existing (1967) and forecast (1990) participant demand. These 16 activities, by rank order of forecast demand, were: pleasure driving, swimming, sightseeing, picnicking, golfing, boating, fishing, bicycling, nature walking, camping, hunting, hiking, water skiing, skiing, horseback riding, and canoeing. These 16 outdoor recreational activities were grouped into five classifications, based on the type or degree of site development required in order to meet demands of participants in each activity.

The first group contains the five major outdoor recreational activities—swimming, golfing, picnicking, camping, and skiing—that require specific intensive site development. Forecasts were made of 1990 demand for land for each of these five major activities. The second group contains only one activity—hunting—which can generally be accommodated on both publicly and privately owned recreational and resource conservancy lands and on lands in other uses, such as agriculture. Thus, no specific 1990 land demand forecast was made for this activity. The third group contains four water-based activities—boating, fishing, water skiing, and canoeing—which require extensive areas of surface water with only a minimal amount of intensive land development, such as boat-launching sites. Because such development is usually undertaken in conjunction with other land- and water-based outdoor recreational activities, no specific 1990 land demand forecasts were made for these activities. The fourth group contains three activities—hiking, horseback riding, and nature walking—the participant demand for which, it was assumed, could be met on existing public recreation and conservancy lands, as well as on nonpublic recreation, agricultural, or other open-space lands. The fifth group contains three activities—pleasure driving, bicycling, and sightseeing—the participant demand for which, it was assumed, could be met on existing and future public highway rights-of-way. Thus, no specific 1990 land demand forecasts were made for any of the activities in the fourth and fifth groups.

Based on the foregoing assumptions, it was determined that a total of approximately 17,480 acres of land in the Milwaukee River watershed would be needed by 1990 to meet the forecast demand for the five major outdoor recreational activities that require extensive site development. Existing land area in the watershed, both public and private, devoted to the five major activities totals 6,642 acres, leaving a forecast need of about 10,840 acres of additional outdoor recreation land in the watershed. This forecast of additional outdoor recreation land demand became the basis for the preparation of the alternative outdoor recreation and related open-space plan elements.

Potential Park and Related Open-Space Sites

As indicated in Chapter IV of Volume 1 of this report, an inventory of potential park sites conducted by the Commission revealed that there are a relatively large number of good potential park and related outdoor recreation sites remaining in the Milwaukee River watershed. Of the 131 potential park sites found in the watershed, having a total area of 21,935 acres, 59 sites, having a total area of 12,786 acres, were classified as high-value sites.[4] This represents almost 30 percent of the total number and over 26 percent of the total area of such high-value sites in the Southeastern Wisconsin Region and that part of the Milwaukee River watershed outside the Region. Thus, the Milwaukee River watershed serves as an important recreational resource base, not only for watershed residents but also for residents of the entire Region. These high-value potential park sites, whether developed publicly or privately, can best serve as the basis for the satisfaction of the forecast 1990 recreational land use demand in the watershed. It should be pointed out, however, that urbanization within the watershed may destroy many of these potential park sites for outdoor recreation and related open-space use unless effective measures are taken now to preserve these sites for such use.

Recreational Land Standards in the Regional Land Use Plan

As discussed in Chapter II of this volume, the Commission has, in its planning efforts to date, adopted regional land use development objectives with supporting principles and standards. One of these objectives and two of these standards deal with recreational land and are of particular importance in the design of alternative outdoor recreation plans for the Milwaukee River watershed. These two standards, as set forth in Chapter II and as modified to include the out-of-Region portion of the Milwaukee River watershed, specify that, for each additional 1,000 persons expected to reside within the total watershed, four acres of land should be set aside for regional public park development, and 10 acres should be set aside for local public park development. These standards were used in the design of the adopted regional land use plan and the recommended controlled existing trend plan for the out-of-Region portion of the watershed and, therefore, are fully met by those plan elements.

Minimum Alternative Outdoor Recreation Plan Element

The first alternative outdoor recreation and related open-space plan element considered was based primarily upon application of the aforementioned recreational land use standards to the forecast resident population of the watershed. The existing (1967) population of the watershed was estimated at 544,000 persons; and the 1990 population of the watershed was forecast at 678,000 persons, an increase of 134,000 persons over the 1967 level. Applying the standard of four acres of regional park land to the incremental resident population of the watershed results in the need for a total of about 540 acres of additional regional park land within the watershed. Applying the standard of 10 acres of local park land to the incremental resident population of the watershed results in the need for a total of about 1,340 acres of additional local park land within the watershed. Thus, the estimated total park land need within the watershed under this alternative is about 1,880 acres.

There are five existing regional outdoor recreation sites in the Milwaukee River watershed, totaling 1,921 acres in area. The area encompassed by these sites closely approximates the recommended standard for the existing population of the watershed (see Map 4). These five sites are:

1. Lincoln Park (County) in the City of Milwaukee, Milwaukee County, with a total existing site area of 305 acres.

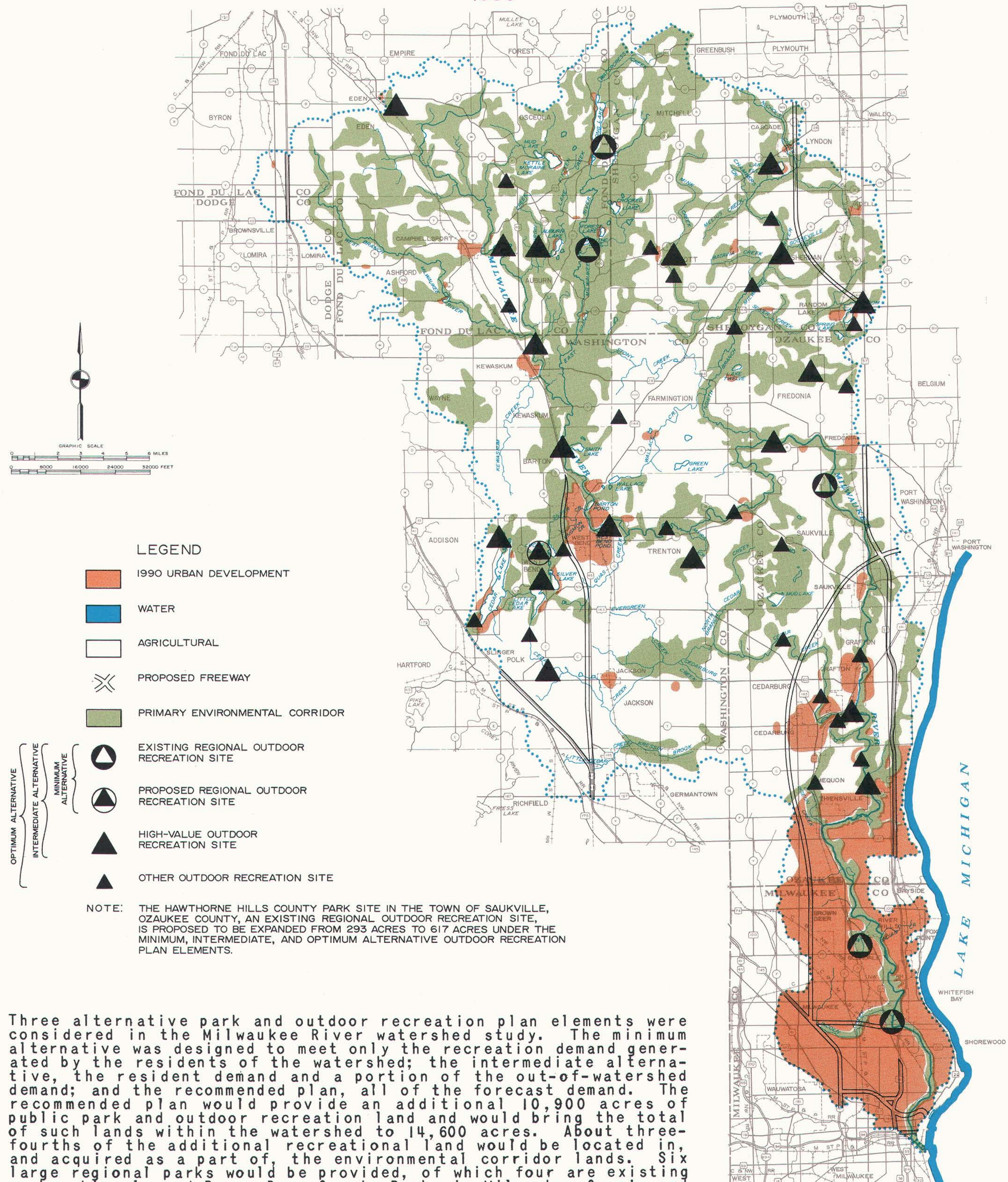
2. Brown Deer Park (County) in the City of Milwaukee, Milwaukee County, with a total existing site area of 368 acres.

3. Hawthorne Hills Park (County) in the Town of Saukville, Ozaukee County, with a total existing site area of 293 acres.

[4]*Of the 131 potential park sites identified in the watershed, 107 sites, totaling 19,428 acres, or 83 percent of the total sites and 90 percent of the acreage, lie within, or are adjacent to, the primary environmental corridors of the watershed.*

Map 4

ALTERNATIVE OUTDOOR RECREATION PLAN ELEMENTS FOR THE MILWAUKEE RIVER WATERSHED 1990



Three alternative park and outdoor recreation plan elements were considered in the Milwaukee River watershed study. The minimum alternative was designed to meet only the recreation demand generated by the residents of the watershed; the intermediate alternative, the resident demand and a portion of the out-of-watershed demand; and the recommended plan, all of the forecast demand. The recommended plan would provide an additional 10,900 acres of public park and outdoor recreation land and would bring the total of such lands within the watershed to 14,600 acres. About three-fourths of the additional recreational land would be located in, and acquired as a part of, the environmental corridor lands. Six large regional parks would be provided, of which four are existing parks--Lincoln and Brown Deer County Parks in Milwaukee County and Mauthe Lake and Long Lake State Recreational Areas in Fond du Lac County. One park, Hawthorne Hills County Park in Ozaukee County, would be enlarged to meet regional park standards; and a new state park would be provided southwest of West Bend.

Source: SEWRPC.

4. Mauthe Lake State Recreation Area in the Kettle Moraine State Forest, Town of Auburn, Fond du Lac County, with a total existing site area of 630 acres.

5. Long Lake State Recreation Area in the Kettle Moraine State Forest, Town of Osceola, Fond du Lac County, with a total existing site area of 325 acres.

The first alternative outdoor recreation plan element includes the maintenance and further development of these five regional park sites. These five park sites presently encompass 1,921 acres of woodland and wetland; and all five sites lie within, or adjacent to, the primary environmental corridors of the watershed.

As noted above, approximately 540 acres of additional regional park land are needed within the watershed to meet the aforementioned standard of four acres per 1,000 incremental resident population. Added to the existing stock of a total of 1,921 acres of regional park land, there would be a total of about 2,460 acres of regional park land in the watershed by 1990. The first alternative outdoor recreation plan element, therefore, includes proposals for the acquisition and development within the watershed of one new regional outdoor recreation site and expansion of one existing regional outdoor recreation site. These two proposals are the following:

1. The Lucas Lake-Paradise Valley site in the Town of West Bend, Washington County, which is proposed to be acquired and developed with a total proposed site area, including adjacent urban environmental corridor lands, of 1,500 acres, of which 350 acres would be developed for intensive outdoor recreation uses.

2. The Hawthorne Hills Park (County) site in the Town of Saukville, Ozaukee County, which is proposed to be expanded in area by 324 acres in order to accommodate a wide range of multi-purpose outdoor recreational activities. The total proposed site area for the Hawthorne Hills County Park is 617 acres, including the addition of 324 acres to the existing 293 acre site.

The Lucas Lake-Paradise Valley site in Washington County was rated as one of the eight best remaining potential park sites within the entire seven-county Region in the 1964 inventory of potential park and open-space sites. It should be noted that the Washington County Park and Planning Commission has established an approximately 100 acre county park on the former Ridge Run Farm just north of the proposed Lucas Lake-Paradise Valley regional park site. This county park could form the nucleus for the development of the future regional park. Expansion of the Hawthorne Hills County Park in Ozaukee County would enable the accommodation of more activities than are currently being accommodated at the park.

Site expansion of the Hawthorne Hills site is proposed to the north of the existing county park site along the Milwaukee River, so that the Hawthorne Hills site would eventually be linked to the Waubedonia County Park site on the Milwaukee River just west of the Village of Fredonia.

The one new proposed regional outdoor recreation site, together with the proposed expansion of an existing regional outdoor recreation site, would encompass a total area of 674 acres and would bring the total regional park area within the watershed to 2,595 acres. All of the 674 acres proposed to be acquired and developed for regional park sites would be acquired under the primary environmental corridor land acquisition recommended in the natural resource protection plan element at an estimated cost of $1,208,900. The estimated cost of developing the entire 674 acres of new regional park land is $1,011,000.

Existing local park lands in the Milwaukee River watershed total 1,752 acres. The first alternative outdoor recreation plan element includes the maintenance and further development, as necessary, of this existing local park acreage. In addition, the plan proposes the acquisition and development as community and neighborhood parks of an additional 1,338 acres of land in order to meet the standard of 10 acres of local park land per 1,000 incremental resident population. It is estimated that up to one-fourth of this additional local park land could be acquired through dedication during land subdivision development in expanding urban areas of the watershed. The remaining acreage could generally be provided within the primary environmental corridors. In Milwaukee County, however, only 248 of the estimated 752 local park acres needed could be provided within the primary environmental corridors. Of the remaining 504 acres, it is estimated that approximately 188 acres could be acquired through subdivision dedication. The remaining 316 acres would have to be acquired within the watershed or in areas adjacent to the watershed. The estimated cost of acquiring this land in Milwaukee County is $1,580,000. The acquisition cost of $1,240,000 for the 248 acres of land in the urban corridor to be used for local parks was included in the recommended natural resource protection plan element; and implementation of the corridor acquisition recommendations would reduce the need for local park land. Acquisition of the primary environmental corridors lying within urban areas of the watershed above Milwaukee County, as proposed earlier in this chapter, would provide all of the land needed for three-fourths of the required additional local park land development in that portion of the watershed. The acquisition cost of $846,000 for this land was included in the recommended natural resource protection plan element. The estimated cost of developing all local park sites in the watershed is $6,690,000.

The total outdoor recreation land proposed to be acquired and developed under the first alternative plan element is 2,012 acres, or about 19 percent of the 10,840 acres of land required to meet the total recreation demand which can be expected to be exerted on the watershed by 1990 from both resident and non-resident and in-Region and out-of-Region populations (see Table 9). It is assumed under this alternative that the demand not met through public action will be met through private recreational development. If such private development is not forthcoming, the excess demand will either result in overcrowding and overuse of the available public park and recreation areas and in the deterioration and destruction of the recreation-related resource base or will require that limitations be placed on the use of the available public park lands.

Intermediate Alternative Outdoor Recreation Plan Element

As noted earlier in this section, the three alternative outdoor recreation and related open-space plan elements prepared for the Milwaukee River watershed are cumulative in nature. Thus, the second alternative plan includes all of the elements of the first alternative plan (see Table 9). In addition, the second alternative plan element proposes public acquisition and development of an additional 18 high-value potential park sites within the watershed (see Map 4 and Table 10). These 18 sites are primarily located near, or adjacent to, bodies of water. Four of the sites are located in Ozaukee County, one in the City of Mequon, one in the Town of Grafton, and two in the Town of Fredonia. Seven of the sites are located in Wash-

Table 9

EXISTING AND PROPOSED LOCAL AND REGIONAL PARKS IN THE MILWAUKEE RIVER WATERSHED BY COUNTY--1967 AND 1990 ALTERNATIVE OUTDOOR RECREATION PLAN ELEMENTS[a]

COUNTY	LOCAL PARKS					
	EXISTING (1967)		PLANNED INCREMENT		TOTAL (1990)	
	ACRES	PERCENT OF WATERSHED	ACRES	PERCENT CHANGE	ACRES	PERCENT OF WATERSHED
FOND DU LAC.....	16	0.9	1	6.3	17	0.6
MILWAUKEE.......	1,245	71.1	752	60.4	1,997	64.6
OZAUKEE.........	145	8.3	470	324.1	615	19.9
SHEBOYGAN.......	58	3.3	5	8.6	63	2.0
WASHINGTON......	288	16.4	110	38.2	398	12.9
TOTAL	1,752	100.0	1,338	76.4	3,090	100.0

COUNTY	REGIONAL PARKS					
	EXISTING (1967)		PLANNED INCREMENT		TOTAL (1990)	
	ACRES	PERCENT OF WATERSHED	ACRES	PERCENT CHANGE	ACRES	PERCENT OF WATERSHED
FOND DU LAC.....	955	49.7	--	--	955	36.8
MILWAUKEE.......	673	35.0	--	--	673	25.9
OZAUKEE.........	293	15.3	324	110.5	617	23.8
SHEBOYGAN.......	--	--	--	--	--	--
WASHINGTON......	--	--	350	--	350	13.5
TOTAL	1,921	100.0	674	35.0	2,595	100.0

COUNTY	TOTAL					
	EXISTING (1967)		PLANNED INCREMENT		TOTAL (1990)	
	ACRES	PERCENT OF WATERSHED	ACRES	PERCENT OF WATERSHED	ACRES	PERCENT OF WATERSHED
FOND DU LAC.....	971	26.4	1	0.1	972	17.1
MILWAUKEE.......	1,918	52.2	752	39.2	2,670	47.0
OZAUKEE.........	438	11.9	794	181.2	1,232	21.7
SHEBOYGAN.......	58	1.7	5	8.6	63	1.1
WASHINGTON......	288	7.8	460	159.7	748	13.1
TOTAL	3,673	100.0	2,012	54.8	5,685	100.0

[a] THE PLANNED INCREMENT IN LOCAL AND REGIONAL PARKS SET FORTH IN THIS TABLE IS INCLUDED IN THE MINIMUM, INTERMEDIATE, AND OPTIMUM ALTERNATIVE OUTDOOR RECREATION AND RELATED OPEN-SPACE PLAN ELEMENTS AS DESCRIBED IN THIS CHAPTER.

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND SEWRPC.

Table 10

PROPOSED ADDITIONAL PARKS AT SELECTED POTENTIAL HIGH-VALUE PARK SITES IN THE MILWAUKEE RIVER WATERSHED BY COUNTY--1990 INTERMEDIATE ALTERNATIVE OUTDOOR RECREATION PLAN ELEMENT

COUNTY	ADDITIONAL PARKS		
	NUMBER	ACRES	PERCENT OF TOTAL ACRES
FOND DU LAC....	3	435	9.8
MILWAUKEE......	--	--	--
OZAUKEE........	4	1,162	26.1
SHEBOYGAN......	4	831	18.7
WASHINGTON.....	7	2,021	45.4
TOTAL	18	4,449	100.0

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND SEWRPC.

ington County, including one in the Town of Polk, one in the Town of Trenton, three in the Town of West Bend, one in the Town of Barton, and one in the Town of Kewaskum. Three of the sites are located in Fond du Lac County, including one in the Town of Eden and two in the Town of Auburn. Four of the sites are located in Sheboygan County, including two in the Town of Sherman, one in the Town of Lyndon, and one in the Town of Scott. Public development of such sites would provide a greater recognition of the need to meet through public action the increasing demand for water-based outdoor recreational activities. The total amount of land proposed to be acquired for these 18 high-value sites is 4,449 acres. Of this total, 3,560 acres, or 80 percent, lying within the environmental corridors would be acquired at an estimated cost of $2,917,900 for public use under the recommended natural resource protection plan element. The cost of acquiring the remaining 889 acres is estimated at $444,500. The estimated cost of developing the entire 4,449 acres is $4,449,000.

The total outdoor recreation land proposed to be acquired under the second alternative plan element is 6,461 acres, or 59 percent of the 10,842 acres of land required to meet fully the forecast recreation demand. Like the first alternative, the second alternative assumes that the demand not met through public action will be met through private recreation development.

Optimum Alternative Outdoor Recreation Plan Element

The third alternative outdoor recreation and related open-space plan element prepared for the Milwaukee River watershed included all of the elements proposed in the first two alternative plan elements. In addition, the third alternative plan element proposes public acquisition in the development of an additional 22 high-value potential park sites within the watershed (see Map 4 and Table 11). Eight of these additional high-value sites are located in Ozaukee County, including two in the City of Mequon, one in the Town of Grafton, three in the Town of Cedarburg, one in the Town of Saukville, and one in the Town of Fredonia. Six of these additional high-value sites are proposed in Washington County, including two in the Town of Trenton, two in the Town of Polk, one in the Town of West Bend, and one in the Town of Farmington. Two of the proposed additional high-value sites are located in Fond du Lac County, including one in the Town of Auburn and one in the Town of Osceola. The remaining six sites are proposed to be located in Sheboygan County, including three in the Town of Scott and three in the Town of Sherman. The total amount of land proposed to be acquired for these 22 sites is 4,423 acres. Of this total, 3,092 acres, or 70 percent, lying within the environmental corridors would be acquired at an estimated cost of $3,763,100 for public use under the recommended natural resource protection plan element. The cost of acquiring the remaining 1,331 acres is estimated at $665,500. The estimated cost of developing the entire 4,423 acres is $4,423,000.

Total outdoor recreation lands proposed to be acquired under the third alternative plan element are 10,884 acres. Thus, the third alternative plan would meet and, indeed, slightly exceed the 10,840 acres of land needed to meet the forecast recreational demand. Of the required 10,840 acres, 3,213 acres, or 30 percent, are estimated to be needed to meet the forecast recreational demand generated by out-of-state residents.

Concluding Remarks—Alternative Outdoor Recreation and Related Open-Space Plan Elements

The three alternative outdoor recreation development plan elements meet, to varying degrees, through public acquisition and development, the forecast 1990 land use demand for recreation land for major outdoor recreational activities. The first alternative considered would meet about 19 percent of the total recreation land use demand through public acquisition and development. The second alternative would meet about 59 percent of the total recreation land use demand through public acquisition and development. The third alternative would meet the entire anticipated recreation land use demand through public acquisition and development. The forecast demand includes expected use of the watershed recreation-related

Table 11

PROPOSED ADDITIONAL PARKS AT SELECTED POTENTIAL HIGH-VALUE PARK SITES IN THE MILWAUKEE RIVER WATERSHED BY COUNTY--1990 OPTIMUM ALTERNATIVE OUTDOOR RECREATION PLAN ELEMENT

COUNTY	ADDITIONAL PARKS		
	NUMBER	ACRES	PERCENT OF TOTAL ACRES
FOND DU LAC....	2	160	3.6
MILWAUKEE......	--	--	--
OZAUKEE........	8	1,696	38.3
SHEBOYGAN......	6	842	19.0
WASHINGTON.....	6	1,725	39.1
TOTAL	22	4,423	100.0

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND SEWRPC.

resource base by watershed residents; by residents in the remainder of the Southeastern Wisconsin Region; and by residents outside the Region, including residents of the populous northeastern Illinois metropolitan region and residents of those counties bordering the Milwaukee River watershed on the north and the west. The relative effectiveness of the three alternative outdoor recreation plan elements in meeting the watershed development objectives and standards relating to park and recreation lands is summarized in Table 12.

It is not anticipated that the forecast 1990 recreational demand will be lessened to any significant degree by any failure to provide the necessary outdoor recreation land within the watershed. Instead, such failure would result in overcrowding and overuse of the facilities provided, in serious conflicts between user demands, and either in the deterioration and destruction of the recreation-related natural resources where the outdoor recreation areas are located and upon which they depend for their value or will require that limitations be placed on the use of the available public park lands. It is, therefore, recommended that the third, or optimum, alternative outdoor recreation and related open-space plan element, as described above, be included as an integral part of the comprehensive Milwaukee River watershed plan. This plan element would provide an additional 10,884 acres of public outdoor recreation land in the watershed and would fully meet the forecast recreational demand. Of the total of 10,884 acres of additional outdoor recreation land recommended to be acquired, 7,997 acres, or about 73 percent, would be acquired at an estimated cost of $9,975,900 under the recommended natural resource protection plan element. An additional 335 acres would be acquired at no cost through dedication during subdivision development. The cost of acquiring the remaining 2,200 acres is estimated at $1,110,000. The estimated cost of developing the entire 10,884 acres is $16,573,000.

In making this recommendation, it is fully recognized that private recreational development has been and will continue to play an important role in meeting outdoor recreation demands within the watershed. The future extent of such private outdoor recreation development cannot, however, be reliably forecast. It is known that, at the present time, about 13 percent of the developed recreation land in the watershed devoted to the five major outdoor recreational activities upon which the 1990 forecast demand for outdoor recreation land is based is in private ownership and operation. This level of private activity may continue in the future. To the extent that it does, it will reduce the need to publicly acquire and develop the needed land. Thus, in a very real sense, the recommended outdoor recreation plan element is conservative in nature because implementation of the recommended plan, eventually through public acquisition programs, but initially through land reservation by sound zoning and official mapping measures, will ensure that the best remaining outdoor recreation sites within

Table 12

COMPARISON OF THE RELATIVE ABILITY OF THE ALTERNATIVE OUTDOOR RECREATION PLAN ELEMENTS TO MEET ADOPTED DEVELOPMENT STANDARDS

OBJECTIVE	MINIMUM ALTERNATIVE OUTDOOR RECREATION PLAN ELEMENT	INTERMEDIATE ALTERNATIVE OUTDOOR RECREATION PLAN ELEMENT	OPTIMUM ALTERNATIVE OUTDOOR RECREATION PLAN ELEMENT
PARK AND RECREATION-RELATED STANDARDS[a]			
PARK AND RECREATION LAND ALLOCATION			
A. LOCAL--1.00 ACRE/100 ADDED POPULATION......	1.25 ACRES/100[b]	1.25 ACRES/100[b]	1.25 ACRES/100[b]
B. REGIONAL--0.40 ACRE/100 ADDED POPULATION...	0.63 ACRE/100[c]	0.63 ACRE/100[c]	0.63 ACRE/100[c]
C. SWIMMING--0.45 ACRE/100 PARTICIPANTS.......	PARTIALLY MET[d]	COULD BE MET[e]	MET
D. PICNICKING--12.50 ACRES/100 PARTICIPANTS...	PARTIALLY MET[d]	COULD BE MET[e]	MET
E. GOLFING--32.79 ACRES/100 PARTICIPANTS......	PARTIALLY MET[d]	PARTIALLY MET[d]	MET
F. CAMPING--133.33 ACRES/100 PARTICIPANTS.....	PARTIALLY MET[d]	PARTIALLY MET[d]	MET
G. SKIING--3.70 ACRES/100 PARTICIPANTS........	MET ON EXISTING ACRES[f]	MET ON EXISTING ACRES[f]	MET ON EXISTING ACRES[f]

[a]THE INDICATED STANDARDS ARE SET FORTH IN FULL IN CHAPTER II OF THIS VOLUME.

[b]ADDITIONAL LOCAL AREAS ASSIGNED TO MAKE UP DEFICIT BETWEEN EXISTING LOCAL PARK ACRES AND EXISTING POPULATION.

[c]ADDITIONAL REGIONAL ACRES ASSIGNED BECAUSE OF MILWAUKEE RIVER WATERSHED'S HIGH PROPORTION OF THE REGION'S PRIME REGIONAL RECREATION SITES.

[d]ACTIVITY NEEDS WOULD BE PARTIALLY MET BY LOCAL AND REGIONAL DETAILED PARK DEVELOPMENT.

[e]ACTIVITY NEEDS COULD BE MET BY PLAN DESIGN WHICH FOCUSES ON WATER-ORIENTED PARK SITES, DETAILED DESIGN OF THESE PARK SITES COULD PROVIDE THESE ACTIVITIES.

[f]SKIING DEMAND CURRENTLY BEING MET BY EXISTING COMMERCIALLY OPERATED SKI AREAS.

SOURCE- SEWRPC.

the watershed are preserved for recreational development, whether ultimately that development is accomplished through public or private investment.

It is important to note that, if the Waubeka multipurpose reservoir alternative flood control plan element, as presented in Chapter IV of this volume, is included in the recommended comprehensive plan for the Milwaukee River watershed, it would affect the intermediate and optimum, but not the minimum, outdoor recreation and open-space plan elements described in this chapter. Construction of the Waubeka Reservoir would, by providing opportunities for the development of multi-purpose outdoor recreation sites on the reservoir shoreline, in effect create new high-value potential park and related open-space sites within the watershed. With respect to the intermediate outdoor recreation plan alternative, it is expected that 6 of the 18 high-value outdoor recreation sites, totaling 1,240 acres, designated for development would be eliminated in favor of fewer, but better and larger, alternative sites along the Waubeka Reservoir shoreline, thus reducing the total cost of acquiring the high-value outdoor recreation sites by $620,000. Similarly, construction of the Waubeka Reservoir would affect the third alternative outdoor recreation and open-space plan element by eliminating the need to construct 6 of the 22 recommended selected additional park sites, totaling 866 acres, in favor of better alternate development on, or adjacent to, the Waubeka Reservoir shoreline, thus reducing the total cost of acquiring the additional park sites by $433,000. Map 5 indicates the locations where such outdoor recreation development could be suitably accommodated along the shoreline of the Waubeka Reservoir (see also Appendix D).

ALTERNATIVE PARKWAY AND SCENIC DRIVE PLAN ELEMENTS

As noted in Chapter XIV, Volume 1, of this report, pleasure driving constitutes the most popular outdoor recreational activity in the Milwaukee River watershed, with a forecast 1990 total participant demand on an average seasonal Sunday of about 124,000 persons, an increase of about 68 percent over the estimated current (1967) total of 74,000 participants. It is important, therefore, to consider parkway and scenic drives as an integral part of the recreation and recreation-related elements of the comprehensive watershed plan for the Milwaukee River watershed.

It is important in this respect to distinguish between a parkway pleasure drive and a scenic pleasure drive. A parkway pleasure drive is defined for the purposes of this report as a non-arterial roadway usually established in an elongated area of publicly owned park land along lakeshore, stream valley, or ridge lines and intended to provide scenic continuity by linking major outdoor recreation areas within a total park and recreation system, while at the same time preserving in open-space uses lands, such as natural floodplains, which should not be developed for intensive urban uses.[5] Milwaukee County has one of the best and most extensive parkway systems in the United States, a system that includes a parkway pleasure drive along the Milwaukee River from E. Capitol Drive in the Village of Shorewood to Green Tree Road in the City of Glendale. It is also important to note the distinction being made in this report between a "parkway pleasure drive," and a "parkway." A parkway pleasure drive is an actual roadway intended to carry traffic through a linear parkway. Thus, the term "parkway" is defined in this report as the linear strip of park and open-space land through which parkway pleasure drives may be located. Parkways should, by design, seek to encompass all of the primary environmental corridor lands within urban areas but do not always have to include parkway pleasure drives in order to meet the intended objective.

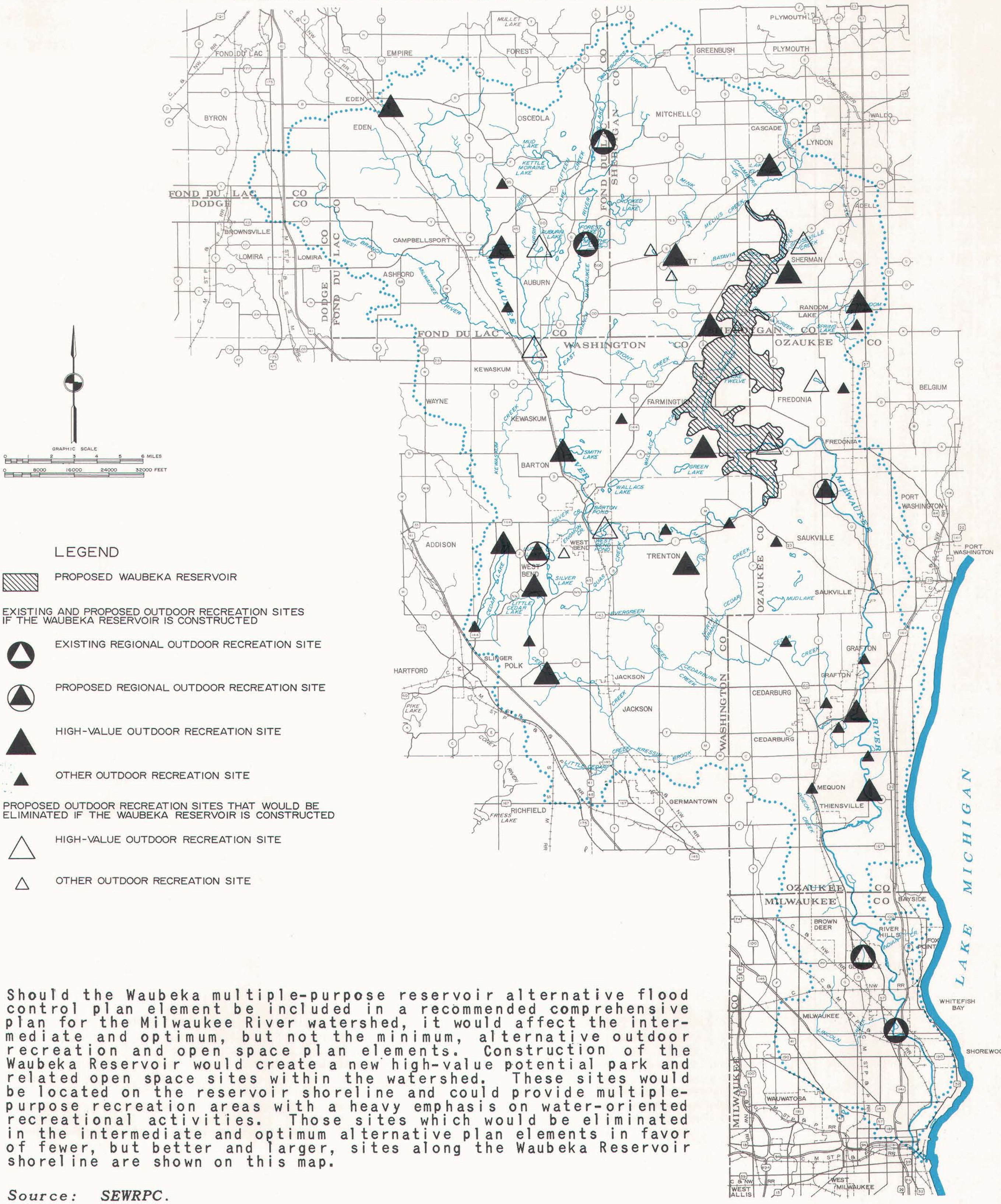
While parkway pleasure drives, as defined above, are certainly scenic, the term "scenic pleasure drive" is, for the purpose of this report, reserved

---

[5] *It should be noted that the definition of a parkway pleasure drive, as used in this report, is quite different than the more common definition of a parkway drive as a special-purpose arterial highway limited to noncommercial traffic with full or partial control of access located within a park or ribbon-like area of a park. Lincoln Memorial Drive within the Milwaukee area is an example of an arterial parkway, while Estabrook Park Drive is an example of a parkway pleasure drive as these two terms are defined and used herein. One of the primary purposes of both the parkway pleasure drive, as defined in this report, and the parkway drive, as more commonly defined, is to preserve and protect the natural resource base by preserving native ground cover, woodland and wetland areas, and such features as historic sites and scenic overlooks. Both can serve to provide open green space within a city, preserve and protect watercourses and lake shorelines for public use, provide rights-of-way for trunk sewers and water mains, and serve to enhance abutting property values. Both may also provide locations for certain kinds of recreational facilities, such as bridle paths and bicycle and hiking trails.*

Map 5

IMPACT OF THE WAUBEKA RESERVOIR ON THE OUTDOOR RECREATION SITES AS PROPOSED IN THE 1990 ALTERNATIVE OUTDOOR RECREATION PLAN ELEMENTS



Should the Waubeka multiple-purpose reservoir alternative flood control plan element be included in a recommended comprehensive plan for the Milwaukee River watershed, it would affect the intermediate and optimum, but not the minimum, alternative outdoor recreation and open space plan elements. Construction of the Waubeka Reservoir would create a new high-value potential park and related open space sites within the watershed. These sites would be located on the reservoir shoreline and could provide multiple-purpose recreation areas with a heavy emphasis on water-oriented recreational activities. Those sites which would be eliminated in the intermediate and optimum alternative plan elements in favor of fewer, but better and larger, sites along the Waubeka Reservoir shoreline are shown on this map.

Source: SEWRPC.

for marked routes over existing roadways that traverse aesthetically pleasing geographical areas, including areas of topographic, vegetative, and geological interest, as well as areas that contain clusters of significant cultural and historic sites. An example of a marked scenic drive in the Milwaukee River watershed is the state-established Kettle Moraine Scenic Drive. In general, then, scenic drives are appropriately established in rural areas, while parkway drives are more appropriately established in urban areas.

Alternative Parkway Drive Plan Elements

Three alternative parkway pleasure drive plan elements were considered for the Milwaukee River watershed. Each alternative adds to the existing and committed Milwaukee River Parkway Drive in Milwaukee County from Capitol Drive through Estabrook Park north to Good Hope Road. These three alternatives are:

1. Construction of a Milwaukee River Parkway as an arterial highway facility from the Juneau Interchange of the Lake and Park Freeways to the proposed Bay Freeway-North-South Freeway Interchange, as recommended in the adopted regional transportation plan, and as a parkway pleasure drive from Lincoln Park north to Good Hope Road.

2. Construction of a parkway pleasure drive from Lincoln Memorial Drive near the McKinley Marina to Capitol Drive and Estabrook Park, thus providing for a continuous parkway pleasure drive along the Milwaukee River from Lincoln Memorial Drive to Good Hope Road.

3. Construction of a parkway pleasure drive along the Milwaukee River north of Good Hope Road, through the Village of River Hills and the City of Mequon, to the Village of Grafton which, when combined with the previous alternative, would provide for a continuous parkway pleasure drive from Lincoln Memorial Drive north to the Village of Grafton.

Each of these three alternatives is further described in the following discussion.

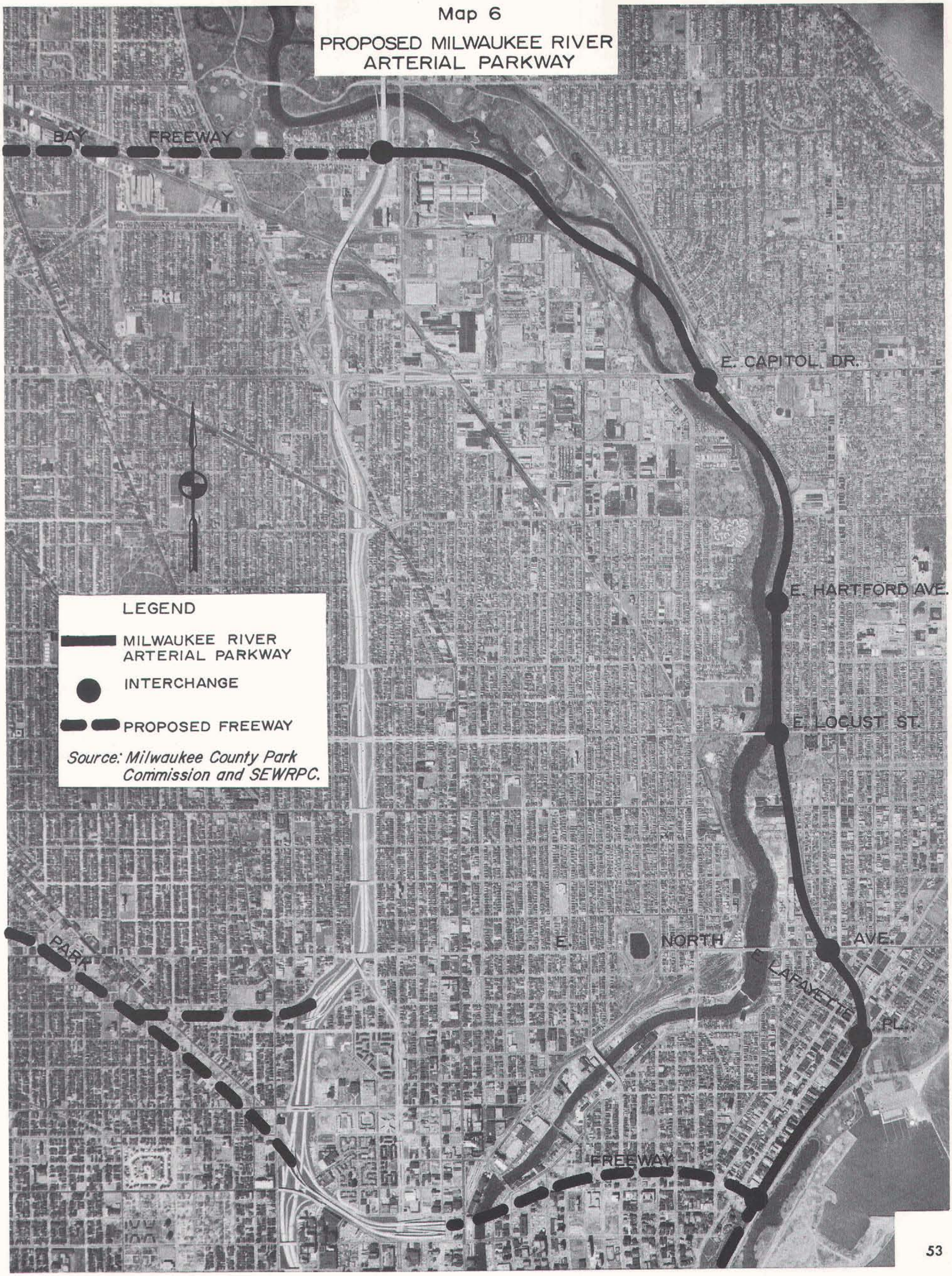
Milwaukee River Parkway Arterial (Regional Transportation Plan): The adopted regional transportation plan recommended that an arterial parkway facility be constructed in the Milwaukee River corridor from the Juneau Interchange of the Park and Lake Freeways to the Hampton Interchange of the Bay and North-South Freeways (see Map 6). This recommendation was made after careful study and evaluation of alternatives, which ranged from an attempt to meet the growing traffic demand in the major north-south traffic corridors through the Milwaukee area entirely on standard surface arterials to an attempt to meet such traffic demand in part by the provision of a Milwaukee River freeway facility located along the Milwaukee River from the Juneau Interchange to the Hampton Interchange.

The recommended arterial parkway along the Milwaukee River was envisioned as a four-lane divided facility constructed in a ribbon-like area of park development on a 130 foot right-of-way, carefully designed and fitted to the landscape along the Milwaukee River valley. Such a parkway was to be designed to provide operating speeds of 35 miles per hour and a capacity of about 40,000 vehicles per day, with both the recommended operating speed and capacity being substantially less than corresponding freeway speeds and capacities. The arterial parkway was included as a recommended facility in the adopted regional transportation plan in order to reduce the anticipated 1990 congestion on the existing North-South Freeway and, more importantly, on the local arterial street system in the northeasterly portion of Milwaukee County. The provision of such an arterial parkway was intended to strike a balance between the reduction of freeway and local street system traffic congestion and the disruptive effects of freeway construction on the Milwaukee River valley, greatly reducing the impact of a heavy traffic carrier on an important primary environmental corridor while providing direct access to an important potential recreational asset.

It was recommended in the adopted regional transportation plan that the proposed Milwaukee River Parkway be built and maintained by the Milwaukee County Park Commission, and no commercial traffic in the form of trucks was to be allowed to use the facility. It was proposed, however, to allow buses to use the proposed parkway facility during weekdays in order to provide a high level of transit service as an integral part of a regional rapid and modified rapid transit system to the University of Wisconsin-Milwaukee Campus and adjacent areas.

Map 6

PROPOSED MILWAUKEE RIVER ARTERIAL PARKWAY



The Milwaukee County Park Commission began almost immediately after adoption of the regional transportation plan to implement the proposed Milwaukee River Parkway plan element. Preliminary landscape, architectural, and engineering plans were prepared by a consultant retained for this purpose by the County Park Commission.[6] At subsequent public hearings on the preliminary parkway plans, however, adamant and vociferous opposition developed on the part of individual citizens and organized groups from within the neighborhoods bordering the proposed parkway who felt themselves adversely affected by the proposed facility. This opposition had not been expressed at any of the 11 public hearings previously held by the Regional Planning Commission prior to adoption of the regional transportation plan and is assumed to reflect changing community values and an apparent decision by those individuals living in the Milwaukee River corridor area to accept, in the alternative to the Milwaukee River Parkway, the effects of existing and anticipated future traffic congestion on the local street system. The Commission was, accordingly, notified by the Milwaukee County Park Commission that it was suspending all work on the arterial parkway proposal pending a reevaluation of the arterial parkway in conjunction with a reevaluation by the Regional Planning Commission of the proposed Bay Freeway, requested by the Milwaukee County Expressway and Transportation Commission. The Regional Planning Commission is currently undertaking such a reevaluation. Pending the final results of such an investigation, however, the Commission directed that the Milwaukee River Watershed Committee proceed with the development of a comprehensive watershed plan, considering at least two alternatives with respect to the Milwaukee River corridor; namely, the Milwaukee River Parkway as an arterial parkway and the Milwaukee River Parkway as a pleasure drive parkway facility.

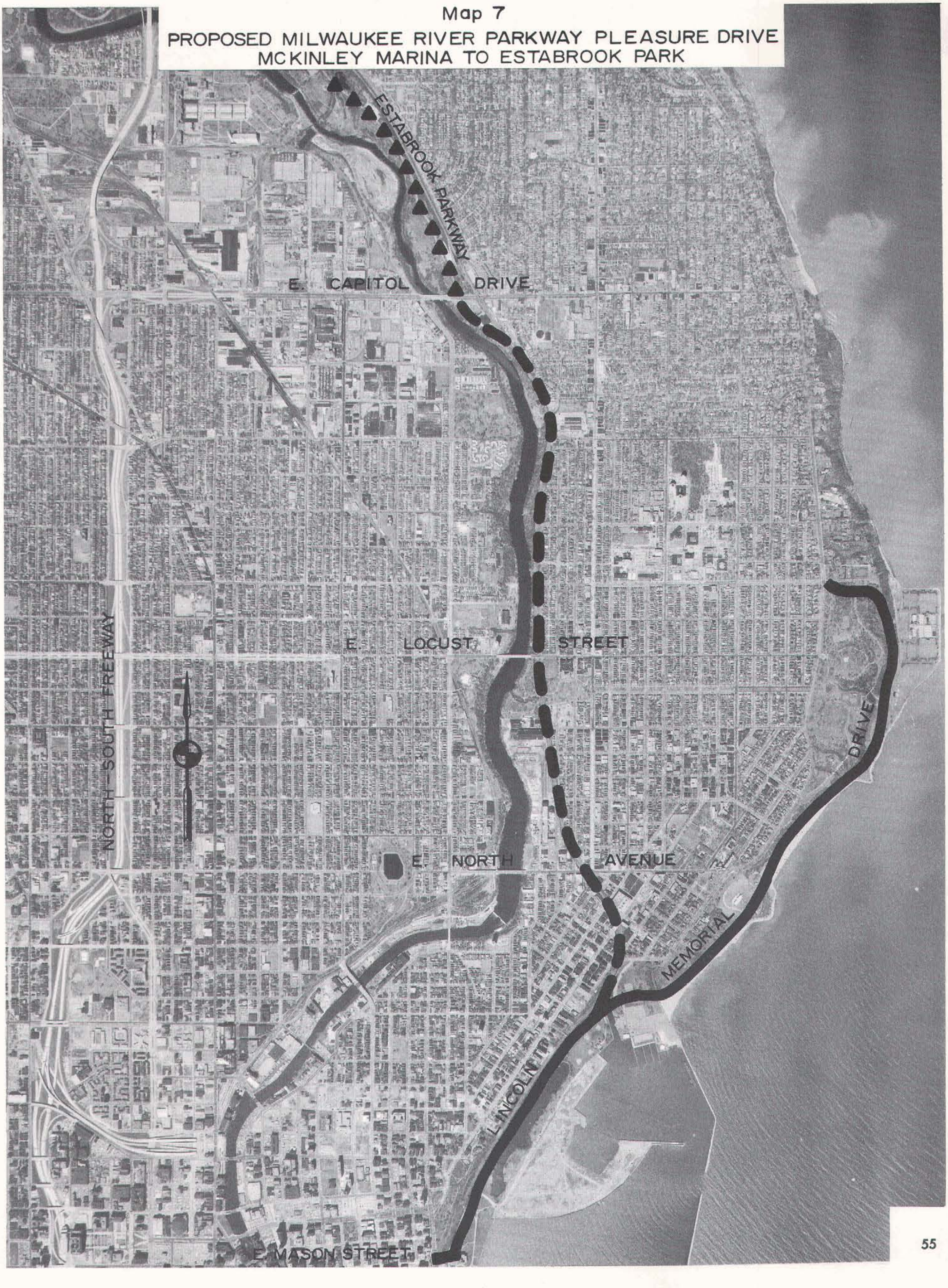
Milwaukee River Parkway Drive—Lincoln Memorial Drive to Good Hope Road: The second alternative parkway drive plan element considered is the construction of a parkway pleasure drive from Lincoln Memorial Drive near the McKinley Marina, to and along the Milwaukee River valley, joining the existing Estabrook Park Drive at its intersection with Capitol Drive in the Village of Shorewood (see Map 7). Such a parkway pleasure drive would not be a divided facility; would be designed for operating speeds of 25 miles per hour; and would not be intended to serve heavy volumes of through-trips, except for pleasure trips. It is proposed, however, that such a parkway pleasure drive be utilized as a route for buses to serve the University of Wisconsin-Milwaukee Campus area, thus preserving to a limited degree the service concept contained in the recommended regional rapid and modified rapid transit system. This parkway alternative would, when combined with existing and committed parkway drives, provide for a continuous pleasure drive from the mouth of the Milwaukee River along the Lake Michigan shoreline to a point near the McKinley Marina and along the Milwaukee River to Good Hope Road, a total distance of 8.6 miles. Total length of the proposed new parkway drive, not including already constructed segments, is about 2.4 miles. Estimated construction costs are $240,000 per mile, or a total of $576,000.

Milwaukee River Parkway Drive—Good Hope Road to Grafton: The third alternative parkway drive plan element considered is the construction of a continuous parkway pleasure drive along the Milwaukee River from its present terminus near Good Hope Road in the City of Glendale north to the Village of Grafton (see Map 8). This alternative plan element, when combined with the existing Milwaukee River Parkway, the existing Estabrook Park Drive, and the parkway pleasure drive facility described in the preceding alternative, would provide a continuous parkway pleasure drive from the Lake Michigan shoreline along the Milwaukee River to the Village of Grafton, a total distance of 22.2 miles. In some cases existing connecting streets would be utilized because the already intensive development along the shoreline of the river precludes full parkway development. The proposed route would follow Good Hope, Green Bay, and Range Line Roads for a distance of 2.1 miles to a point just north of the Milwaukee River, where a new parkway pleasure drive facility would begin. This section of new parkway pleasure drive would continue through the Village of River Hills to the Milwaukee-Ozaukee County line, a distance of 1.7 miles, of which 0.2 mile would be routed over existing Upper River Road. From there the parkway pleasure drive would be routed over River Road for a distance of 3.0 miles, to a point just south of the Milwau-

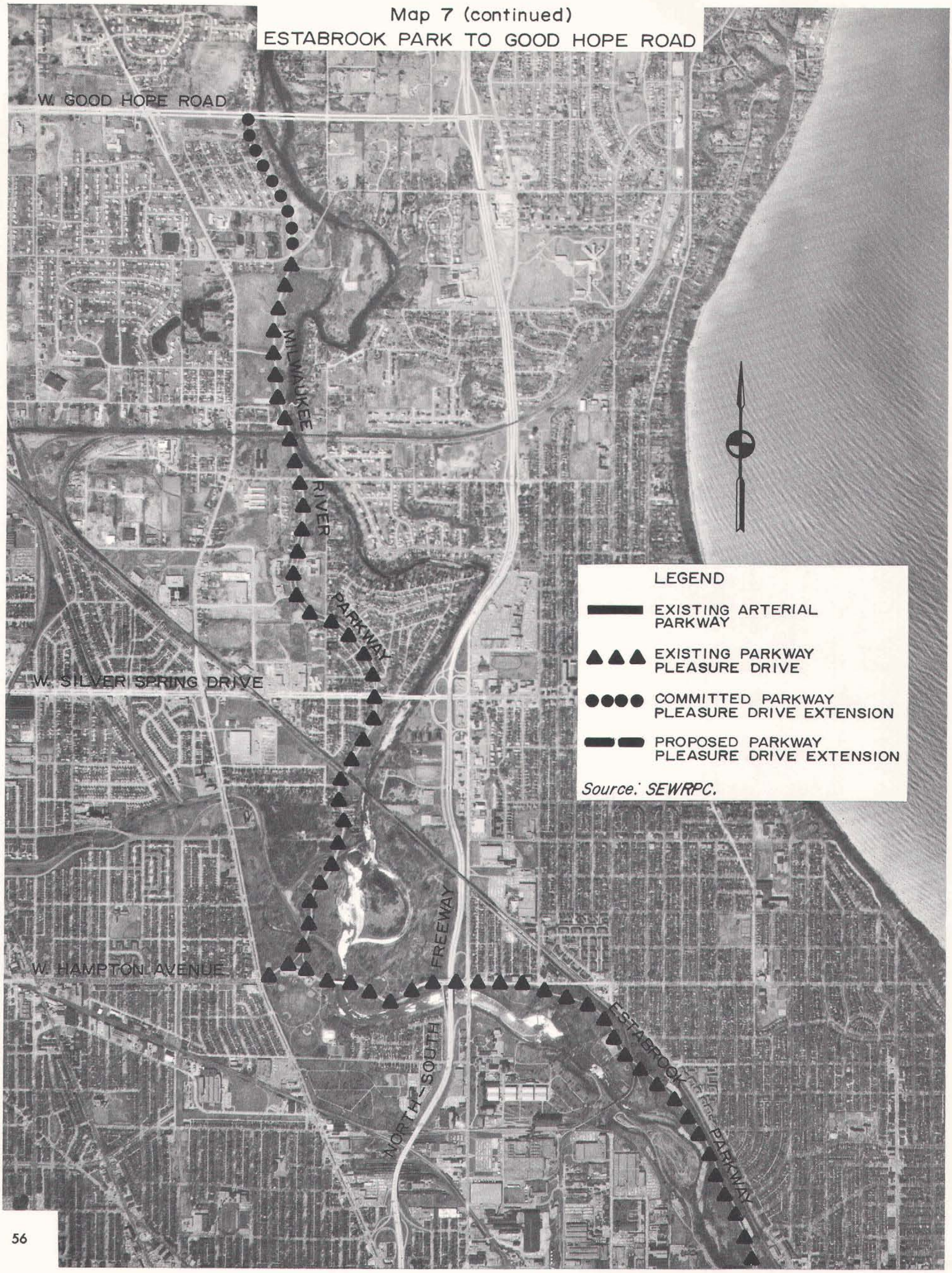
[6] *Preliminary Design Report, Milwaukee River Parkway, Milwaukee County, Wisconsin, (Draft), Vollmer Associates, New York, New York, May 1969.*

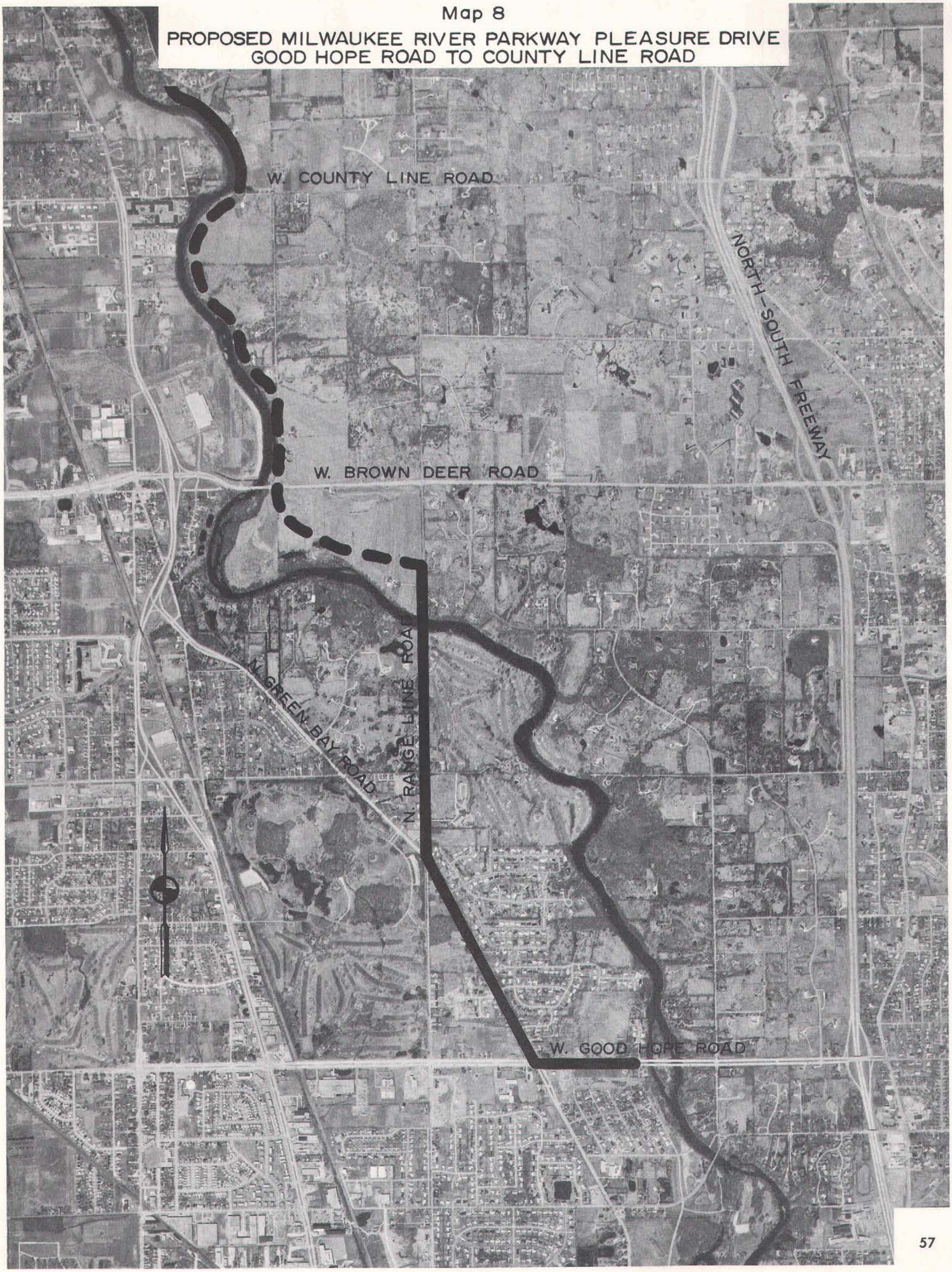
Map 7

PROPOSED MILWAUKEE RIVER PARKWAY PLEASURE DRIVE
MCKINLEY MARINA TO ESTABROOK PARK

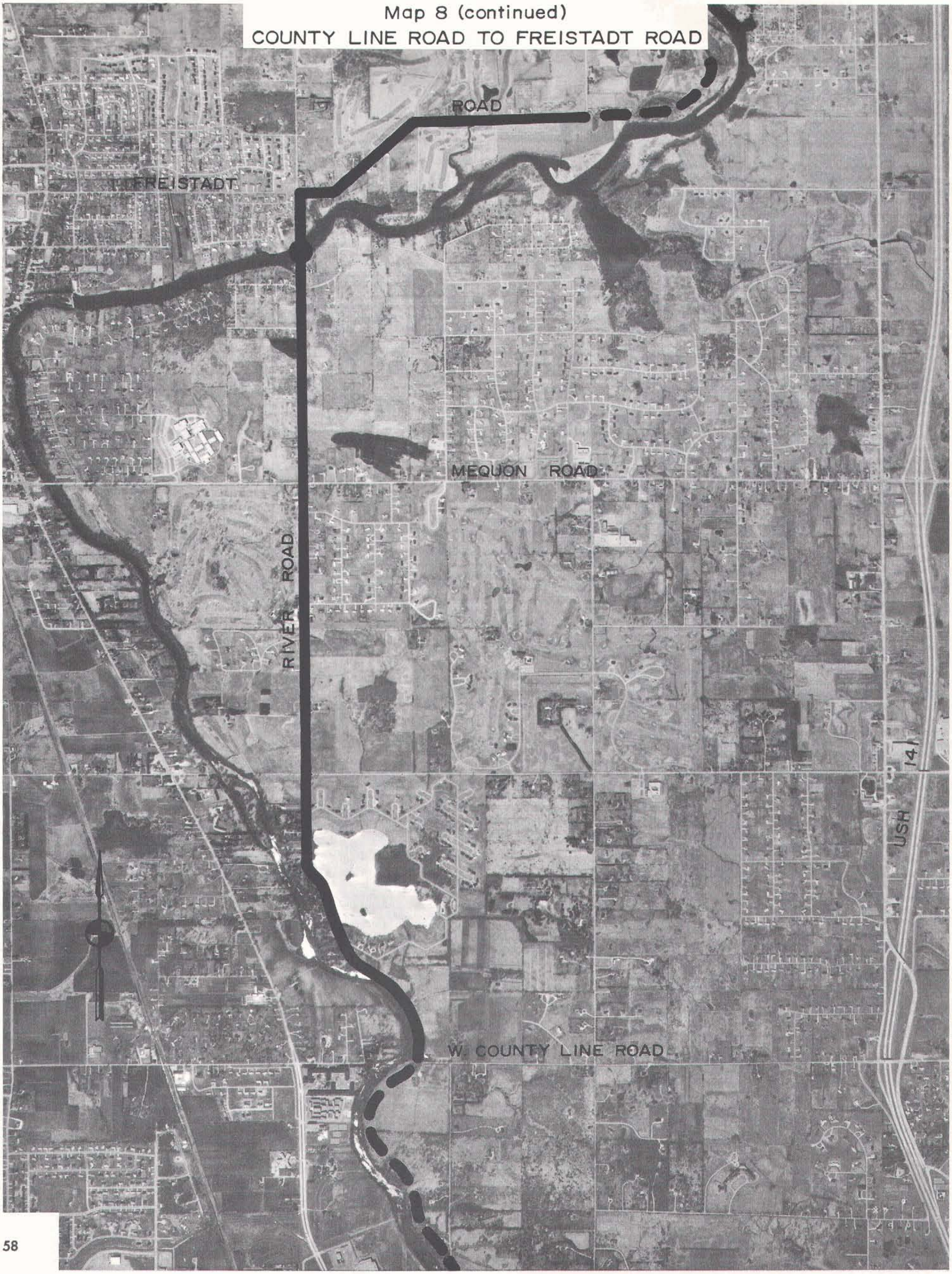


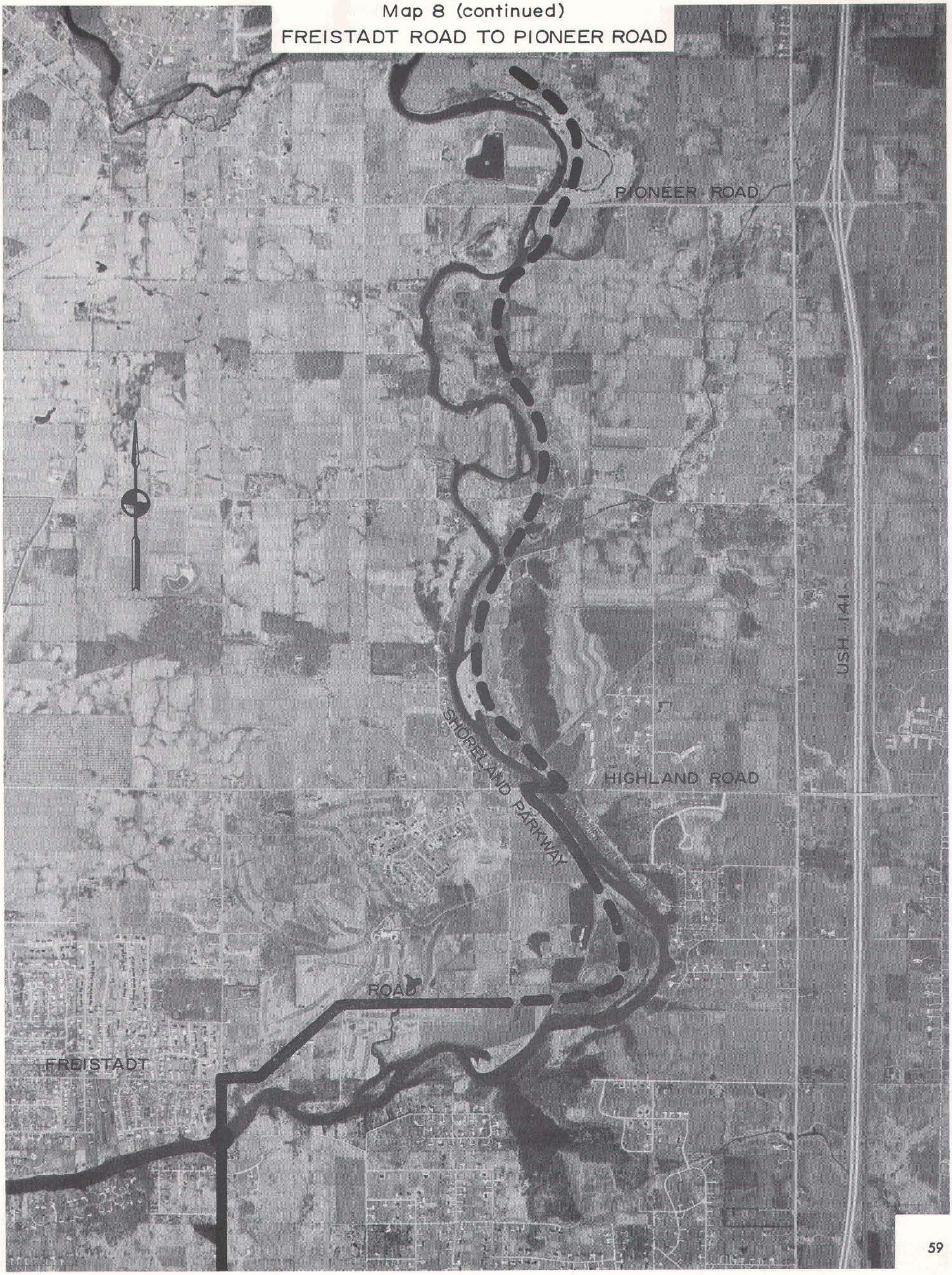
Map 7 (continued)
ESTABROOK PARK TO GOOD HOPE ROAD





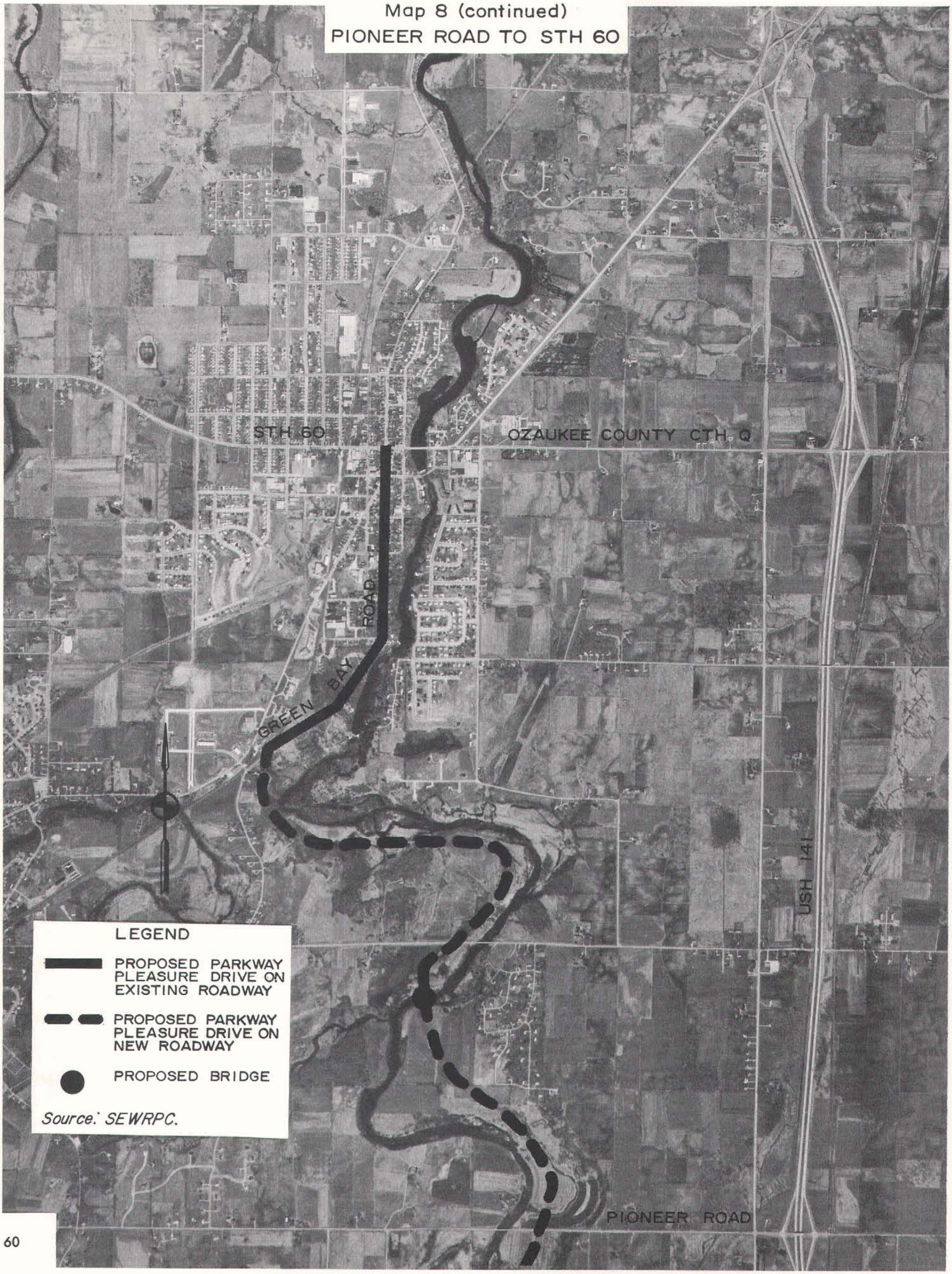
Map 8
PROPOSED MILWAUKEE RIVER PARKWAY PLEASURE DRIVE
GOOD HOPE ROAD TO COUNTY LINE ROAD
W. COUNTY LINE ROAD
NORTH-SOUTH FREEWAY
W. BROWN DEER ROAD
N. GREEN BAY ROAD
N. RANGE LINE ROAD
W. GOOD HOPE ROAD


Map 8 (continued)
COUNTY LINE ROAD TO FREISTADT ROAD
ROAD
FREISTADT
MEQUON ROAD
RIVER ROAD
USH 141
W. COUNTY LINE ROAD


Map 8 (continued)
FREISTADT ROAD TO PIONEER ROAD
PIONEER ROAD
USH 141
SHORELAND PARKWAY
HIGHLAND ROAD
ROAD
FREISTADT

Map 8 (continued)

PIONEER ROAD TO STH 60



kee River, crossing the River on a new structure. From this point the parkway pleasure drive would join Freistadt Road for a distance of about 1.2 miles, at which point a new parkway facility would begin again. A connection would be made with Shoreland Parkway and Highland Road, crossing the River on an existing structure. From this point a new facility would follow the Milwaukee River all the way into the Village of Grafton, crossing the river on a new structure in Section 36 of the Town of Cedarburg, where it would connect with local streets and terminate at STH 60. The total length of the Good Hope Road-to-Grafton segment of this alternative parkway is 14.9 miles, of which 7.0 miles would be entirely new parkway and 7.9 miles, connecting streets. The estimated construction cost of the new parkway drive is $240,000 per mile, or a total of $1,680,000. The estimated cost of constructing the two new bridges across the Milwaukee River is $550,000, resulting in a total cost for this alternative of $2,230,000. All land needed for construction of the new parkway pleasure drives would be acquired under the natural resource protection plan element.

Scenic Drive Plan Elements

In conjunction with the parkway pleasure drive plan elements just described, it is proposed that a system of scenic pleasure drives be established in the watershed (see Map 9). Such scenic pleasure drives, which would be appropriately signed and publicized, would begin at the terminus of the parkway pleasure drives either at Good Hope Road in the City of Glendale or at STH 60 in the Village of Grafton, depending on which alternative parkway drive plan element is included in the recommended comprehensive watershed plan. One major scenic drive, the Kettle Moraine Scenic Drive, already exists in the watershed for a distance of nearly 35 miles. It is proposed that the following additional scenic drives be established and linked to the Kettle Moraine Scenic Drive:

1. A primary Milwaukee River Scenic Drive, totaling about 59 miles, which would follow the Milwaukee River from Glendale north to Fredonia. From Fredonia, the drive would branch into two sections, one leading west to West Bend and the Paradise Valley area along the main stem of the Milwaukee River and joining the Kettle Moraine Scenic Drive just northwest of West Bend and the other following the North Branch of the Milwaukee River and Stony Creek, joining the Kettle Moraine Scenic Drive at New Fane. One short segment of new roadway would have to be constructed; namely, the northerly extension of W. Shoreland Road to Bonniwell Road in the City of Mequon, a distance of 0.3 mile.

2. A network of secondary Milwaukee River Scenic Drives, totaling nearly 94 miles, as shown on Map 9, including one along Cedar Creek from Grafton to Slinger, passing through the Jackson Marsh; one from Horns Corners to Newburg along the western boundary of the Cedarburg Bog; one from Fredonia along the North Branch of the Milwaukee River to Cascade; one from Cascade to the Kettle Moraine Scenic Drive, providing access to the Old Wade House state historic site located in the unincorporated Village of Greenbush outside the watershed; and one from Dundee through the Campbellsport drumlin area and joining another secondary drive from New Fane before leading to the Horicon Marsh Wildlife Preserve located outside the watershed.

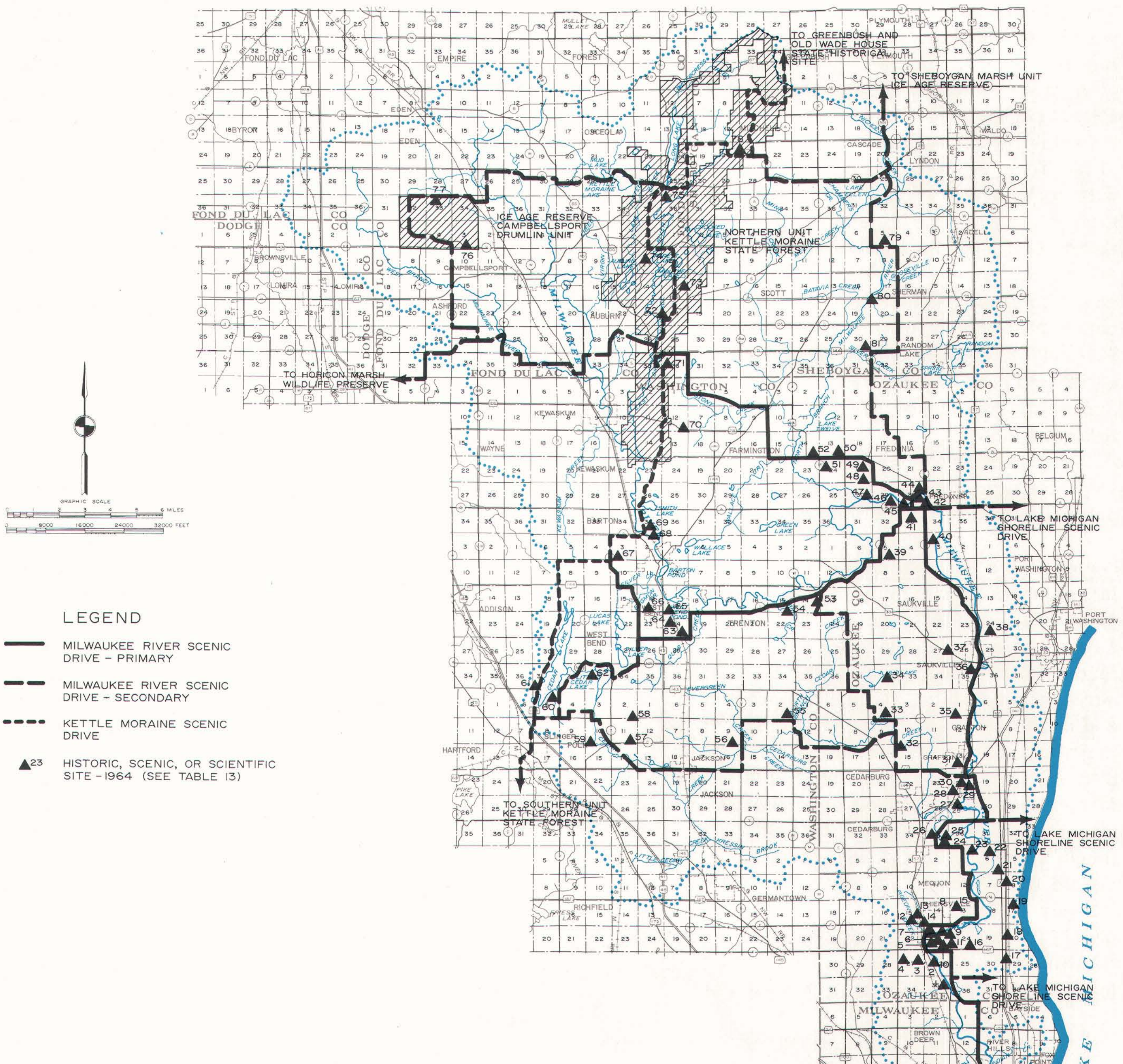
Areas or sites of historical and cultural significance, as well as sites of scenic and scientific interest, located adjacent to or near the proposed scenic drives would serve to enhance the pleasure driving and sightseeing activities. A total of 81 such sites lie on, or in proximity to, the proposed scenic drive system, as shown on Map 9 and as described in Table 13.

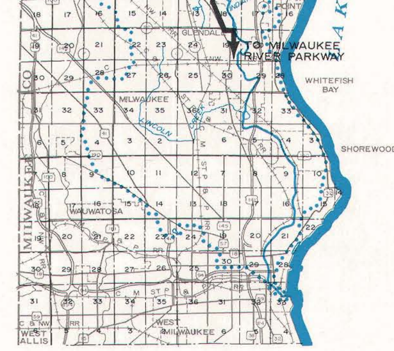
Concluding Remarks—Parkway and Scenic Drive Plan Elements

It is recommended that the following combination of parkway pleasure drives and scenic pleasure drives be included in the comprehensive plan for the Milwaukee River watershed: 1) a new parkway pleasure drive from Lincoln Memorial Drive near the McKinley Marina to and along the Milwaukee River valley to a junction with the existing Estabrook Park Drive at its intersection with Capitol Drive in the Village of Shorewood; 2) the existing Estabrook Park Drive and Milwaukee River Parkway northerly to its committed terminus at Good Hope Road; and 3) a system of primary and secondary Milwaukee River Scenic Drives, as shown on Map 9, beginning at the northerly terminus of the Milwaukee River Parkway in the City of Glendale and extending throughout the watershed, with connections to the existing and long-established Kettle Moraine Scenic Drive. The recommended

Map 9

PROPOSED SCENIC DRIVES IN THE MILWAUKEE RIVER WATERSHED 1990





A system of scenic pleasure drives should be established in the Milwaukee River watershed to assist in accommodating the anticipated increase in pleasure driving, the most popular outdoor recreational activity in the Milwaukee River watershed. The scenic pleasure drive system shown on this map would be appropriately signed and publicized and would supplement the existing and very popular Kettle Moraine Scenic Drive. The scenic drive system would pass near about 80 sites of historic, cultural, scenic, and scientific interest, thus serving to enhance the pleasure driving and sightseeing activities.

Source: SEWRPC.

Table 13

HISTORIC, SCENIC, AND SCIENTIFIC SITES IN PROXIMITY TO PROPOSED SCENIC DRIVES IN THE MILWAUKEE RIVER WATERSHED--1964

SITE NUMBER[a]	LOCATION			NAME OR DESCRIPTION	DATE
	TWN	RGE	SEC		
1	9	21	35	TRINITY EVANGELICAL LUTHERAN CHURCH	1853
2	9	21	26	BUTCHER SHOP AND ICEHOUSE	--
3	9	21	27	OPITY & ZIMMERMAN BREWERY	1857
4	9	21	27	LANDMARK TAVERN	1845
5	9	21	23	SEYFERTS DRUG STORE	1875
6	9	21	23	MILL DAM HEADGATES	1842
7	9	21	23	OLD SCHOOL	--
8	9	21	23	THEIRMANN HOUSE	1870
9	9	21	23	ZIMMERMAN STORE	--
10	9	21	23	STONE HOUSE	
11	9	21	23	JOHN WESTON HOME - 1ST SETTLER IN AREA	1837
12	9	21	15	INDIAN VILLAGE	--
13	9	21	15	INDIAN GRAVES	--
14	9	21	14	HENRY HAYSSEN HOUSE	1847
15	9	21	13	HOLSTEIN SCHOOL	--
16	9	21	24	CHURCH	1901
17	9	22	29	OCTAGONAL BARN	--
18	9	22	20	OCTAGONAL BARN	--
19	9	22	17	OCTAGONAL BARN	--
20	9	22	8	OCTAGONAL BARN	--
21	9	21	6	OCTAGONAL BARN	--
22	9	21	6	OCTAGONAL BARN	--
23	9	21	1	WOODWORTH FARM	--
24	10	21	35	TURNER HALL	C.1860
25	10	21	35	OLD MILL	--
26	10	21	35	HAMILTON-NEW DUBLIN IRISH SETTLEMENT	--
27	10	21	25	LIME KILNS ON MILWAUKEE RIVER	--
28	10	21	24	BLACKSMITH SHOP	--
29	10	21	24	GRAFTON WOOLEN MILLS	--
30	10	21	24	WOODS HOTEL	--
31	10	21	13	RAYMOND VAN LONGENS HOME	--
32	10	21	15	COVERED BRIDGE	--
33	10	21	4	OCTAGONAL SCHOOL	--
34	11	21	32	CEDARBURG BOG	--
35	10	21	1	RUINS OF UNION STEEPLE CATHOLIC CHURCH	--
36	11	21	35	SAUKVILLE SETTLEMENT	--
37	11	21	27	HWY 33-MILITARY ROAD	--
38	11	21	24	DAM AND SPILLWAY OF OLD MILL SITE	--
39	11	21	5	ST. FINBARS SETTLEMENT	--
40	11	21	3	LOG CABIN	--
41	12	21	33	CIGRAND BIRTHPLACE	--
42	12	21	28	CIGRAND MEMORIAL	--
43	12	21	28	MILL AND DAM	--
44	12	21	28	STONEY HILL SCHOOL	--
45	12	21	28	ROBERT COOLEY HOME	--
46	12	21	29	INDIAN VILLAGE SITE	--
47	12	21	30	INDIAN MOUNDS	--
48	12	21	19	HALF TIMBER HOUSE	--
49	12	21	19	LITTLE KOHLER	--
50	12	20	13	KESSIG HOTEL	1860
51	12	20	24	TURNER HALL	--
52	12	20	14	AURIG FARM-CAULDRON BAKE OVEN SMOKE HOUSE	--
53	11	20	14	LAND OWNED BY DANIEL WEBSTER	1838
54	11	20	15	HASHEK BARN	1860
55	10	20	2	OLD COUNTY HOME	1844
56	10	20	9	JACKSON MARSH	--
57	10	19	11	COACH STOP--HALFWAY POINT BETWEEN MILWAUKEE AND FOND DU LAC	1846
58	10	19	2	STAGE ROUTE	--
59	10	19	10	CEDAR CREEK POST OFFICE	1860
60	10	19	5	CEDAR LAKE YACHT CLUB	1884
61	10	19	31	CEDAR LAKE--ROSENHEIMER RECREATION AREA	1884
62	11	19	33	WOLFRUM--PRIVATE PICNIC GROUNDS	1850
63	11	19	24	LOG SHANTY--FIRST IN WEST BEND	1845
64	11	19	24	WEST SIDE SHOOTING PARK	1868
65	11	19	13	LITHIA COMPANY--WEST BEND EAGLE BREWERY	1850
66	11	19	14	COURT HOUSE SQUARE	1854
67	11	19	3	FIRST RURAL ELECTRIC POWER TRANSMISSION LINE IN WISCONSIN	1919
68	12	19	35	YOUNG AMERICA SETTLEMENT	1845
69	12	19	35	SALISBURY MILL	1845
70	12	19	12	ST. MICHAELS CHURCH	1848
71	13	19	36	COVERED BRIDGE	--
72	13	19	23	PIONEER CHURCH	--
73	13	19	13	LOCAL FESTIVAL CELEBRATION	--
74	13	19	11	LOCAL FESTIVAL CELEBRATION	--
75	14	19	25	OLD MILL	--
76	13	18	3	ICE AGE RESERVE CAMPBELLSPORT DRUMLIN UNIT-SCENIC OVERLOOK	--
77	14	18	33	ICE AGE RESERVE CAMPBELLSPORT DRUMLIN UNIT-SCENIC OVERLOOK	--
78	14	20	20	OLD CEMETERY	--
79	13	21	5	HISTORICAL MARKER	--
80	13	21	17	OLD MILL	--
81	13	21	30	OLD FORT	--

[a]SEE MAP 9.

SOURCE- SEWRPC.

system of parkway and scenic drives would provide the facilities necessary to meet the anticipated 1990 recreational activity demand for pleasure driving and sightseeing.

SUMMARY

The amount of land devoted to urban use within the Milwaukee River watershed is forecast to increase from the present (1967) total of about 102 square miles, or about 15 percent of the total area of the watershed, to about 133 square miles, or about 19 percent of the total area of the watershed, by 1990. It is extremely important that this new urban development be related sensibly to soil capabilities; to long-established utility systems; to the delineated floodlands of the Milwaukee River system; and to the wetland, woodland, and surface water resources of the watershed. If such new urban development is not so related, the already severe developmental and environmental problems of the watershed may be expected to continue to intensify.

The recommended land use plan element forms the basic element of the comprehensive watershed plan. With respect to that portion of the Milwaukee River watershed lying within the Southeastern Wisconsin Region, the watershed land use plan is set within the context of, and reflects the concepts and recommendations contained in, the adopted regional land use plan. With respect to that portion of the Milwaukee River watershed lying outside the Southeastern Wisconsin Region, the watershed land use plan is an entirely new plan element prepared under the Milwaukee River watershed study. As such, it represents both a conscious extension of the adopted regional land use plan and the concepts and development objectives underlying that plan to those areas of the Milwaukee River watershed adjacent to the Region and an integration of those concepts and development objectives with the concepts and development objectives expressed in planning work currently being conducted at the county level in Fond du Lac and Sheboygan Counties. The adopted regional and watershed development objectives and standards serve, in effect, to control the 1990 spatial distribution of land uses within the watershed in order to achieve a safer, more healthful, pleasant, and efficient land use pattern, while meeting the gross land use demand requirements set forth above. Thus, the land use plan element emphasizes efficient utility services, cohesive urban development on suitable soils, preservation of prime agricultural lands, preservation of unique resource areas, and protection of floodplain areas from urban encroachment.

Under the recommended watershed land use plan element, residential development would be channeled into low-, medium-, and high-density residential areas properly located with respect to the natural resource base elements and public utility service areas. In addition, prime agricultural lands, environmental corridor areas, and potential park sites would be protected from incompatible development. Specific regulations would govern the use of shorelands and floodlands. Existing land uses and structures not developed in conformance with these proposals would be considered nonconforming, and regulations would provide for their eventual discontinuance or removal. The attainment of a sound land use pattern throughout the watershed, as well as within the riverine areas, is thus made a basic objective of the comprehensive watershed plan.

In the adaptation, refinement, and detailing of the adopted regional land use plan for the Milwaukee River watershed, three alternative natural resource protection plan elements and three alternative outdoor recreation and related open-space plan elements were considered. The resource protection plan element recommended for incorporation into the comprehensive watershed plan is the third such alternative presented in this chapter. This alternative recommends the public acquisition for resource conservation, recreation, and related open-space purposes of all of the remaining undeveloped primary environmental corridors of the watershed lying within those areas of the watershed expected to be in urban use by 1990; of all of the remaining undeveloped environmental corridor lands along the main stem of the Milwaukee River; and of certain selected additional environmental corridor lands containing high-value woodlands and wetlands throughout the watershed.

This plan element would serve to permanently protect through public acquisition 7,269 acres of woodlands, or nearly 10 percent of the remaining woodlands of the watershed, covering about 2 percent of the total watershed area, and 22,603 acres of wetlands, or slightly over 31 percent of the remaining wetlands in the watershed, covering nearly 5 percent of the total watershed area. This plan element would also serve to permanently protect through public acquisition a total of 41,584 acres, or over 41 percent of the primary environmental corridors of the watershed, covering over 9 percent of the total watershed area, of which 9,847 acres would be within areas expected to be in urban use by 1990. The remaining primary environmental corridors of the watershed lying in areas expected to remain in rural use through 1990 would be protected through appropriate agricultural, shoreland, floodland, conservancy, and low-density residential zoning.

The outdoor recreation and related open-space plan alternative recommended for incorporation into the comprehensive Milwaukee River watershed development plan is the third alternative presented in this chapter. It recommends the acquisition of 10,884 acres of park and related open-space land for public use to fully meet the total 1990 forecast outdoor recreational demand within the watershed. Of this total, 7,329 acres, or about 67 percent, are located within primary environmental corridor areas proposed to be acquired for public use under the recommended natural resource protection plan element. Consequently, implementation of the natural resource protection plan element would serve to significantly implement the recommended outdoor recreation plan element. Encompassed within this total land area are 674 acres for the development of two new regional parks in the watershed and 1,338 acres for the development of neighborhood and community parks as urban development proceeds within the watershed.

Under the recommended outdoor recreation and related open-space plan, the total recreational user demand in the watershed would be met and damaging overuse of the facilities and the concomitant damaging effect on the resource base thereby avoided. Not only would the residents of the Region and the watershed be provided with sufficient recreation areas to meet their day-to-day needs, but such needs would be met without extensive conflict between the recreation users within the watershed.

Three alternative parkway drive plan elements were considered in the preparation of the comprehensive plan for the Milwaukee River watershed. These three alternative parkway drive elements include the construction of a Milwaukee River Parkway as an arterial highway facility, as recommended in the adopted regional transportation plan; the construction of a nonarterial parkway pleasure drive along the Milwaukee River from Lincoln Memorial Drive to the existing Estabrook Park Drive; and the construction of a nonarterial parkway pleasure drive along the Milwaukee River north of Good Hope Road to the Village of Grafton.

In addition to these three alternative parkway drive plan elements, a system of primary and secondary scenic pleasure drives was proposed which, when combined with the parkway drive plan elements, would provide the facilities necessary to meet the anticipated 1990 recreational activity demand for pleasure driving and sightseeing.

The system of parkway and scenic pleasure drives recommended to be included in the comprehensive plan for the Milwaukee River watershed consists of a new parkway pleasure drive from Lincoln Memorial Drive near the McKinley Marina to and along the Milwaukee River valley to a junction with the existing Estabrook Park Drive; the existing Estabrook Park Drive and Milwaukee River Parkway northerly to its committed terminus at Good Hope Road; and a system of primary and secondary Milwaukee River scenic drives beginning at the northerly terminus of the Milwaukee River Parkway in the City of Glendale and extending to points throughout the watershed. This system of parkway and scenic pleasure drives will provide the continuity necessary to accommodate anticipated 1990 demand for pleasure driving as an outdoor recreational activity in the Milwaukee River watershed.

(This page intentionally left blank)

Chapter IV

ALTERNATIVE FLOOD CONTROL PLAN ELEMENTS

INTRODUCTION

As urban development within the Milwaukee River watershed continues, the problems and monetary losses associated with flooding can, in the absence of a sound flood-damage control program, be expected to increase. Because of the relatively large amount of lake, wetland, and floodplain storage area still present in the watershed, the Milwaukee River system, as it exists today, does not generate the very high peak flood flows that have occurred on the river systems of other watersheds in Wisconsin. Although major flood peaks generated in the Milwaukee River watershed by spring snowmelt are not expected to increase in size, the continued loss of wetland and floodplain storage, which can be expected to accompany continued development of riverine areas within the watershed, and the increased runoff potential resulting from areawide urban development may be expected to combine to increase both the size of, and the damage produced by, summer rainfall floods. Because urbanization increases both the volume and the rate of storm water, because floodplain storage is so vital in reducing flood peaks, and because sound land use development in relation to the riverine areas of the watershed is so essential to the prevention of flood damage, the basic flood control element in any comprehensive plan for the watershed must consist of proposals for sound land use development, not only in the riverine areas, but in the watershed as a whole. Such land use proposals are set forth for the Milwaukee River watershed in Chapter III of this volume.

This chapter describes the structural and nonstructural flood control plan elements that were considered in the Milwaukee River watershed study as possible adjuncts to the basic land use development proposals advanced to facilitate the attainment of regional and watershed development objectives. These flood control plan elements are considered subordinate to the basin-wide land use plan elements, and their incremental benefits and costs can be separated from those of the basin-wide land use plan element. All of the flood control plan elements can be incorporated into any of the land use plan alternatives considered, although some are unnecessary with certain land use plan alternatives.

Three basic types of structural flood control measures—*reservoir construction*, *levee construction* and *channel improvement*, and *diversion of floodwaters to Lake Michigan*—were considered. These three basic types of structural measures were used to develop six distinct alternative structural flood control plan elements. Analysis indicated that four of these structural alternative plan elements could provide both urban and agricultural flood-damage reduction along relatively long channel reaches of the stream system. A description of each of the six alternative structural plan elements is presented in this chapter, along with a discussion of the anticipated performance, an evaluation of the attendant costs and benefits, and an evaluation of the effect of the proposal on watershed development objectives and standards. The multiple-use potential of each reservoir alternative is identified, with particular emphasis placed upon streamflow augmentation, water-oriented recreation, improvement of fish and wildlife habitat, and municipal and industrial water supply functions, in addition to the function of flood control.

One predominantly nonstructural flood-damage control plan element was considered—that of *floodland structure removal and structure floodproofing*—and is described herein, together with the attendant benefits and costs. Removal of flood-damage-prone urban development would provide land that could be used for public park and related open-space purposes; and to this extent, this nonstructural flood control alternative would be of a multiple-purpose nature.

Finally, certain accessory flood control plan elements are discussed, including the provision of adequate bridge waterway openings and the enactment of floodland regulations to assure intelligent use of riverine areas. Accessory plan elements are not intended, either individually or in combinations, to offer a viable means of significantly reducing flood losses in existing high damage reaches of the stream system. They are, however, designed to be effective as supplements to one of the seven aforementioned major structural or nonstructural flood control plan elements in high damage reaches and, most importantly, to avoid the continued intrusion of flood-damage-prone land use development into floodland areas, with the attendant increase over time of potential flood damages. Thus, complete watershed-wide flood damage control, particularly in the as yet undeveloped riverine areas of the watershed, requires judicious application of the accessory plan elements, with emphasis on floodland regulation.

In calculating the benefits associated with each alternative flood control measure, it was assumed that existing land use development trends within the watershed would continue. The benefits attendant to each alternative were then calculated as the reduction of flood damages associated with application of the structure or measure to the resulting land use pattern within the watershed. Implementation of the recommended watershed land use plan could be expected to reduce these calculated benefits somewhat. Any such reduction would be slight, however, since the major flood control benefits in the watershed are derived from the protection of existing floodland development.

The quantitative hydrologic and hydraulic analyses necessary to evaluate the effectiveness of each alternative structural plan element involved the preparation of a forecast of the amount of water to be carried by the existing and proposed water control facilities. This forecast was based upon the assumption that the adopted regional land use plan would be implemented. Departures from the adopted regional land use plan could be expected to increase the hydraulic loadings on the water control facilities only to the extent that such departures encroach on existing floodways or eliminate existing floodplain storage.

REVIEW OF PREVIOUS FLOOD CONTROL INVESTIGATIONS

A careful review of previous studies related to flood control within the Milwaukee River watershed was made as a part of the Milwaukee River watershed study. This review indicated that work had been accomplished by seven governmental agencies, acting individually or cooperatively: the Federal Works Progress Administration; U. S. Department of Agriculture, Soil Conservation Service; U. S. Department of the Army, Corps of Engineers; U. S. Department of Health, Education, and Welfare, Public Health Service; U. S. Department of the Interior, Bureau of Outdoor Recreation; the Wisconsin Public Service Commission; and the Wisconsin State Planning Board.

Federal Works Progress Administration and Wisconsin Public Service Commission—1938

Records on file with the Wisconsin Public Service Commission indicate that in 1938 the Federal Works Progress Administration and the Wisconsin Public Service Commission undertook a joint investigation of topographic and foundation conditions at two reservoir sites within the watershed: the Waubeka reservoir site on the Milwaukee River and the Horns Corners reservoir site on Cedar Creek. Topographic maps at a scale of 1:4800 with a five-foot contour interval were prepared for the dam sites and reservoir areas. Eighteen test holes were bored in alluvium to depths of about 15 feet at one of three alternate axes at the Horns Corners site. One hundred fifty holes were bored to rock through loam, clay, sand, and gravel at the Waubeka site. Depths of the bores ranged from one to 17 feet. Four geologic sections were prepared for the river valley at the proposed Waubeka site. Although the topographic maps and data on the borings and geologic sections were still on file with the Wisconsin Public Service Commission, it was not possible to locate a report describing or interpreting the results of these investigations.

Wisconsin State Planning Board—1940

A report entitled The Milwaukee River Basin was published by the Wisconsin State Planning Board in 1940. This report set forth the findings and recommendations of a study initiated in 1935. Flood control was the sole purpose of the potential structures described and discussed in the report. The possibility of constructing a diversion channel and tunnel near Thiensville for bypassing floodwater to Lake Michigan was considered, along with reservoir sites identified near Horns Corners on Cedar Creek and near Waubeka on the Milwaukee River. The Waubeka site has been considered in most subsequent studies; and both the Waubeka and Horns Corners sites were further investigated in the Milwaukee River watershed study, along with the diversion channel and tunnel near Thiensville.

U. S. Soil Conservation Service—1961

The Soil Conservation Service of the U. S. Department of Agriculture prepared a report in 1961 entitled Report for Flood Control in the Milwaukee River Watershed. The report describes the findings and recommendations of a reconnaissance survey of potential reservoir sites located in the basin upstream from Saukville. Although nine potential sites were identified and investigated in this study, none were found to warrant further consideration for flood control purposes.

U. S. Army Corps of Engineers—1964

A Survey Report for Flood Control on the Milwaukee River and Tributaries, Wisconsin was prepared by the Chicago District of the U. S. Army Corps of Engineers in 1964. The report describes the results of investigations of the Waubeka and Horns Corners reservoir sites and of a diversion channel located near Saukville as possible alternative flood control projects. Recreation, pumped-storage hydroelectric power development, and low-flow augmentation, as multiple-purpose functions of the Waubeka site, were given consideration in this study. A diversion channel at Saukville which would provide protection against floods having an average recurrence interval of 100 years was credited with a benefit-cost ratio of 1.09, whereas the maximum benefit-cost ratio assigned to the reservoirs considered was 0.7. It was concluded that a single-purpose diversion channel would be the only alternative that could be constructed at a cost ($5,350,000) commensurate with the anticipated benefits. Updated analyses of the economics of constructing both the diversion channel and the Waubeka Reservoir are presented in this chapter, wherein, under the different assumptions used by the Regional Planning Commission particularly with respect to interest rates and periods of amortization, but also with respect to uses of the reservoir, the benefit-cost ratio of the diversion channel is estimated to be 0.28, and of the reservoir, 1.35.

U. S. Public Health Service—1965

In 1965 reservoir storage requirements for water quality control through low-flow augmentation and for municipal water supply were investigated by the U. S. Department of Health, Education, and Welfare, Public Health Service, for the Waubeka site. Studies for water quality control were limited to the main stem of the Milwaukee River below Waubeka in Ozaukee County. For water supply purposes, the study area was limited to those areas of the watershed lying within 10 miles of the proposed dam site. The report, entitled Water Supply and Water Quality Control Study, Waubeka Reservoir, Milwaukee River Basin, Wisconsin, issued by the U. S. Public Health Service, concludes that reservoir storage is not required for these purposes within the study area.

U. S. Bureau of Outdoor Recreation—1966

A special reconnaissance report on outdoor recreational needs in the Milwaukee River watershed as related to the proposed Waubeka reservoir site was prepared by the U. S. Department of the Interior, Bureau of Outdoor Recreation, in 1966. It was concluded in the report that there is sufficient demand for water-based recreation in the Region to warrant consideration of the Waubeka site for a reservoir with a conservation pool level at approximately Elevation 825 feet, Mean Sea Level Datum. Annual visitation for recreation was estimated to be 1.2 million people within the first one-to-five years after project construction. It was estimated that more than 3 million annual visitations would occur after 35 years if the reservoir were to be fully developed for recreation purposes.

Net benefit values of $1.35 per visitation (recreation day) were assigned in accordance with the range set forth in Supplement 1 (June 4, 1964) of Senate Document 97, 87th Congress.[1] The initial annual recreation benefit was estimated as $1,620,000 and the ultimate annual benefit, as $4,050,000. It was estimated that capital costs for recreation facilities would be $4,137,000 and $9,510,000 respectively, for initial and ultimate conditions of development.

Other Sources

A review of historic newspaper articles and other published information was also made, and members of several private organizations devoted to community betterment were interviewed to determine plans that may have been considered locally for the solution of watershed problems. During 1967 members of the Milwaukee River Restoration Council proposed to that Council that consideration be given to the construction of an earthfill dam on the Milwaukee River near CTH C less than one mile downstream of the mouth of Cedar Creek for purposes of flood control and silt removal. A dam on the Milwaukee River in the Hawthorne Hills County Park north of Saukville was also proposed by this group for recreational and aesthetic purposes.[2] In 1970 Mr. Fred W. Uihlein, a prominent private citizen of the Village of River Hills, proposed the construction of a dam on the Milwaukee River in the vicinity of Good Hope Road for pollution abatement purposes.

---

[1] *It is stated in this document that, "The unit values per recreation day set forth herein are intended to measure the amount that the users should be willing to pay, if such payment were required, to avail themselves of the project recreation resource."*

[2] *The Milwaukee Sentinel, July 31, 1976, and Prospectus--Milwaukee River, The Milwaukee River Restoration Council, Inc., 1967.*

ALTERNATIVE STRUCTURAL FLOOD CONTROL PLAN ELEMENTS

As noted in the introductory section of this chapter, three types of structural flood control measures or facilities were considered and evaluated under the watershed study. Dams and reservoirs could be located at several sites within the watershed and would be effective in reducing large watershed-wide floods. Such reservoirs would be multiple-purpose developments in that they would also provide recreation, low-flow augmentation, and water supply benefits. A diversion channel designed to eliminate essentially all flood damages on the Lower Milwaukee River by carrying floodwaters from the river across the watershed divide to Lake Michigan was also evaluated. Finally, combination dike-floodwall facilities were evaluated for those reaches of the watershed having major concentrations of flood-vulnerable urban development.

Reservoirs

Although several governmental agencies at both state and federal levels have, in the past, completed studies related to flood control reservoirs in the Milwaukee River watershed, there has been no prior comprehensive investigation of all potential reservoir sites. Under the Milwaukee River watershed study, 19 potential reservoir locations, including five sites not located directly on any of the 11 principal river reaches defined for the purpose of the watershed study, were systematically identified and screened to determine their potential to provide flood protection, water-based recreation, augmentation of low streamflow, and municipal and industrial water supply. The screening process was carried out to identify, in a preliminary manner, the relative potential of all of the sites; and, based upon this screening process, three reservoir sites plus one reservoir alternative, consisting of a combination of two of the individual sites, were selected for further consideration in the study. These four reservoir alternatives having the most desirable characteristics for multiple-purpose development were then investigated in greater depth and detail; preliminary layout plans were prepared; hydrologic and hydraulic analyses were made; and benefit-cost ratios were calculated.

The screening evaluations were based on several factors related primarily to potential uses of the reservoirs and to the physical and hydrologic characteristics of the dam sites and tributary drainage areas. Evaluation of recreational potential of the reservoir sites was emphasized in the screening because, as noted in the foregoing discussion, earlier studies made by the U. S. Army Corps of Engineers, the U. S. Public Health Service, and the U. S. Bureau of Outdoor Recreation indicated that the major economic benefit of any sizable reservoir within the watershed would accrue from recreational use, while any such reservoir devoted solely to flood control or to flood control and electric power generation would have benefit-cost ratios of considerably less than one; and no significant benefits would accrue from low-flow augmentation or water supply uses.

The public popularity of water-oriented recreational pursuits, as well as the desirability of providing the means and facilities for such activities, particularly in southeastern Wisconsin, has been established. The Wisconsin Department of Natural Resources, in a recent study of state recreation resources and needs, emphasizes the key role of water in leisure-time activity by stating:

> ...The six primary recreational activities in Wisconsin, in terms of numbers of visits, are all either directly or indirectly related to water: Pleasure driving, swimming, sight-seeing, boating, fishing and picnicking.[3]

The report singles out southeastern Wisconsin[4] as the area with the greatest current shortage of outdoor recreational areas and facilities and the greatest amount of conflicting land use, with the latter factor resulting in the "... usurping of potential recreation sites faster than in any other planning area...."[5] Although the need to consider the water-oriented recreational benefits of any potential reservoir site was recognized, the need to weigh these water-oriented recreational benefits against the potential loss of existing natural resources, such as wetlands, woodlands, and scenic topography, and associated land-based recreation benefits was also recognized and carefully considered.

---

[3] *Wisconsin Department of Natural Resources, Wisconsin's Outdoor Recreation Plan, p. C-18, 1968.*

[4] *The Wisconsin Department of Natural Resources defined southeastern Wisconsin, for the purpose of the recreation study, as the seven-county region served by the SEWRPC plus Columbia, Dane, Dodge, Jefferson, and Rock Counties.*

[5] *Wisconsin Department of Natural Resources, op. cit., p. B-12.*

Preliminary Identification of Reservoir Sites: As previously noted, a total of 19 potential reservoir sites were considered during the initial screening process utilized in the flood control portion of the watershed study. Of this total, 12 had been identified in the previous studies summarized above. Seven additional new reservoir sites were identified through careful study of available topographic maps. All but one of the newly identified sites are located on the main stem of the Milwaukee River. Map 10 shows the location of all of the potential reservoir sites that were considered in the initial screening process. Reservoir site locations are described by river mile station and by U. S. Public Land Survey section, township, and range in Table 14, which table also presents, in summary form, certain other pertinent information about each of the potential sites.

A potential site for an impounding structure, as described and discussed herein, may include more than one axis; that is, alignment of the centerline of the dam across the stream channel. If topographic and foundation conditions were found to be favorable for the construction of a dam at several closely spaced locations along a reach of a stream, these locations were considered in the initial screening process as one reservoir site with alternate dam axes. A final selection of a recommended dam axis was made only for the three best reservoir sites identified in the screening process during the course of the subsequent feasibility and design studies of those three sites plus one reservoir alternative combining two of the individual sites.

The preliminary examination of each potential reservoir site was initiated by an evaluation of topographic and structural factors; and, in the absence of prohibitive limitations, this was followed by an assessment of the multiple-purpose potential of the site by a systematic examination of its recreation, flood control, low-flow augmentation, and water supply capabilities. The subsequent discussion describes the criteria used to identify and evaluate the 19 reservoir sites in the initial screening process.

Topographic and Structural Considerations: Land surface contours, as depicted on topographic maps, were used to delineate the absolute longitudinal and lateral extent of each potential reservoir site. The approximate dam site was then selected; and the aforementioned maximum inundation limits were modified, as necessary, so as to preclude major structural or foundation problems with respect to the dam and also to avoid excessive land acquisition costs and extensive relocation of existing highways, railroads, utilities, and other structures with respect to the impoundment.

Recreational Evaluation: The recreational development potential of a given reservoir site was determined by evaluating that site with respect to five characteristics: proximity to urban population concentrations and suitability for four prime recreational uses, namely, boating and water skiing, picnicking and sightseeing, swimming, and fishing. Each site was rated within each category according to the following scale: 4 for excellent, 3 for good, 2 for fair, 1 for poor, and 0 for no value. Potential reservoir locations receiving a high total rating, as obtained by summing the numerical ratings for each of the five characteristics, exhibit superior recreation potential in comparison with the other sites considered. The results of this evaluation are summarized in Table 15 and are discussed below in order to identify the principal factors that were considered in the assignment of a numerical rating.

Proximity to Urban Population

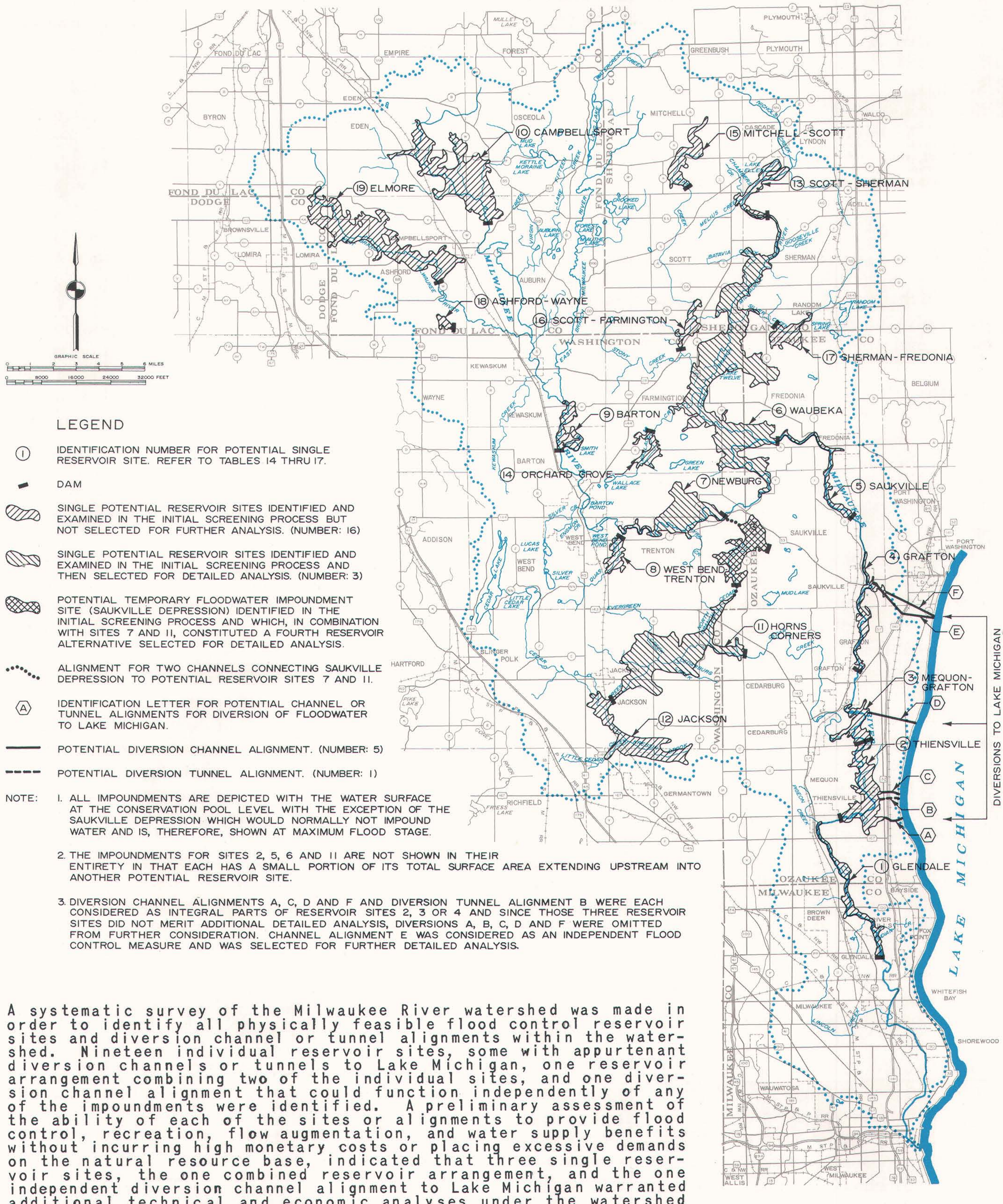
The relative recreational value of a reservoir will not only depend upon the potential recreational uses which can be made of the site but also upon the relative accessibility of the site to potential users. This relative accessibility was evaluated on the basis of the distance to the Milwaukee urbanized area and on the quality of the highway access and the driving time from the Milwaukee urbanized area. In considering access, distance is not as important a factor as is driving time. A higher value was assigned for those sites nearest to good arterial highway routes, existing or planned, which connect directly to the regional freeway system.

Boating and Water Skiing

For motorboating and water skiing activities, the water surface area and average depth of a reservoir should have minimum values of 300 acres and 5 feet, respectively. Water skiing alone requires about 20 acres of water surface per participant, while the combination of sailing, power-boating, water skiing, and fishing demands an average of 5 to 10 acres of water surface for each boat. The reservoir should be wide enough to per-

Map 10

POTENTIAL RESERVOIR SITES AND DIVERSION CHANNEL AND TUNNEL ALIGNMENTS IN THE MILWAUKEE RIVER WATERSHED



LEGEND

(1) IDENTIFICATION NUMBER FOR POTENTIAL SINGLE RESERVOIR SITE. REFER TO TABLES 14 THRU 17.

DAM

SINGLE POTENTIAL RESERVOIR SITES IDENTIFIED AND EXAMINED IN THE INITIAL SCREENING PROCESS BUT NOT SELECTED FOR FURTHER ANALYSIS. (NUMBER: 16)

SINGLE POTENTIAL RESERVOIR SITES IDENTIFIED AND EXAMINED IN THE INITIAL SCREENING PROCESS AND THEN SELECTED FOR DETAILED ANALYSIS. (NUMBER: 3)

POTENTIAL TEMPORARY FLOODWATER IMPOUNDMENT SITE (SAUKVILLE DEPRESSION) IDENTIFIED IN THE INITIAL SCREENING PROCESS AND WHICH, IN COMBINATION WITH SITES 7 AND 11, CONSTITUTED A FOURTH RESERVOIR ALTERNATIVE SELECTED FOR DETAILED ANALYSIS.

ALIGNMENT FOR TWO CHANNELS CONNECTING SAUKVILLE DEPRESSION TO POTENTIAL RESERVOIR SITES 7 AND 11.

(A) IDENTIFICATION LETTER FOR POTENTIAL CHANNEL OR TUNNEL ALIGNMENTS FOR DIVERSION OF FLOODWATER TO LAKE MICHIGAN.

POTENTIAL DIVERSION CHANNEL ALIGNMENT. (NUMBER: 5)

POTENTIAL DIVERSION TUNNEL ALIGNMENT. (NUMBER: 1)

NOTE:

1. ALL IMPOUNDMENTS ARE DEPICTED WITH THE WATER SURFACE AT THE CONSERVATION POOL LEVEL WITH THE EXCEPTION OF THE SAUKVILLE DEPRESSION WHICH WOULD NORMALLY NOT IMPOUND WATER AND IS, THEREFORE, SHOWN AT MAXIMUM FLOOD STAGE.
2. THE IMPOUNDMENTS FOR SITES 2, 5, 6 AND 11 ARE NOT SHOWN IN THEIR ENTIRETY IN THAT EACH HAS A SMALL PORTION OF ITS TOTAL SURFACE AREA EXTENDING UPSTREAM INTO ANOTHER POTENTIAL RESERVOIR SITE.
3. DIVERSION CHANNEL ALIGNMENTS A, C, D AND F AND DIVERSION TUNNEL ALIGNMENT B WERE EACH CONSIDERED AS INTEGRAL PARTS OF RESERVOIR SITES 2, 3 OR 4 AND SINCE THOSE THREE RESERVOIR SITES DID NOT MERIT ADDITIONAL DETAILED ANALYSIS, DIVERSIONS A, B, C, D AND F WERE OMITTED FROM FURTHER CONSIDERATION. CHANNEL ALIGNMENT E WAS CONSIDERED AS AN INDEPENDENT FLOOD CONTROL MEASURE AND WAS SELECTED FOR FURTHER DETAILED ANALYSIS.

A systematic survey of the Milwaukee River watershed was made in order to identify all physically feasible flood control reservoir sites and diversion channel or tunnel alignments within the watershed. Nineteen individual reservoir sites, some with appurtenant diversion channels or tunnels to Lake Michigan, one reservoir arrangement combining two of the individual sites, and one diversion channel alignment that could function independently of any of the impoundments were identified. A preliminary assessment of the ability of each of the sites or alignments to provide flood control, recreation, flow augmentation, and water supply benefits without incurring high monetary costs or placing excessive demands on the natural resource base, indicated that three single reservoir sites, the one combined reservoir arrangement, and the one independent diversion channel alignment to Lake Michigan warranted additional technical and economic analyses under the watershed study for possible inclusion in a final watershed plan.

Source: Harza Engineering Company and SEWRPC.

Table 14

SUMMARY OF INITIAL EVALUATION OF POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED

Dam Location								Impoundment				Dam			Ratings[e]			
River Reach	Name	Number	River Mile Station	Section	Town	Range	Area Tributary to Dam[a] (Acres)	Conservation Pool Level[b] (Feet)	Surface Area[c] (Acres)	Shore Length[c] (Miles)	Storage Volume[c] (Acre-Feet)	Height of Crest Above Streambed (Feet)	Crest Length (Feet)	Spillway Discharge Capacity[d] (CFS)	Recreation	Flood Control	Water Supply and Flow Augmentation	Potential as a Multiple-Purpose Project
Lower Milwaukee River	Glendale	1	11.5	19	8	22	412,500	650	800	20	7,000	28	1,100	55,500	11	0	1	NO
	Thiensville	2	20.5	24	9	21	391,000	670	2,080	23	18,300	30	1,700	54,400	15	3	2	YES
	Mequon-Grafton	3	26.3	31	10	22	377,000	700	700	12	10,000	45	3,600	52,000	13	3	1	NO
	Grafton	4	31.4	13	10	21	291,000	750	700	20	7,000	26	1,100	50,000	11	3	1	NO
	Saukville	5	40.3	14	11	21	275,000	785	700	17	12,000	39	1,100	49,000	11	0	1	NO
	Waubeka	6	47.0	29	12	21	260,000	825	10,400	50	155,000	57	1,200	50,000	17	3	4	YES
Middle Milwaukee River	Newburg	7	55.6	13	11	20	163,000	865	2,300	17	16,000	40	850	38,000	15	1	3	YES
	West Bend-Trenton[f]	8	63.9	19	11	20	5,120	900	600	7	6,600	33	1,600	O-GE	11	0	1	NO
	Barton	9	71.4	27	12	19	136,000	930	1,060	12	10,000	25	850	36,200	13	0	1	NO
Upper Milwaukee River	Campbellsport	10	88.6	7	13	19	37,100	1,020	3,650	28	46,000	40	850	O-GE	13	0	3	NO
Cedar Creek	Horns Corners	11	41.5	7	10	21	63,000	843.5	5,000	23	35,000	36	700	O-GE or 21,000	14	1	3	YES
	Jackson	12	49.6	20	10	20	30,000	854	2,100	16	12,000	29	1,000	O-GE	13	0	1	NO
North Branch	Scott-Sherman	13	63.9	6	13	21	24,300	845	1,200	8	12,000	30	700	O-GE	12	0	1	NO
	Orchard Grove[f]	14	52.8	29	12	20	8,960	870	480	10	4,000	29	1,100	O-GE	9	0	1	NO
	Mitchell Scott[f]	15	57.9	34	14	20	7,680	1,020	1,100	10	30,000	69	1,000	O-GE	12	0	1	NO
	Scott-Farmington[f]	16	57.9	3	12	20	14,700	875	610	7.5	7,400	45	3,800	O-GE	11	0	1	NO
Silver Creek (Sheboygan Co)	Sherman-Fredonia	17	57.3	32	13	21	6,400	853	490	3	3,100	23	1,700	O-GE	9	0	0	NO
West Branch	Ashford-Wayne	18	83.5	36	13	18	2,560	1,020	150	2.5	1,700	40	1,000	O-GE	12	0	0	NO
	Elmore	19	86.9	23	13	18	19,200	1,020	2,500	30	43,000	50	700	O-GE	8	0	2	NO
Middle Milwaukee River and Cedar Creek	Newburg Reservoir connected to Horns Corners Reservoir via Saukville Depression[g]						230,000	865 and 843.5	7,300	40	51,000	40 and 36	850 and 700	38,000 and 21,000	15	2	4	YES

[a]THE TOTAL AREA OF THE MILWAUKEE RIVER WATERSHED IS 693.8 SQUARE MILES, OR 444,000 ACRES.

[b]CONSERVATION POOL LEVEL IS DEFINED AS THAT ELEVATION AT WHICH THE WATER SURFACE OF A RESERVOIR IS TO BE MAINTAINED FOR NORMAL USE DURING MOST MONTHS OF THE YEAR. DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT.

[c]THE PARAMETERS WERE DETERMINED BASED ON THE ASSUMPTION THAT THE IMPOUNDMENT IS AT THE CONSERVATION POOL LEVEL.

[d]SPILLWAY DESIGN DISCHARGES WERE DETERMINED ONLY FOR RESERVOIR SITES WITH LARGE TRIBUTARY AREAS OR FOR LOCATIONS WHERE SIGNIFICANT FLOOD STORAGE ABOVE THE CONSERVATION POOL LEVEL IS NOT FEASIBLE DUE TO HIGH LAND ACQUISITION COSTS. THE ABBREVIATION, O-GE, MEANS OUTLET WITH GRASSED EMERGENCY SPILLWAYS HAVING A CREST ELEVATION BELOW THE DAM CREST. SOME FLOODWATER WOULD BE STORED IN THE RESERVOIR DURING ANY FLOOD EVENT, WITH THE REMAINDER BEING RELEASED THROUGH THE OUTLET DURING SMALL FLOODS, WHILE THE GRASSED SPILLWAY WOULD PROVIDE ADDITIONAL RELIEF DURING MAJOR FLOOD EVENTS. *DISCHARGE CAPACITIES HAVE NOT BEEN ASSIGNED TO GRASS SPILLWAYS FOR THIS PRELIMINARY ASSESSMENT OF RESERVOIR SITES.*

[e]RATINGS FOR FLOOD MITIGATION AND FOR WATER SUPPLY-FLOW AUGMENTATION FUNCTIONS ARE QUANTIFIED ACCORDING TO THE FOLLOWING SCALE AND ARE DEVELOPED IN TABLES 16 AND 17.
EXCELLENT- 4
GOOD- 3
FAIR- 2
POOR- 1
NO VALUE- 0
RECREATIONAL RATINGS ARE DEVELOPED IN TABLE 15, WITH THE RECREATION FUNCTION BEING WEIGHTED APPROXIMATELY FIVE TIMES AS MUCH AS EITHER OF THE OTHER TWO FUNCTIONS.

[f]THESE ARE OFF-CHANNEL POTENTIAL RESERVOIR SITES; THAT IS, THEY ARE NOT LOCATED ON ONE OF THE 11 PRINCIPAL RIVER REACHES DEFINED FOR THE PURPOSE OF THIS WATERSHED STUDY. *RIVER MILE STATIONS CITED FOR THESE SITES DEFINE THE POINT OF CONFLUENCE OF ONE OF THE 11 PRINCIPAL RIVER REACHES AND THE CREEK OR STREAM ON WHICH THE SITE IS LOCATED.*

[g]THE SAUKVILLE DEPRESSION, A LARGE, TOPOGRAPHICALLY LOW AREA, WOULD FUNCTION AS A HYDRAULIC CONNECTION BETWEEN THE NEWBURG AND HORNS CORNERS RESERVOIRS, IMPOUNDING WATER ONLY DURING MAJOR FLOOD EVENTS, AT WHICH TIME IT WOULD PROVIDE 12,000 ACRE-FEET OF STORAGE AT THE MAXIMUM FLOOD POOL ELEVATION OF 870 FEET MEAN SEA LEVEL.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

mit reservation of a "no-wake zone" 200 to 500 feet wide along developed shoreland. The largest reservoirs, over 3,000 acres in size, were assigned higher ratings than were either the smallest reservoirs, 300 to 1,000 acres in size, or the medium-sized reservoirs, 1,000 to 3,000 acres in size.

Picnicking and Sightseeing

For picnicking and sightseeing development, it is desirable that the potential reservoir be set in a wooded landscape, with ease of accessibility to the reservoir itself and with numerous potential overlooks for viewing the reservoir. Picnic areas should be located in attractive natural settings, preferably partially shaded, with pleasant views of the water and surrounding terrain, and should be reasonably level so that visitors do not have to climb or descend steep hills going to or from the picnic area to parking or other use areas. Potential parking areas requiring relatively flat land must be available in close proximity to, but preferably shielded from, the picnic areas and other points of interest. The local access routes should have potential for viewing the reservoir both while vehicles are in motion and while parked at particularly scenic overlooks.

Table 15

RECREATIONAL RATINGS OF POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED

DAM LOCATION							RECREATIONAL ANALYSIS[a]					
RIVER REACH	NAME	NUMBER	RIVER MILE STATION	SECTION	TOWN	RANGE	BOATING AND WATER SKIING	PICNICKING AND SIGHTSEEING	SWIMMING	FISHING	PROXMITY TO URBAN POPULATION	TOTAL
LOWER MILWAUKEE RIVER	GLENDALE	1	11.5	19	8	22	2	2	2	1	4	11
	THIENSVILLE	2	20.5	24	9	21	3	3	4	1	4	15
	MEQUON-GRAFTON	3	26.3	31	10	22	2	3	3	1	4	13
	GRAFTON	4	31.4	13	10	21	1	3	2	1	4	11
	SAUKVILLE	5	40.3	14	11	21	2	3	2	1	3	11
	WAUBEKA	6	47.0	29	12	21	4	3	4	3	3	17
MIDDLE MILWAUKEE RIVER	NEWBURG	7	55.6	13	11	20	4	3	4	1	3	15
	WEST BEND-TRENTON	8	63.9	19	11	20	1	3	2	2	3	11
	BARTON	9	71.4	27	12	19	3	3	4	1	2	13
UPPER MILWAUKEE RIVER	CAMPBELLSPORT	10	88.6	7	13	19	4	3	3	2	1	13
CEDAR CREEK	HORNS CORNERS	11	41.5	7	10	21	4	3	3	1	3	14
	JACKSON	12	49.6	20	10	20	3	3	3	1	3	13
NORTH BRANCH	SCOTT-SHERMAN	13	63.9	6	13	21	3	3	3	2	1	12
	ORCHARD GROVE	14	52.8	29	12	20	1	3	2	1	2	9
	MITCHELL SCOTT	15	57.9	34	14	20	3	3	2	3	1	12
	SCOTT-FARMINGTON	16	57.9	3	12	20	2	3	2	2	2	11
SILVER CREEK (SHEBOYGAN CO)	SHERMAN-FREDONIA	17	57.3	32	13	21	1	3	2	1	2	9
WEST BRANCH	ASHFORD-WAYNE	18	83.5	36	13	18	3	3	3	2	1	12
	ELMORE	19	86.9	23	13	18	0	2	2	3	1	8
MIDDLE MILWAUKEE RIVER AND CEDAR CREEK	NEWBURG RESERVOIR CONNECTED TO HORNS CORNERS RESERVOIR VIA SAUKVILLE DEPRESSION[b]						4	3	4	1	3	15

[a] RATINGS FOR EACH RECREATIONAL ACTIVITY ARE QUANTIFIED ACCORDING TO THE FOLLOWING SCALE-
EXCELLENT- 4
GOOD- 3
FAIR- 2
POOR- 1
NO VALUE- 0

[b] THE SAUKVILLE DEPRESSION, A LARGE, TOPOGRAPHICALLY LOW AREA, WOULD FUNCTION AS A HYDRAULIC CONNECTION BETWEEN THE NEWBURG AND HORNS CORNERS RESERVOIRS, IMPOUNDING WATER ONLY DURING MAJOR FLOOD EVENTS, AT WHICH TIME IT WOULD PROVIDE 12,000 ACRE-FEET OF STORAGE AT THE MAXIMUM FLOOD POOL ELEVATION OF 870 FEET MEAN SEA LEVEL.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Swimming

For the development of swimming areas, natural topographic conditions at the reservoir site should provide shoreline slopes of less than 10 percent for beach use, while underwater slopes should range between 3 and 7 percent. Swimming area development should be accomplished with very few physical changes either above or below the water surface. Finally, the development of a swimming center at a potential reservoir site requires supporting parking and picnicking areas and good access facilities.

Fishing

A critical factor influencing the establishment and maintenance of a fishery in a proposed reservoir is the year-round existence of zones or strata with dissolved oxygen concentrations above certain minimum levels and temperatures below certain maximum levels. Water quality standards for the maintenance of a warm-water fishery, as well as the more stringent standards conducive to desired levels of fish reproduction, are discussed in Chapter IX of Volume 1 of this report.

Large reservoirs generally exhibit, both temporally and spatially, a variety of dissolved oxygen and thermal regimes, thereby essentially assuring that the water quality standards can be met within some stratum of the impoundment at any time of the year. This statement, however, is subject to some qualifications. First, the reservoir must not be subjected to excessive loadings of organic, nutrient, or thermal pollution, thereby destroying the desirable oxygen concentration (4.0 mg/l minimum) and temperature level (89°F maximum) normally present. The second qualification relates to the depth of the proposed impoundment, inasmuch as it should be deep enough to produce thermal stratification in the summer and thereby assure the presence of desirable cooler water below the surface. The minimal oxygen requirements under such conditions of stratification will normally be satisfied at an intermediate depth in such a reservoir, above the thermocline. The reservoir should also be deep enough to prevent fish kills caused by oxygen depletion occurring subsequent to ice formation in the winter. The likelihood of organic, nutrient, and thermal pollution and the potential depth were considered in the numerical rating of the fishery potential of each reservoir site.

Another consideration important to the evaluation of the potential fishery value of a proposed reservoir site is the possible inflow of substances toxic to fish or to humans, since fish may carry and concentrate these materials. Possible upstream industrial or commercial sources of toxic substances were, therefore, also considered in evaluating the reservoir sites.

Flood Control Potential: The relative effectiveness of each reservoir site for the purpose of flood mitigation is basically dependent upon three factors:

1. The extent of the total watershed area controlled by, or upstream of, the proposed location.

2. The amount of storage available, in addition to the normal reservoir volume, for receiving and temporarily detaining runoff from a major flood event.

3. The relative position of the reservoir site within the watershed stream system with respect to the high flood-damage reaches.

Generally speaking, larger impoundments located in the lower watershed, but upstream of the flood-vulnerable reaches, would be more effective for flood-damage reduction than smaller reservoirs situated in headwater areas.

A systematic evaluation procedure was utilized so as to incorporate the above criteria in a quantitative manner and thus assist in the analysis of each potential impoundment location and in determining its flood mitigation value relative to the other sites. The evaluation procedure utilized is described below, while the results of that procedure, including the final flood control rating assigned to each potential reservoir location, are summarized in Table 16.

Fundamental to the evaluation procedure used is the criterion that flood damages associated with the 100-year recurrence interval watershed-wide flood event would be essentially eliminated if the corresponding uncontrolled maximum flood discharge of 16,000 cubic feet per second (cfs) at Estabrook Park in Milwaukee were reduced to a maximum discharge of 5,000 cubic feet per second which discharge, based upon analyses of the hydraulic characteristics of the existing channel, approximately represents the bank-full flow capacity of the channel system. The total drainage area above the Estabrook Park gage in the City of Milwaukee is 686 square miles. It is estimated that the 5,000 cfs bank-full discharge at this gage would be produced during the 100-year flood event by 100 square miles of drainage area located upstream of the gage. Therefore, at least 586 square miles of drainage area above the gage must be controlled in order for a reservoir to give full protection against a 100-year recurrence interval flood. The correspondence between 100 square miles of drainage area and the 5,000 cfs peak discharge is based on the assumption that peak discharge is proportional to tributary area

Table 16

FLOOD CONTROL RATING OF POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED

DAM LOCATION							FLOOD CONTROL ANALYSIS							
							AREA TRIBUTARY TO DAM[a]							
RIVER REACH	NAME	NUMBER	RIVER MILE STATION	SECTION	TOWN	RANGE	(ACRES)	(PROPORTION OF WATERSHED)	CONTROL RATIO[b]	FLOOD STORAGE VOLUME[c] (ACRE-FEET)	CONTROL RATIO TIMES FLOOD STORAGE VOLUME[d]	ADJUSTMENT FOR LOCATION[e]	CONTROL RATIO TIMES FLOOD STORAGE VOLUME TIMES LOCATION ADJUSTMENT[f]	FLOOD CONTROL RATING[g]
LOWER MILWAUKEE RIVER	GLENDALE	1	11.5	19	8	22	412,500	0.93	1.00	--	--	--	--	0
	THIENSVILLE	2	20.5	24	9	21	391,000	0.88	1.00	124,600	124,600	0.50	62,300	3
	MEQUON-GRAFTON	3	26.3	31	10	22	377,000	0.85	1.00	124,600	124,600	0.70	87,200	3
	GRAFTON	4	31.4	13	10	21	291,000	0.65	0.78	124,600	97,000	0.80	77,500	3
	SAUKVILLE	5	40.3	14	11	21	275,000	0.62	0.74	3,750	2,800	0.90	2,500	0
	WAUBEKA	6	47.0	29	12	21	260,000	0.58	0.70	85,000	59,500	1.00	59,500	3
MIDDLE MILWAUKEE RIVER	NEWBURG	7	55.6	13	11	20	163,000	0.37	0.44	16,000	7,000	1.00	7,000	2
	WEST BEND-TRENTON	8	63.9	19	11	20	5,120	0.01	0.01	--	--	--	--	0
	BARTON	9	71.4	27	12	19	136,000	0.31	0.37	6,800	2,500	1.00	2,500	0
UPPER MILWAUKEE RIVER	CAMPBELLSPORT	10	88.6	7	13	19	37,100	0.08	0.10	--	--	--	--	0
CEDAR CREEK	HORNS CORNERS	11	41.5	7	10	21	63,000	0.14	0.17	47,000	8,000	0.85	6,800	2
	JACKSON	12	49.6	20	10	20	30,000	0.07	0.08	--	--	--	--	0
NORTH BRANCH	SCOTT-SHERMAN	13	63.9	6	13	21	24,300	0.05	0.07	--	--	--	--	0
	ORCHARD GROVE	14	52.8	29	12	20	8,960	0.02	0.02	--	--	--	--	0
	MITCHELL-SCOTT	15	57.9	34	14	20	7,680	0.02	0.02	--	--	--	--	0
	SCOTT-FARMINGTON	16	57.9	3	12	20	14,700	0.03	0.04	--	--	--	--	0
SILVER CREEK (SHEBOYGAN CO)	SHERMAN-FREDONIA	17	57.3	32	13	21	6,400	0.01	0.02	--	--	--	--	0
WEST BRANCH	ASHFORD-WAYNE	18	83.5	36	13	18	2,560	0.01	0.01	--	--	--	--	0
	ELMORE	19	86.9	23	13	18	19,200	0.04	0.05	--	--	--	--	0
MIDDLE MILWAUKEE RIVER AND CEDAR CREEK	NEWBURG RESERVOIR CONNECTED TO HORNS CORNER RESERVOIR VIA SAUKVILLE DEPRESSION[h]						230,000	0.52	0.62	75,000	46,500	1.00	46,500	3

[a]THE TOTAL AREA OF THE MILWAUKEE RIVER WATERSHED IS 693.8 SQUARE MILES, OR 444,000 ACRES.

[b]CONTROL RATIO IS DEFINED AS THE AREA TRIBUTARY TO THE DAM SITE DIVIDED BY THE WATERSHED AREA THAT MUST BE CONTROLLED TO REDUCE A 100-YEAR RECURRENCE INTERVAL FLOOD EVENT AS ESTABROOK PARK IN MILWAUKEE FROM THE UNCONTROLLED MAXIMUM PEAK DISCHARGE OF 16,000 CUBIC FEET PER SECOND TO A PEAK VALUE OF 5,000 CUBIC FEET PER SECOND, WHICH WAS ASSUMED TO REPRESENT BANK-FULL CONDITIONS. AS DESCRIBED IN THE TEXT, THAT AREA WAS DETERMINED TO BE APPROXIMATELY 586 SQUARE MILES, OR 375,000 ACRES. WHEN THE COMPUTED VALUE EXCEEDED UNITY, A CONTROL RATIO OF 1.0 WAS ASSUMED AND ENTERED IN THE TABLE.

FLOOD CONTROL ANALYSIS WAS NOT EXTENDED FOR SITES HAVING CONTROL RATIOS LESS THAN 0.15 BECAUSE OF THEIR OBVIOUS INEFFECTIVENESS FOR FLOOD CONTROL PURPOSES, AND, THEREFORE, FOR THESE SITES THE REMAINING COLUMNS, WITH THE EXCEPTION OF THE LAST COLUMN, DO NOT HAVE ANY ENTRIES.

[c]FLOOD STORAGE VOLUME IS BASED ON FIVE FEET OF WATER ABOVE THE CONSERVATION POOL LEVEL AT EACH RESERVOIR LOCATION EXCEPT FOR THE FOLLOWING-
GLENDALE SITE--NO STORAGE IS AVAILABLE.
THIENSVILLE, MEQUON-GRAFTON AND GRAFTON SITES--THESE IMPOUNDMENTS ARE ALLOTTED THE TOTAL RUNOFF VOLUME OF A 100-YEAR RECURRENCE INTERVAL FLOOD EVENT FOR THE TRIBUTARY AREA SINCE, BECAUSE OF THEIR LOCATION, THE POTENTIAL EXISTS TO DIVERT ALL THE FLOODWATERS DIRECTLY TO LAKE MICHIGAN.
WAUBEKA AND HORNS CORNERS SITES--EIGHT FEET AND SEVEN FEET, RESPECTIVELY, OF FLOODWATER STORAGE ABOVE THE CONSERVATION POOL LEVEL WERE READILY AVAILABLE AND, THEREFORE, USED IN THE DETERMINATION OF STORAGE VOLUME.

[d]THIS PARAMETER, INASMUCH AS IT IS PROPORTIONAL TO BOTH THE CONTROL RATIO AND STORAGE VOLUME, PROVIDES A RELATIVE MEASURE OF THE FLOOD MITIGATION EFFECTIVENESS OF THE POTENTIAL RESERVOIR SITES. IT DOES NOT, HOWEVER, SPECIFICALLY ACCOUNT FOR THE SITES' POSITION WITHIN THE WATERSHED STREAM SYSTEM RELATIVE TO THE EXISTING FLOOD-VULNERABLE REACHES.

[e]THIS ADJUSTMENT FOR LOCATION IS A MEASURE OF THE IMPOUNDMENTS POTENTIAL, BECAUSE OF ITS RELATIVE POSITION WITHIN THE WATERSHED STREAM SYSTEM TO PROVIDE FLOOD PROTECTION FOR THE HIGH FLOOD-DAMAGE REACHES ALONG THE LOWER MILWAUKEE RIVER BETWEEN AND INCLUDING THE CITY OF GLENDALE AND THE VILLAGE OF SAUKVILLE.

[f]THIS NUMBER, WHICH IS THE PRODUCT OF THE ENTRIES IN THE PRECEDING TWO COLUMNS, SUMMARIZES THE ANALYSIS AND PROVIDES A RELATIVE MEASURE OF EACH SITE'S FLOOD MITIGATION EFFECTIVENESS BY ACCOUNTING FOR ITS TRIBUTARY AREA, THE VOLUME AVAILABLE FOR FLOODWATER STORAGE AND THE POSITION OF THE SITE RELATIVE TO THE FLOOD-VULNERABLE RIVERINE AREAS.

[g]FLOOD CONTROL RATINGS ARE QUANTIFIED ACCORDING TO THE FOLLOWING SCALE-
EXCELLENT- 4
GOOD- 3
FAIR- 2
POOR- 1
NO VALUE- 0

[h]THE SAUKVILLE DEPRESSION, A LARGE, TOPOGRAPHICALLY LOW AREA, WOULD FUNCTION AS A HYDRAULIC CONNECTION BETWEEN THE NEWBURG AND HORNS CORNERS RESERVOIRS, IMPOUNDING WATER ONLY DURING MAJOR FLOOD EVENTS, AT WHICH TIME IT WOULD PROVIDE 12,000 ACRE-FEET OF STORAGE AT THE MAXIMUM FLOOD POOL ELEVATION OF 870 FEET MEAN SEA LEVEL.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

to the 0.6 power.[6] The extent to which each site was capable of controlling the required watershed area was quantified by computing its control ratio, defined as the area in square miles, tributary to the potential dam site, divided by the required 586 square miles. In those instances where a computed value exceeded unity, a control ratio of 1.0 was used. Flood control analysis was terminated for sites which were found in the screening process to have control ratios less than 0.15 because of their obvious ineffectiveness for flood control purposes. Control ratios for each potential reservoir site are presented in Table 16.

The next step in the preliminary evaluation or screening procedure was to determine the volume available at each site for temporary storage of runoff from major flood events. For flood control purposes, a reservoir should have a large surface area astride the channel or be located where floodwaters can be diverted to large off-channel storage areas, such as large wetlands or Lake Michigan, so that flood flows can be accommodated with a relatively small rise in the water surface level over the conservation pool level.[7] The interception, storage, and release of floodwaters in such an impoundment may be accomplished with a minimum disruption of recreational uses; and the incremental cost of the dam for the flood control function is less than would be required to provide an equal amount of floodwater storage capacity in a reservoir with a smaller lake area.

An estimate was made of the potential storage volume available in each reservoir for flood control use during the summer recreation season. This volume was assumed to be that contained between the maximum elevation of the reservoir, as limited by topography or relocation constraints, and the elevation of the conservation pool. This difference in elevation available for flood control is estimated to be zero for the Glendale, Grafton, and Thiensville sites; 10 feet for the Waubeka site; seven feet for the Horns Corners site; and five feet for all other sites. Since the Grafton, Mequon-Grafton, and Thiensville sites, however, would achieve flood control by diversion to Lake Michigan, rather than by actual storage, these three sites were credited with being able to, in effect, store the total runoff volume of a 100-year recurrence interval flood. The control ratio was multiplied by the flood storage volume to obtain an adjusted volume figure that reflects both the volume of flood storage that would actually be available at each site and the ability to fill, and thereby effectively use, that storage to essentially eliminate damage during a 100-year recurrence interval flood event. The flood storage volume and the accompanying adjusted value for each of the potential impoundment locations considered are set forth in Table 16.

A critical consideration in the evaluation procedure was the location of each potential impoundment site relative to the high flood-damage reaches of the river system located between and including the City of Glendale and the Village of Saukville. Regardless of the amount of watershed area controlled and the flood storage volume available, an impoundment must be located in the stream system so that it is, in a hydraulic sense, upstream of the flood-vulnerable areas and thus physically positioned so as to prevent excessive floodwaters from reaching those areas. An adjustment factor for location, having a maximum value of 1.0, was assigned to each potential reservoir site; and the previously established relative flood control ratings were reduced in proportion to this factor. The adjustment for location and the final flood control ratings developed for each potential impoundment location are set forth in Table 16.

Flow Augmentation and Water Supply Potential: The effectiveness of a reservoir for the purposes of low-flow augmentation or water supply is primarily dependent upon its potential to continuously deliver large, guaranteed flow rates with a minimum drawdown so as not to interfere with other reservoir uses, particularly recreation. These requirements are most likely to be met by large impoundments located in the lower portion of the watershed, since, by virtue of both position and size, such reservoirs will capture much of

---

[6] *Thus,* $\frac{Q_2}{Q_1} = \frac{A_1^{0.6}}{A_2^{0.6}}$; *and, substituting* $Q_1 = 16{,}000$ *cfs, the 100-year recurrence interval watershed-wide flood peak discharge at Estabrook Park under uncontrolled land use development conditions; substituting* $A_1 = 686$ *square miles, the watershed area producing that discharge; and substituting* $Q_2 = 5{,}000$ *cfs, the peak discharge which could be contained within the channel at Estabrook Park, it follows that* A_2*, the watershed area that would generate 5,000 cfs and, therefore, need not be controlled, is 98 square miles, or approximately 100 square miles.*

[7] *The term "conservation pool level" is defined as that elevation at which the water surface of a reservoir is to be maintained for normal use throughout most months of the year.*

the watershed runoff for storage and subsequent release as needed and by virtue of size, particularly with respect to surface area, will produce a minimum change in water surface elevation for a given volume of low-flow augmentation or water supply release, thus minimizing interference with other uses.

The reservoir sites were assigned relative ratings for low-flow augmentation and water supply potential by determining the continuous, uniform discharge that each could guarantee over a 12-month period based on an arbitrarily selected five-foot drawdown occurring under conditions of no inflow to the reservoir. In those few instances where the discharge so determined exceeded the reservoir's annual yield—that is, the estimated average annual flow delivered to the impoundment from its tributary area—the discharge was reduced accordingly. The analysis and final low-flow augmentation and water supply ratings are set forth in Table 17.

Preliminary Design of Spillways and Outlet Works: A preliminary design for a spillway and outlet works was prepared for each potential reservoir site, assuming, for the screening purposes, that the dams would be either grassed earthfill embankments or predominantly concrete structures. Selection of an earthfill embankment or a concrete structure for a given dam site was determined by consideration of topographic and foundation conditions at the proposed location and by the hydraulic requirements that the structure store as much of the 100-year recurrence flood volume as possible and safely divert the remainder to off-channel storage or Lake Michigan or, in situations where diversion is not possible, discharge the excess floodwaters to the river downstream of the dam. Furthermore, the choice of the type of structure and its preliminary design included consideration of, and provision for, diversion or discharge of the maximum probable flood, an extremely severe flood event having a peak discharge greatly in excess of the 100-year recurrence interval flood.

Outlet works for all of the sites were assumed to consist of small control structures in the reservoir connected to conduits under the dams. The outlet works would be structurally and hydraulically designed to control reservoir releases to meet downstream low flow or water supply needs, floodwater control requirements, and other miscellaneous needs. Although not developed in detail for all reservoir sites during the preliminary screening process, it is recognized that the optimum use of the water within, and released from, any impoundment deep enough to develop thermal stratification requires, in addition to consideration of the quantity and timing of the reservoir releases, provision for manipulation of the quality of those releases. Summer thermal stratification produces a condition of quality stratification within a reservoir; that is, the development of horizontal layers or strata exhibiting markedly different water quality characteristics. Incorporation of multiple-depth withdrawal capability into the dam outlet works permits the selective extraction of waters with desirable quality characteristics while selectively excluding strata with undesirable characteristics. The concepts of water quality stratification and selective withdrawal are further discussed later in this chapter, where several of the more promising potential dam and reservoir developments are treated in more detail.

Selection of Reservoir Sites for Further Consideration: The initial screening of the 19 potential reservoir locations remaining in the watershed plus one reservoir arrangement consisting of a combination of two individual sites revealed a wide range of potential for multiple-purpose development, as indicated by the recreation, flood control, and low-flow augmentation-water supply ratings summarized in Table 14. Some sites were eliminated from further consideration because they were assessed as having no value or, at best, very low values in two of the three rating categories. The remaining reservoir sites were then evaluated in terms of their potential for contributing to the achievement of the watershed development objectives and the likelihood of public acceptance and, thus, a higher probability of implementation. To gain the necessary public acceptance and support, it was assumed that a site would have to have relatively high ratings in at least two of the three major rating categories, preferably in the flood control and recreation categories.

Flood control, regardless of the relatively small monetary value in comparison to recreational benefits, is generally recognized as a desirable public objective; and it was judged unlikely that public support would be given to any proposal for a major river development project which would not provide significant flood control benefits, regardless of the potential for other benefits.

Table 17

WATER SUPPLY AND LOW-FLOW AUGMENTATION RATINGS OF POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED

DAM LOCATION								IMPOUNDMENT			WATER SUPPLY AND LOW-FLOW AUGMENTATION ANALYSIS		
RIVER REACH	NAME	NUMBER	STATION	SECTION	TOWN	RANGE	AREA TRIBUTARY TO DAM[a] (ACRES)	CONSERVATION POOL LEVEL[b] (FEET)	SURFACE AREA[c] (FEET)	STORAGE VOLUME[c] (ACRE-FEET)	VOLUME PRODUCED BY FIVE FEET OF DRAWDOWN[d] (ACRE-FEET)	CONTINUOUS DISCHARGE POTENTIAL[e] (CUBIC FEET PER SECOND)	WATER SUPPLY AND LOW-FLOW AUGMENTATION RATING[f]
LOWER MILWAUKEE RIVER	GLENDALE	1	11.5	19	8	22	412,500	650	800	7,000	3,500	4.8	1
	THIENSVILLE	2	20.5	24	9	21	391,000	670	2,080	18,300	9,000	12.3	2
	MEQUON-GRAFTON	3	26.3	31	10	22	377,000	700	700	10,000	4,000	5.5	1
	GRAFTON	4	31.4	13	10	21	291,000	750	700	7,000	3,500	4.8	1
	SAUKVILLE	5	40.3	14	11	21	275,000	785	700	12,000	5,000	6.8	1
	WAUBEKA	6	47.0	29	12	21	260,000	825	10,400	155,000	36,000	48.0	4
MIDDLE MILWAUKEE RIVER	NEWBURG	7	55.6	13	11	20	163,000	865	2,300	16,000	16,000	21.9	3
	WEST BEND-TRENTON	8	63.9	19	11	20	5,120	900	600	6,600	3,000 (2,500)	3.4	1
	BARTON	9	71.4	27	12	19	136,000	930	1,060	10,000	5,000	6.8	1
UPPER MILWAUKEE RIVER	CAMPBELLSPORT	10	88.6	7	13	19	37,100	1,020	3,650	46,000	19,000	26.0	3
CEDAR CREEK	HORNS CORNERS	11	41.5	7	10	21	63,000	843.5	5,000	35,000	16,000	21.9	3
	JACKSON	12	49.6	20	10	20	30,000	854	2,100	12,000	6,500	8.9	1
NORTH BRANCH	SCOTT-SHERMAN	13	63.9	6	13	21	24,300	845	1,200	12,000	6,000	8.2	1
	ORCHARD GROVE	14	52.8	29	12	20	8,960	870	480	4,000	2,500	3.4	1
	MITCHELL SCOTT	15	57.9	34	14	20	7,680	1,020	1,100	30,000	10,000 (3,800)	5.2	1
	SCOTT-FARMINGTON	16	57.9	3	12	20	14,700	875	610	7,400	3,000	4.1	1
SILVER CREEK (SHEBOYGAN CO)	SHERMAN-FREDONIA	17	57.3	32	13	21	6,400	853	490	3,100	1,600	2.2	0
WEST BRANCH	ASHFORD-WAYNE	18	83.5	36	13	18	2,560	1,020	150	1,700	800	1.1	0
	ELMORE	19	86.9	23	13	18	19,200	1,020	2,500	43,000	16,000 (9,600)	13.1	2
MIDDLE MILWAUKEE RIVER AND CEDAR CREEK	NEWBURG RESERVOIR CONNECTED TO HORNS CORNERS RESERVOIR VIA SAUKVILLE DEPRESSION[g]						230,000	865 AND 843.5	7,300	51,000	32,000	43.8	4

[a]THE TOTAL AREA OF THE MILWAUKEE RIVER WATERSHED IS 693.8 SQUARE MILES, OR 444,000 ACRES.

[b]CONSERVATION POOL LEVEL IS DEFINED AS THAT ELEVATION AT WHICH THE WATER SURFACE OF A RESERVOIR IS TO BE MAINTAINED FOR NORMAL USE DURING MOST MONTHS OF THE YEAR. DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT.

[c]THE PARAMETERS WERE DETERMINED BASED ON THE ASSUMPTION THAT THE IMPOUNDMENT WAS AT THE CONSERVATION POOL LEVEL.

[d]THIS VOLUME IS THAT WHICH WOULD BE DISCHARGED FROM THE RESERVOIR BY DRAWING THE WATER SURFACE DOWN FIVE FEET FROM THE CONSERVATION POOL LEVEL UNDER CONDITIONS OF NO INFLOW TO THE IMPOUNDMENT. NUMBERS IN PARENTHESES INDICATE THE AVERAGE ANNUAL YIELD BASED ON AN ASSUMED SIX INCHES OF RUNOFF FROM THE AREA TRIBUTARY TO THE DAM SITE. AVERAGE ANNUAL YIELD IS THE ANNUAL VOLUME OF WATER THAT, ON THE AVERAGE, WILL BE SUPPLIED TO, AND, THEREFORE, MAY BE RELEASED FROM, A GIVEN IMPOUNDMENT. AVERAGE ANNUAL YIELD IS ENTERED IN THE TABLE ONLY FOR THOSE RESERVOIRS IN WHICH IT IS LESS THAN THE VOLUME OF WATER ASSOCIATED WITH THE AFOREMENTIONED FIVE-FOOT DRAWDOWN.

[e]ONE CUBIC FOOT PER SECOND OF CONTINUOUS DISCHARGE OVER A 24-HOUR PERIOD IS EQUIVALENT TO A VOLUME OF APPROXIMATELY TWO ACRE-FEET, OR IN A YEAR, WOULD PRODUCE ABOUT 730 ACRE-FEET. CONTINUOUS DISCHARGE POTENTIAL IS THE VOLUMETRIC FLOW WHICH COULD BE OBTAINED FROM AN IMPOUNDMENT BY UNIFORMLY AND CONTINUOUSLY DISCHARGING, OVER A 12-MONTH PERIOD, THE VOLUME OF WATER PRODUCED BY A FIVE-FOOT DRAWDOWN FROM THE CONSERVATION POOL LEVEL OR, IF IT IS SMALLER, THE VOLUME OF WATER EQUAL TO THE AVERAGE ANNUAL YIELD OF THE RESERVOIR. THIS PARAMETER PROVIDES A RELATIVE MEASURE OF THE LOW-FLOW AUGMENTATION OR WATER SUPPLY POTENTIAL OF EACH SITE. IT SHOULD BE NOTED THAT THE SAME VOLUME OF WATER COULD BE USED TO PRODUCE LARGER LOW-FLOW AUGMENTATION OR WATER SUPPLY DISCHARGES OVER SHORTER PERIODS OF TIME.

[f]LOW-FLOW AUGMENTATION AND WATER SUPPLY RATINGS ARE QUANTIFIED ACCORDING TO THE FOLLOWING SCALE-

EXCELLENT- 4
GOOD- 3
FAIR- 2
POOR- 1
NO VALUE- 0

[g]THE SAUKVILLE DEPRESSION, A LARGE, TOPOGRAPHICALLY LOW AREA, WOULD FUNCTION AS A HYDRAULIC CONNECTION BETWEEN THE NEWBURG AND HORNS CORNERS RESERVOIRS, IMPOUNDING WATER ONLY DURING MAJOR FLOOD EVENTS, AT WHICH TIME IT WOULD PROVIDE 12,000 ACRE-FEET OF STORAGE AT THE MAXIMUM FLOOD POOL ELEVATION OF 870 FEET MEAN SEA LEVEL.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

All of the reservoirs shown on Map 10 are attractive recreational projects; and some, by virtue of their sheer size, stand out as potential major recreational developments. Four of the reservoirs would have surface areas exceeding 3,000 acres; and four other impoundments would have surface areas exceeding 2,000 acres, all of which are larger than Cedar Lake, the tenth largest natural lake within southeastern Wisconsin, with a surface area of 932 acres. One of the reservoirs—Waubeka—would have a surface area at its conservation pool level of 10,400 acres, larger than Lake Geneva, the largest natural lake in southeastern Wisconsin, with a surface area of 5,262 acres, and larger than the combined surface areas of all of the major natural lakes within the watershed. Rankings shown in Table 14 reflect this importance of lake size, both recreationally and in terms of flood control and water supply-low-flow augmentation performance.

Based on the ratings summarized in Table 14, in conjunction with the potential for meeting watershed development objectives and the likelihood of public acceptance, the following five reservoir developments were selected for further analysis in the study: Thiensville, Waubeka, Newburg, and Horns Corners sites and a Newburg-Horns Corners combination site. The first three reservoir sites are located on the main stem of the Milwaukee River; and one, Horns Corners, is on Cedar Creek. The fifth reservoir site would encompass both the Milwaukee River and Cedar Creek by virtue of hydraulically connecting these two rivers upstream of their natural confluence. On initiation of the more detailed economic and engineering analyses, it became apparent that the residential development which has already occurred in the Thiensville reservoir site made this site an uneconomic one, thus precluding it from further consideration.

In summary, then, the initial screening of the 19 potential reservoir sites remaining within the watershed identified three single sites—Waubeka, Newburg, and Horns Corners—and one combination site—Newburg-Horns Corners—or a total of four reservoir alternatives, which, by virtue of their location, size, and physical characteristics, would definitely perform recreation, flood control, and low-flow augmentation-water supply functions and as such warranted more detailed analysis. These four technically feasible alternatives are located on Map 10, and the three single sites and their proximity to existing impoundments are also depicted in profile form in Figure 1.

Subsequent sections of this chapter analyze each of the four reservoir alternatives in greater detail in order to support a final identification of the best alternative. This analysis includes a more detailed description of the physical characteristics of each reservoir and impounding structure; and an identification of the monetary costs and benefits attendant to the development of each reservoir.

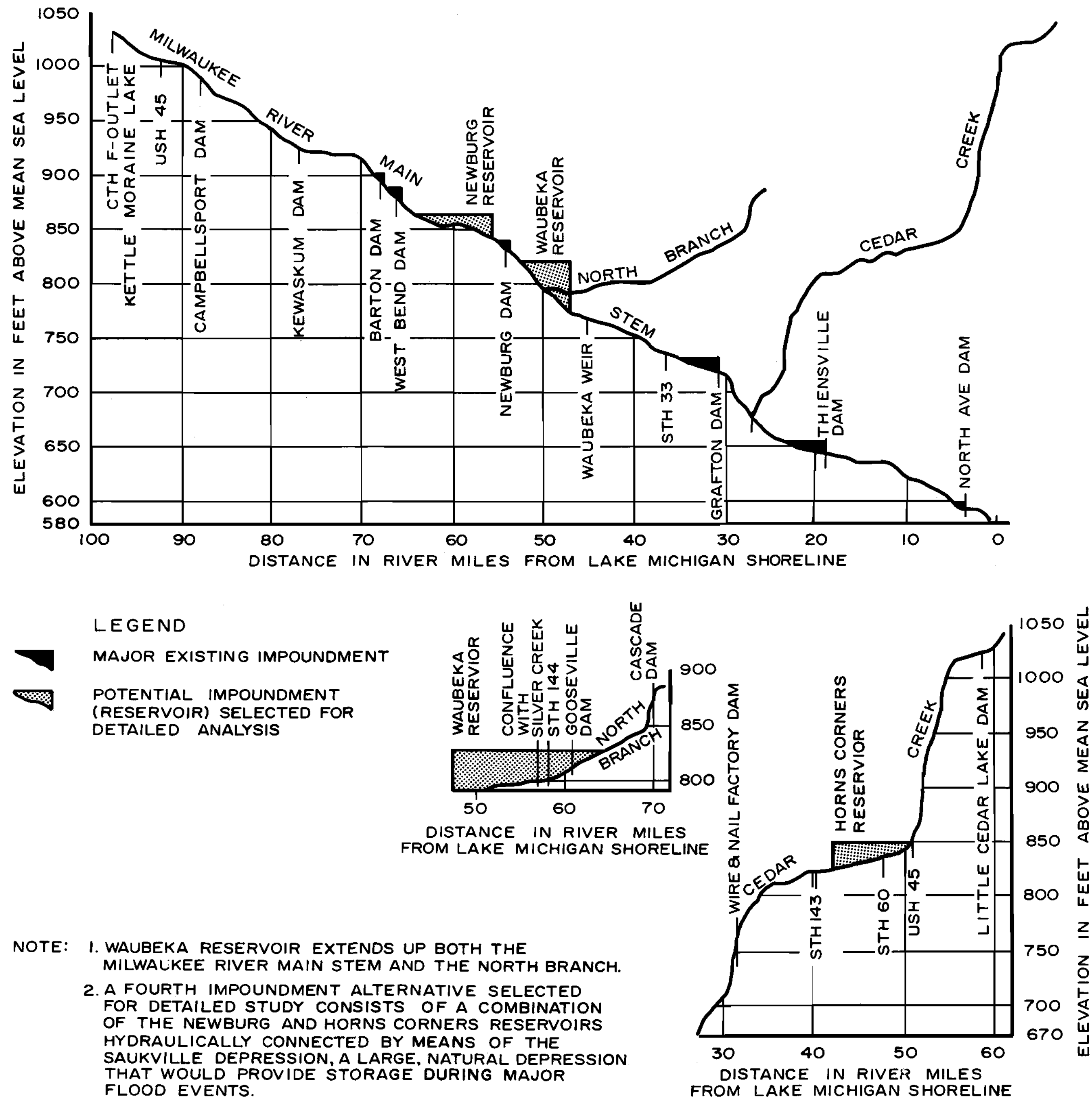
Waubeka Reservoir: The initial screening process indicated that the Waubeka Reservoir was the best of the four practicable reservoir sites remaining in the watershed and deserving more detailed study. Figure 2 illustrates the essential features of the impoundment and the dam, showing, in particular, the horizontal extent of the reservoir when the water surface is at both the conservation and flood pool level; impoundment volume and surface area as a function of pool stage; and the structural aspects of the dam and its spillway, including key elevations.

The impounding structure would be a concrete and earthfill dam, rising 57 feet above the rock foundation in the stream bed of the Milwaukee River at a site in Section 29, Town 12 North, Range 21 East, about one mile upstream from the Village of Waubeka. The proposed reservoir would have a surface area of 10,400 acres at Elevation 825, the proposed conservation pool level. Average lake depth would be about 15 feet, with a maximum depth of 40 feet. Storage at the conservation pool level would be 155,000 acre-feet, and almost all of the 89,500 acre-foot volume of a 100-year recurrence interval watershed-wide flood could be stored in the 85,000 acre-foot flood storage volume between Elevations 825 and 833. At Elevation 833 the area of the lake would grow to 12,200 acres. The storage potential in the conservation pool represents 110 percent of the annual yield from the 260,000-acre drainage area, based on six inches of runoff, for a year of average wetness; and, thus, the reservoir could be expected to fill in about two years.

In addition to providing for flood abatement, the reservoir could perform streamflow augmentation and water supply functions, with little fluctuation of the lake level. Due to its sheer size, the lake would afford excellent opportunities for water-oriented recreation use and for water-related recreation and residential land development in an area within easy commuting distance of the Milwaukee urbanized area.

Figure 1

PROFILE OF THE MILWAUKEE RIVER AND SELECTED TRIBUTARIES SHOWING EXISTING AND POTENTIAL IMPOUNDMENTS



NOTE: 1. WAUBEKA RESERVOIR EXTENDS UP BOTH THE MILWAUKEE RIVER MAIN STEM AND THE NORTH BRANCH.

2. A FOURTH IMPOUNDMENT ALTERNATIVE SELECTED FOR DETAILED STUDY CONSISTS OF A COMBINATION OF THE NEWBURG AND HORNS CORNERS RESERVOIRS HYDRAULICALLY CONNECTED BY MEANS OF THE SAUKVILLE DEPRESSION, A LARGE, NATURAL DEPRESSION THAT WOULD PROVIDE STORAGE DURING MAJOR FLOOD EVENTS.

Source: Harza Engineering Company and SEWRPC.

The construction cost of the dam is estimated at $2,849,000; the cost of acquisition of the lands and relocation of structures, utilities, and roads in the reservoir site, at about $19,000,000; and the development of attendant recreational facilities, at about $4,745,000. This latter cost represents the estimated initial capital outlay for recreational development, with staged construction projected to require additional expenditures of $8,600,000 by about the year 1995 and $12,700,000 additional expenditures by about the year 2015. The average annual costs total $2,514,000 and would be $1,466,000 for the dam and reservoir development, operation, and maintenance and $1,048,000 for related recreational facility development, operation, and maintenance.

Annual benefits of $3,442,000 could be expected to accrue, of which $149,500 would be for flood control; $850,500, for fishery; $2,340,000, for recreation benefits exclusive of fishery benefits; and $102,500 for the enhancement of land values. These primary benefits would result in a project benefit-to-cost ratio of 1.37. No economically viable potential for the generation of electrical power presently exists at this site. In addition to the primary benefits assigned monetary values, significant secondary benefits could be expected to accrue to which no monetary values were assigned. These include, among others, the economic stimulation engendered through construction of the dam and supporting facilities and development of urban and recreational land uses in the vicinity of the reservoir.

The costs of opportunities foregone were not directly identified but were assumed to be included in the costs of land. A modest potential presently exists to support hunting and fishing in several woodland and wetland areas of the proposed reservoir site. The potential for these types of recreational activities and for additional water-oriented recreational activities that would be created by the development of the reservoir are far greater than those supplanted (see Chapter III, Volume 2, of this report). Certain valuable elements of the natural resource base would be lost, including a timber swamp; a small natural lake (Lake Twelve); existing deer, rabbit, and squirrel habitat; and established stream shoreline vegetation. These losses, however, would be offset by the creation of much larger, new, and more desirable wetland areas along certain portions of the shoreline of the reservoir; the reforestation of other reaches of the shoreline; the creation of waterfowl habitat, particularly for spring and fall migrants; and the creation of a large fishery.

The proposed reservoir would center along the North Branch of the Milwaukee River, extend upstream from the dam about 13 miles, and include the existing lake impounded by Gooseville Dam in Sherman Township. During storage of a 100-year recurrence interval flood on a full conservation pool, the lake would extend upstream to the vicinity of Cascade Swamp and Lake Ellen.

Flood Control Operation and Resulting Benefits: Application of the flood-flow simulation model indicated that a 100-year recurrence interval watershed-wide[8] flood event will generate a peak discharge at the Waubeka site of about 11,000 cfs and a corresponding flood volume of approximately 89,500 acre-feet that would require 11 days for its passage. The stage-volume curve for the proposed impoundment shown in Figure 2 indicates that 85,000 acre-feet of water, or essentially all of the 100-year flood volume entering the impoundment, could be stored between the conservation pool level at Elevation 825 and the maximum flood storage pool level at Elevation 833.

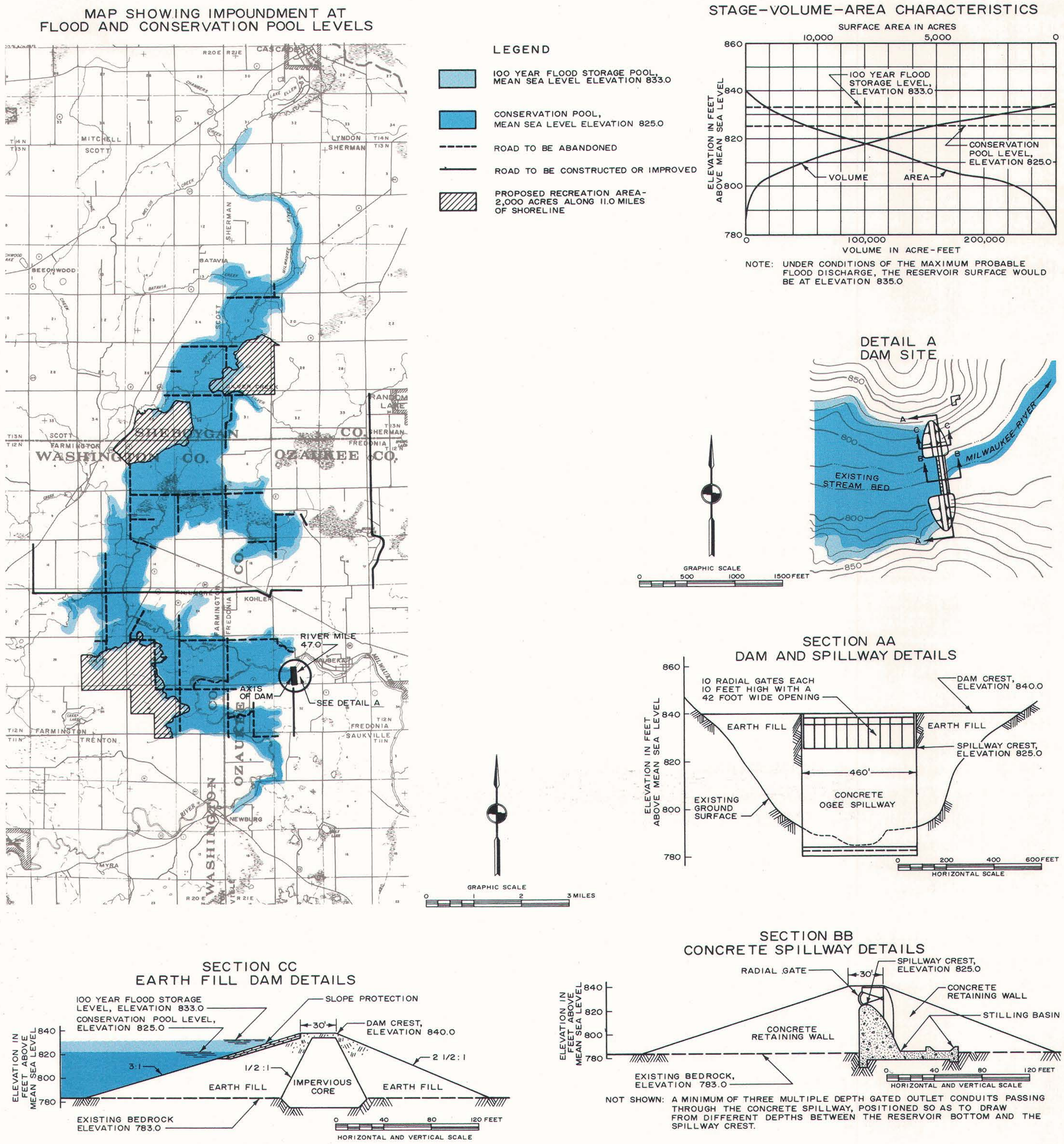
Although major floods on the Milwaukee River can occur in any season of the year, as described in Chapter VI, Volume 1, of this report, such floods are more likely to occur in early spring. Since recreational activity would be at a minimum during this period and there would be no need for flow augmentation during the spring, it would be possible to draw down the reservoir level to an elevation several feet below the conservation pool level during the winter in preparation for storage of spring floodwaters and, thus, completely contain runoff from floods even more severe than the 100-year event. The amount of drawdown would be related to the accumulated snowpack on the watershed. If the snowpack were light, only a minor drawdown would be made, while if the snowpack were deep in terms of its water equivalent, a greater drawdown would be made.

The potential benefits that would accrue to the reservoir for flood control were estimated by operating the flood-flow simulation model for the 10-year and the 100-year recurrence interval watershed-wide floods, with all flows originating upstream from the dam being stored in the Waubeka Reservoir. The reduction to the flood damages, as estimated in Chapter VIII, Volume 1, of this report, was then calculated utilizing the revised flood profiles. With the Waubeka Reser-

[8] *The peak discharge at the Waubeka site for a 100-year recurrence interval flood event occurring only on the watershed area tributary to the site is 12,300 cfs according to the flood-flow simulation model. However, the 11,000 cfs maximum discharge and 89,500 acre-foot flood volume, as would occur at Waubeka during a watershed-wide 100-year recurrence flood event, are used in this analysis since, as discussed earlier, the objective of flood control is to reduce the 100-year recurrence interval watershed-wide flood event from a peak discharge of 16,000 cfs to 5,000 cfs at Estabrook Park in Milwaukee.*

Figure 2

HYDROGRAPHIC AND STRUCTURAL FEATURES OF A POTENTIAL MULTIPLE-PURPOSE WAUBEKA RESERVOIR ON THE MILWAUKEE RIVER AND ITS NORTH BRANCH



Source: Harza Engineering Company.

voir operated as described above, all damages from the 100-year recurrence interval watershed-wide flood would be eliminated in the flood-prone riverine areas of the Lower Milwaukee River.

Flow Augmentation and Water Supply Considerations: A study was made to determine the potential of the Waubeka Reservoir for stabilizing seasonal stream discharge by regulation of low flows experienced along the Milwaukee River and to determine the additional effect of releasing water from storage to augment the regulated low flows. This regulation and augmentation of low flows would be beneficial to fish life, and recreational water uses would enhance water quality both through dilution and flushing and could serve as a source of municipal and industrial water supply. At present, dissolved oxygen levels in the Milwaukee River below the Waubeka reservoir site are often critically low relative to maintenance of fish life and would be significantly enhanced by flow augmentation. Stream water temperatures could be reduced also with a beneficial effect on the fishery. With reservoir releases, canoeing and other forms of water-oriented recreation would be possible, even in low-flow periods.

At present, low-flow augmentation is practiced within the watershed only in the City of Milwaukee, where a 12-foot diameter flushing tunnel pumps water 2,700 feet at a measured rate of up to 420 cfs from a point on the Lake Michigan shoreline inside the harbor breakwater to a point on the Milwaukee River immediately downstream of the North Avenue Dam.[9] The Milwaukee Sewerage Commission operates the tunnel on a regular basis during the summer months; but it is relatively ineffective in flushing noxious aquatic vegetation, oil slicks, turbidity, and floating debris from the estuarine portion of the Milwaukee River downstream of the North Avenue Dam. Supplemental flow augmentation equivalent to several multiples of that provided by the flushing tunnel would be needed to generate river velocities high enough to completely eliminate such floating materials and thereby markedly improve the appearance of the lower river. The Waubeka Reservoir could not continuously supply such large flow augmentation discharges, particularly during the summer period when most needed, without excessive drawdowns and attendant resulting conflict with recreational uses and aesthetic enjoyment of the impoundment.[10] Smaller flow augmentation releases could, however, be provided continuously by the reservoir; and these, with occasional, short-term large discharges, might, in combination with the flushing tunnel, be effective in improving the appearance of the river as it flows through the Milwaukee business district.

As described in Chapter XI, Volume 1, of this report, ground water and withdrawals from Lake Michigan are, at present, the two principal sources for water supply in the watershed. A Waubeka Reservoir would establish a third alternative, with water supplies being provided directly from the reservoir or from the Milwaukee River following release from the reservoir.

The potential for streamflow regulation and augmentation from the Waubeka Reservoir was quantified on the basis of monthly flows tabulated in the USGS Water Supply Papers for the period 1914 to 1966. Of these 53 years of record, 42 were complete enough for use in determining river discharges during the critical low-flow period, from May through November.

Low flows, such as those which occurred during the three most critical years of record—1934, 1932, and 1958—can be expected to occur at intervals of 43, 24, and 21 years, respectively. An analysis was made to determine the average flows that could have been maintained in these years with the release of three to five feet of storage from an initially full conservation pool in the Waubeka Reservoir, drawdowns which should not interfere unduly with recreational activity on the reservoir. Three feet of drawdown between the conservation pool elevation of 825 and Elevation 822 would result in a 7 percent reduction in the lake surface area and would yield about 25,000 acre-feet of water, while five feet of drawdown to Elevation 820 would result in a 16 percent reduction in the lake surface area and would yield about 44,000 acre-feet of water.

---

[9] *Consoer, Townsend and Associates, Interim Engineering Report-Humboldt Avenue Pollution Abatement Demonstration Project, Appendix H, April 1970.*

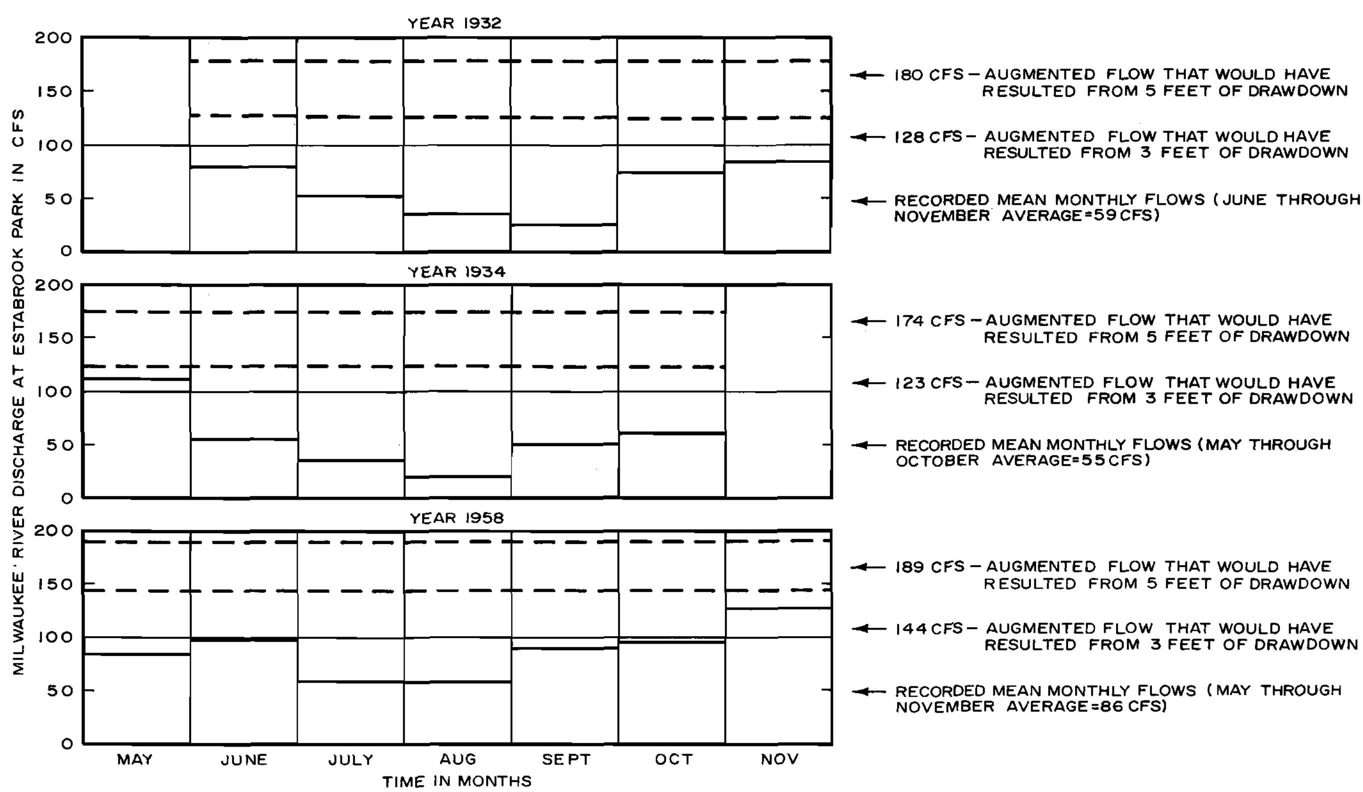
[10] *For example, if the Waubeka Reservoir were to supply, in addition to the average streamflow that presently occurs without the reservoir, a discharge equal to the flushing tunnel capacity (420 cfs) for the four-month June through September period, the reservoir surface would be drawn down from the conservation pool level of 825 feet to an elevation of about 813 feet, during which time approximately 100,000 acre-feet of water would be released from the impoundment; and its surface area would be reduced by about 40 percent.*

During 1934 the minimum monthly flow was 19 cfs, and the May through October average flow was 55 cfs. With three feet of drawdown of the reservoir, flow for this critical six-month period could have been maintained at a constant 123 cfs, equivalent to 1.2 inches of runoff from the entire Milwaukee River watershed tributary to the gaging station at Estabrook Park. During 1932 the minimum mean monthly flow at Estabrook Park was 27 cfs in September, while the June through November average was 59 cfs. With three feet of drawdown of the reservoir, the flow throughout this six-month period could have been maintained at 180 cfs, equivalent to 1.8 inches of runoff from the entire Milwaukee River watershed tributary to the gaging station. During 1958 the minimum monthly flow was 57 cfs, while the May through November average flow was 86 cfs. With three feet of drawdown of the reservoir, the average flow for this seven-month period could have been maintained at 144 cfs.

The duration and sequence of flow augmentation releases corresponding to three feet and five feet of Waubeka Reservoir drawdown for the aforementioned critical years and the resulting augmented streamflows are depicted graphically in Figure 3. The augmented streamflows include inflows to the reservoir and tributary flow to the river downstream of the reservoir in that it was assumed that natural flows entering and leaving the proposed reservoir site and entering the river downstream of the site would continue to do so in the presence of the reservoir; and, therefore, reservoir releases include natural flow plus additional discharge or flow augmentation extracted from reservoir storage. Consider, for example, the hypothetical Milwaukee River flow augmentation sequence for 1934 with three feet of total drawdown, as represented graphically in Figure 3. During June the total average discharge at Estabrook Park would have been 123 cfs. Of this total, 19 cfs would have occurred naturally

Figure 3

HISTORIC EXTREME LOW FLOWS OF THE MILWAUKEE RIVER AT ESTABROOK PARK AND RELATIONSHIP TO THE AUGMENTATION POTENTIAL OF WAUBEKA RESERVOIR



NOTE: DRAWDOWN ASSUMED TO BEGIN AT CONSERVATION POOL LEVEL ELEVATION 825 FEET MEAN SEA LEVEL.

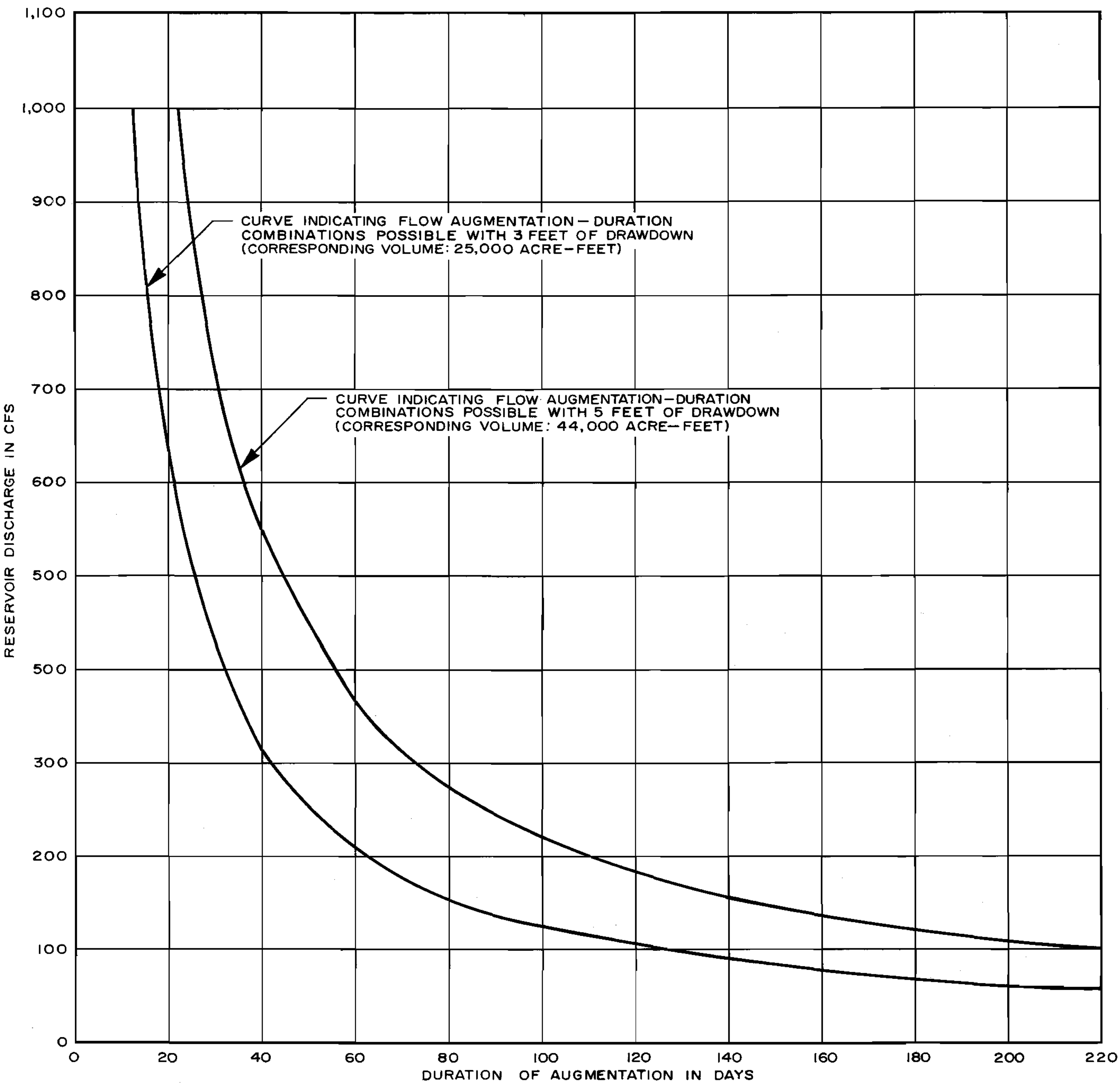
Source: Harza Engineering Company.

in the absence of the impoundment, while the remaining 104 cfs represent streamflow that would have been made possible by, and released from, the Waubeka Reservoir.

Figure 4 shows the time intervals during which various uniform, continuous streamflows could be maintained, exclusive of inflow to the reservoir, by three- and five-foot drawdowns of the Waubeka Reservoir. This graph was used in the aforementioned flow augmentation analyses and would be generally useful in planning the timing, magnitude, and duration of Waubeka Reservoir flow augmentation releases so as to produce drawdowns consistent with use of the reservoir for recreational purposes. Augmentation flows could

Figure 4

WAUBEKA RESERVOIR FLOW AUGMENTATION RELEASES AS A FUNCTION OF DURATION FOR DRAWDOWNS OF 3 AND 5 FEET



NOTE: DRAWDOWN IS ASSUMED TO BEGIN AT CONSERVATION POOL LEVEL, ELEVATION 825 FEET MEAN SEA LEVEL, AND IS EXCLUSIVE OF INFLOW TO THE RESERVOIR.

Source: Harza Engineering Company.

be released at varying times and rates in such a manner as to benefit downstream fish life. Also, occasional large releases could be made to maintain water quality conditions at critical times; to meet unusual water supply needs; or to enhance certain forms of water-oriented recreation, such as canoeing.

Figure 4 indicates that it would be possible to maintain a flow of more than 120 cfs in the river at Estabrook Park, even during a year similar to 1934, the most critical year in the 42-year period of record, and to do so with only three feet of drawdown. The full three feet of drawdown would not have occurred during the three critical low-flow years until October or November, which is well after the close of the lake-oriented recreational season in southeastern Wisconsin. Maintenance of as much as 120 cfs of flow in the Milwaukee River at Milwaukee during the entire summer is probably not necessary, but the drawdown of Lake Waubeka once in 10 years by one to two feet during the peak recreational season and by as much as three feet in the fall would not interfere significantly with other lake uses. It would be possible to refill the reservoir during the subsequent fall-winter-spring period as operation requires.

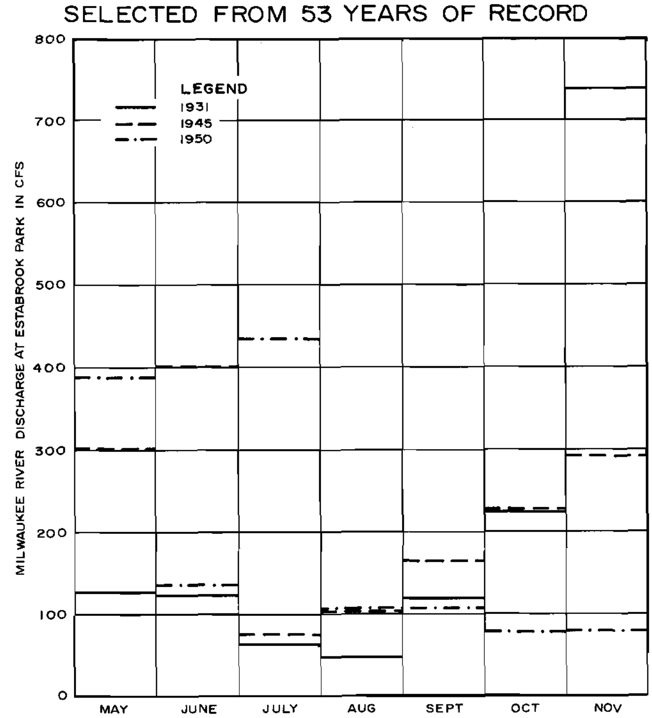
Average monthly Milwaukee River discharges at Estabrook Park for the low-flow periods of three more typical or normal years of record are shown in Figure 5 to provide a comparison with the three years of extreme low flow and to suggest the augmented flow conditions that could exist during years of relatively normal streamflow. For the seven-month period shown in Figure 5, it follows from Figure 4 that three feet of drawdown would increase each monthly average streamflow by 60 cfs, while five feet of drawdown would increase each such streamflow by 100 cfs throughout the seven-month period. It is more likely that, during normal years, water would be released from the reservoir at high rates over selected short periods of time when natural flows are lowest rather than at a uniform rate. For example, in a year with streamflows similar to those that occurred in 1945, releases on the order of 150 cfs or more would be concentrated in the months of July and August, with little flow augmentation provided during other months of the year.

It would be also possible for communities and industries located along the Milwaukee River downstream from Waubeka to utilize the river as a source of water supply by drawing water directly from the river, thus necessitating only very small lifts and short conveyance facilities. Community development on the periphery of, or in close proximity to, the Waubeka Reservoir could consider the impoundment an additional source of water supply, with some areas being served by gravity flow. Such alternatives might prove attractive for some communities within the watershed beyond the design year of the watershed plan as ground water sources are developed to desirable limits. The only other alternative source of water for such communities would be from Lake Michigan, which would require a pump lift of 100 to 300 feet and long conveyance works.

The analyses described above were intended solely to demonstrate the potential of the Waubeka Reservoir to augment low streamflows. No attempt was made to determine or recommend a level at which the low flows should be maintained. Low-flow augmentation requirements will vary with demand conditions and time and would have to be determined in the preparation of an operational plan for the reservoir, should the reservoir be constructed. Although low-flow augmentation would yield fishery, recreation, water supply, and aes-

Figure 5

HISTORIC LOW FLOWS OF THE MILWAUKEE RIVER AT ESTABROOK PARK FOR THREE TYPICAL YEARS SELECTED FROM 53 YEARS OF RECORD



Source: Harza Engineering Company.

thetic benefits throughout the Lower Milwaukee River, the unpredictable nature of the demand for those benefits and their intangible monetary value precludes assignment of a dollar benefit to the low-flow augmentation that would be possible with the development of the Waubeka Reservoir. Therefore, in the subsequent economic analysis of the reservoir, low-flow augmentation benefits are conservatively valued at zero.

Recreation Development: As indicated earlier in this chapter, studies made by the Wisconsin Department of Natural Resources and published in a 1968 report establish the need for additional water-oriented recreational facilities within the Southeastern Wisconsin Region. An evaluation of the capacity of a reservoir to satisfy a portion of this need and the benefits and costs that would accrue to reservoir-recreation development, along with an evaluation of land enhancement that could be expected to take place after a dam and reservoir were built in the watershed, are analyzed and described in Appendix D of Volume 2 of this report. Appendix D indicates that, after a reservoir is constructed, the present worth of the benefits from development of public recreation facilities can be expected to be more than twice the present worth of the recreation facility development and operation costs.

The expected annual visitation to recreation sites is the basis for development of costs of recreation facilities and recreation-user benefits. The demand curve method of analysis, which is determined on a supply-and-demand market basis, was used for evaluation of specific sites. The potential for enhancement of basic land values through residential and commercial development and the economic impact of a reservoir project on the nearby area are also described in Appendix D. The feasibility of a new town development on the shoreline of the reservoir is described in Appendix E.

It is estimated that initial (1970) use of recreation facilities at Waubeka Lake would total 1,560,000 visitations yearly and that recreation use would increase to 2,354,000 annual visitations by 1990 and to nearly 4 million visitations within a period of 50 years. Developed recreation areas would encompass 2,000 acres of land, as shown in Figure 2, with land and facilities required to support the initial levels of use estimated to cost $4,745,000, with additional expenditures of $8,600,000 projected for 1995 and $12,700,000 projected for the year 2015. Annual net benefits from recreation use, exclusive of annual fishery benefits of $850,500, were estimated to total $1,600,000 and $2,470,000, respectively, for the initial and 1990 use levels at Waubeka. For a project with a 50-year life and a discount rate of 6 percent, the present worth of all recreation benefits is $50,362,500, for an average annual benefit of $3,190,000, while the present worth of the recreation capital and operation and maintenance costs is $16,500,000. Therefore, the benefit-to-cost ratio is 3.05. It should be noted that the costs for recreation development around Waubeka Lake are exclusive of allocated reservoir and dam costs.

Enhancement of Land Value and Local Income: Many people have a preference for residential building sites on or near a lakeshore and are willing to pay additional sums of money to satisfy this preference. The resulting increase in the value of land due to the proximity to a water area is an added benefit of a reservoir project. The evaluation of land enhancement benefits was based on the assumption that about 5,220 lots on 3,770 acres adjacent to 120,000 feet of the lakeshore would be sold over a period of 20 years, following development of the reservoir. Land enhancement value, defined as the difference between the present worth of the market value of the developed land minus the present worth of the development costs, is, as calculated in Appendix D of Volume 2 of this report and summarized in Tables D-11 and D-12 of that appendix, $1,615,000, or $435 per acre. Development costs include expenditures for land, sanitary sewers and sewage treatment facilities, water treatment and distribution facilities, street improvements, site preparation, beach and private recreation facilities, planning and engineering services, advertising, sales commissions, and financing. In alternative agricultural use, the land is presently (1969) worth about $3,000,000, or $800 per acre, including structures; and, therefore, residential development on about 45 percent of the periphery of the Waubeka Reservoir would enhance the present worth of the land by $1,615,000, for an increase of approximately 50 percent over its present worth as agricultural land.

Additional evaluations of the impact of a reservoir on the tax base and of the general economy of areas nearby are described in Appendix D of Volume 2 of this report. It is estimated that the gross local income would increase about $3,000,000 annually as a result of the development of the Waubeka Reservoir. As indicated in Appendix D, a temporary decrease in taxable real estate value would probably occur initially; however, in the long run, the municipalities would experience gains more than offsetting such initial losses.

In lieu of benefits from the more usual recreation-related residential land subdivision development described above, land enhancement benefits might in the alternative accrue from the development of a new town complex on a portion of the shoreline of the proposed Waubeka Reservoir. Appendix E of Volume 2 of this report contains a preliminary analysis of three alternative new town complexes, ranging in size from a proposal with a design population of 29,300 people on a total area of 3,950 acres to a community of 57,700 residents encompassing 7,477 acres. New town development was indicated to be feasible at the Waubeka reservoir site, in that the basic requirements for the development of an urban community are met, including sufficient acreage; high-value land and water resources; adequate soil, vegetal, and topographic conditions; and proximity of, and access to, existing employment centers by good transportation facilities. While the aforementioned preliminary assessment establishes the engineering feasibility of new town development at the Waubeka site, it does not indicate whether or not this development would be economically sound, since the extensive analysis required to make that determination is beyond the scope of the watershed study.

Hydroelectric Power Evaluation: A power head of about 30 feet could be developed with the installation of a powerhouse at the Waubeka site discharging to the Milwaukee River. This low head, combined with the flow characteristics of the Milwaukee River, make consideration of a conventional powerhouse at the Waubeka Dam economically unattractive. The U. S. Army Corps of Engineers had previously considered a pumped storage electric power generation project with Waubeka as the upper reservoir and Lake Michigan as the lower reservoir and concluded that such a project was also economically unattractive. For the present study, a similar project was costed for a hydroelectric facility with a peak power capacity of 240,000 kilowatts, a net head of 250 feet, and eight hours of generation per day. The major capital costs for such an installation would be incurred in the construction of water conductors, totaling about 12 miles of open channel and tunnels. The investment cost for powerhouse, switchyard, transmission facilities, water conductors, and engineering would be about $140,000,000, with the water conductors representing almost 85 percent of the cost. This would represent a capital cost of about $585 per kilowatt installed capacity, exclusive of any allocated costs of the dam and reservoir. At present, pumped storage projects are being built for installed capacity costs of about $120 per kilowatt, including costs of the upper reservoirs. The result of this cost analysis was not surprising, as it has been found that pump storage projects of this type are normally uneconomical if the ratio of the length of the conveyance facilities to the head developed is greater than six to one, or if the minimum developable head is less than 300 to 400 feet.

Land and Relocation Considerations and Costs: As shown in Table 18, the cost for purchase and preparation of land and the relocation of houses, buildings, roads, and bridges in the reservoir site, is estimated to total about $19,000,000 and would constitute the largest capital investment incurred in the development of the Waubeka Reservoir. This cost was estimated by assuming that land would be purchased up to the 845-foot contour. There are about 14,500 acres of land enclosed by the 845-foot contour, 2,500 acres more than the area covered during storage of the 100-year watershed-wide flood event, at which time the reservoir surface would be at Elevation 833. Although this represents a conservatively high estimate of the land requirement, it is considered reasonable for cost estimating pur-

Table 18

ESTIMATED LAND AND RELOCATION COSTS FOR THE WAUBEKA RESERVOIR IN THE MILWAUKEE RIVER WATERSHED

ITEM	QUANTITY	UNIT COST	TOTAL COST
ACQUISITION OF LAND (EXCLUSIVE OF IMPROVEMENTS)	14,500 ACRES[a]	$400/ACRE	$ 5,800,000
LAND CLEARING AND PREPARATION (EXCLUSIVE OF STRUCTURE REMOVAL)	3,000 ACRES	500/ACRE	1,500,000
ACQUISITION OF RESIDENTIAL STRUCTURES	170	25,000	4,250,000
ACQUISITION OF OTHER BUILDINGS[b]	260	5,000	1,300,000
RELOCATION OF ROADS AND BRIDGES	--	--	1,150,000
		SUBTOTAL	$14,000,000
CONTINGENCIES - 25 PERCENT			$ 3,500,000
ENGINEERING SERVICES			1,000,000
INTEREST DURING CONSTRUCTION			500,000
		SUBTOTAL	$ 5,000,000
TOTAL RESERVOIR LAND AND RELOCATION COSTS			$19,000,000

[a] INCLUDES 2,500 ACRES IN EXCESS OF THE AREA THAT WILL BE INUNDATED WHEN THE RESERVOIR SURFACE IS AT THE 100-YEAR RECURRENCE INTERVAL FLOOD STORAGE ELEVATION OF 833 FEET, MSL. INCLUSION OF THIS ADDITIONAL LAND IN THE ECONOMIC ANALYSIS IS PRIMARILY INTENDED TO ACCOUNT FOR THE IRREGULAR SHAPE OF REAL PROPERTY BOUNDARY LINES AND THUS THE NECESSITY TO PURCHASE LANDS IN EXCESS OF THAT ACTUALLY REQUIRED TO CONTAIN THE RESERVOIR.

[b] DEMOLITION OR REMOVAL COSTS ARE ASSUMED TO BE EQUAL TO SALVAGE VALUE.

SOURCE- HARZA ENGINEERING COMPANY.

poses at the general planning stage, since taking lines for actual land purchases will have to follow or be otherwise properly related to real property boundary lines rather than topographic contours. The amount of land included in the estimates is enough to contain the dam and reservoir, with 2,000 acres in the flood pool (Elevation 825 to Elevation 833) available for limited shoreland use and an additional 2,500 acres between Elevations 833 and 845 available for less restricted shoreland use.

A survey of property values in the Milwaukee River watershed was made by reviewing classified advertisements appearing in newspapers of local circulation from April of 1968 through March of 1969. Twelve tracts of land suited to agricultural use within or near the Waubeka reservoir area were selected for analysis. The tracts ranged in size from 10 to 163 acres, which areas appeared to be reasonably representative of landholdings within the project area. In general, tracts where a major portion of the cost was in buildings were not selected; and costs for those selected tracts with buildings were adjusted downward by the estimated value of the buildings. Tracts with large areas of wooded and marshy lowlands were also excluded. A weighted average of the owner's asking price per acre was computed for the selected tracts, after deletion of the highest and lowest values. The weighted average was reduced by 5 percent, on the assumption that the asking price is normally about 5 percent higher than the selling price. The adjusted price for the 12 tracts of land ranged from $150 per acre to $700 per acre, exclusive of buildings; and the weighted average price per acre was $346. Based on the results of this survey, a conservative purchase price of $400 per acre, exclusive of structures, was used in the economic analysis of the Waubeka reservoir development.

The value of 170 private homes and 260 other buildings located within the reservoir site was estimated separately from the land values. Average prices of $25,000 per home and $5,000 for each outbuilding were used. Total building counts and estimates of wooded acres which would require clearing within the reservoir site were made based on 1967 aerial photographs. A total of about 3,000 acres of land would require clearing and preparation prior to inundation.

Road and bridge relocation requirements were analyzed from 1967 aerial photographs. Based on the need to relocate 12 miles of two-lane roads and bridges, as shown in Figure 2, the road and bridge relocation cost was estimated at $1,150,000. There were no water or sewage treatment plants, electrical or gas transmission lines, or other major utilities within, or adjacent to, the reservoir site which would require relocation.

Dam and Outlet Work Design and Costs: The required dam could be built on the Milwaukee River at River Mile 47.0, approximately 1.4 miles upstream from the existing weir at Waubeka and about one mile downstream from the mouth of the North Branch tributary, as shown in Figure 2. The dam and spillway would consist of a 1,300-foot-long earth embankment, with a concrete weir and gated control located in the middle portion of the structure. The dam superstructure would rest on the existing rock foundation at Elevation 783 and rise 57 feet to a dam crest elevation of 840. The concrete ogee spillway would have a 50,000 cfs discharge capacity, a total width of 460 feet, a crest elevation of 825, and would be surmounted by a system of 10-foot-high radial gates. The topographic saddle located on the left bank[11] of the river is a potential alternate location for the spillway. The final selection of spillway location would be made during engineering design studies undertaken subsequent to a decision to construct the reservoir.

Site Foundation Characteristics

The dam site is located in a reach of the Milwaukee River which has a broad, flat valley with gentle slopes on both abutments. Soils maps for the reservoir site and environs were available from the detailed operational soil survey conducted for the Commission by the U. S. Soil Conservation Service, and foundation condition data were available from earlier joint studies made by the Federal Works Progress Administration and the Wisconsin Public Service Commission. The latter data from 150 boreholes and two test pits indicate

[11] *"Left" or "right" bank of a river, as identified in this report, is that bank as seen looking downstream.*

bedrock at depths of 1 to 13 feet along the axis of the proposed dam, with the bedrock generally overlain locally by sand and gravel deposits. These deposits, in places are, in turn, generally covered by clay or loam and clay soils. The maximum thickness of the sand and gravel deposits along the axis of the dam is three feet. A thickness in excess of 7.3 feet is reported in borings taken 200 feet upstream to the west. Treatment of these zones would be required to prevent seepage.

Dam site topography, the proposed dam axis, and the location of boreholes and test pits, as reported in the aforementioned joint WPA-PSC study, are shown in Figure 6; and a cross section through the dam site along a line corresponding to the dam axis appears in Figure 7. The soils survey data indicate possible permeable conditions on the south abutment. On the north abutment, clayey subsoil is mapped in the crest area. This material is described as having low bearing capacity when wet and high shrink-swell potential. Also mapped along the axis on the left abutment are areas of loamy outwash overlying loose sand and gravel, a highly permeable zone, and alluvial land. This information compares favorably with information shown on the aforementioned geologic sections.

The analyses of the available foundation investigation and soils data, supported by the results of a field reconnaissance survey conducted by geologists and foundations engineers at the Harza Engineering Company, indicate that the Waubeka site has the most promising foundation conditions of all of the remaining large reservoir sites within the watershed and that no unusual foundation problems or costs should be encountered in the construction of a dam at this site.

Dam and Spillway Configuration

A preliminary project layout, as described below, was made for the purpose of establishing the project features necessary for the preparation of project cost estimates. The proposed layout of the dam, spillway, and outlet works based upon the analyses of information collected by the geologists and engineers of the Harza Engineering Company during the site inspection; upon information obtained in previous investigations of the topographic and subsurface conditions at the site; and upon analyses of the hydrologic, hydraulic, and foundation conditions at the site is shown in Figure 2.

Because of the presence of the sand and gravel deposits overlying the bedrock foundation, a full foundation cutoff, consisting of the extension of the impervious core of the embankment to bedrock, was included in the layout and estimates of cost. Excavation under the concrete ogee spillway and stilling basin was also extended to the bedrock. The rock would be grouted under the dam to complete the seepage barrier.

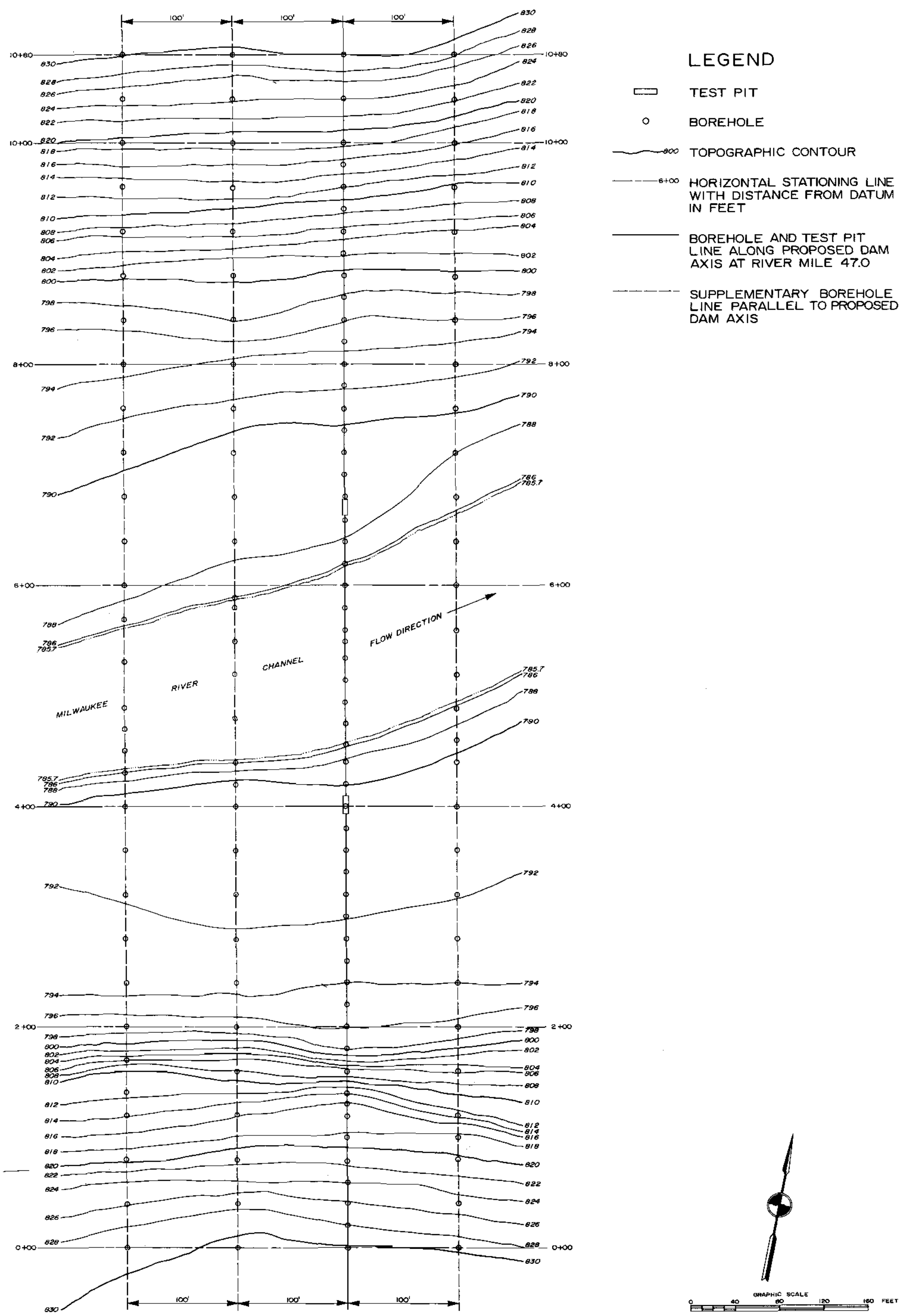
The spillway crest elevation was set at the proposed conservation pool level of 825. This would permit storage of approximately all of the 100-year recurrence interval flood volume of 89,500 acre-feet in eight feet of rise in the reservoir surface to Elevation 833, with the crest gates closed. The spillway was made wide enough to pass the maximum probable flood[12] of 50,000 cfs with a rise of 10 feet to Elevation 835. The gross width of the spillway would be 460 feet; and flow over the crest would be controlled by 10 radial gates, each 10 feet high, with a 42-foot-wide opening. The maximum height from the rock foundation to the ogee crest would be 42 feet, and the dam height would be 57 feet. Energy of the flow over the crest would be dissipated by a concrete stilling basin about 450 feet wide and 50 feet long. Baffle-blocks and an end sill would be positioned in the stilling basin to increase the slope of the energy gradient within the basin.

Downstream low-flow augmentation and water supply quality and quantity requirements would be met with multiple-depth, gated outlet works in the dam, each consisting of a sluice gate mounted in the upstream face of the concrete spillway section connecting

[12] *The maximum probable flood is defined as the largest flood that can be expected, assuming maximum simultaneous occurrence of all theoretically possible flood-producing factors in the watershed area. It would be catastrophic in nature and, for economic reasons, has little bearing on floodland use regulations or even engineering design, except for determining spillway capacities of major dams.*

Figure 6

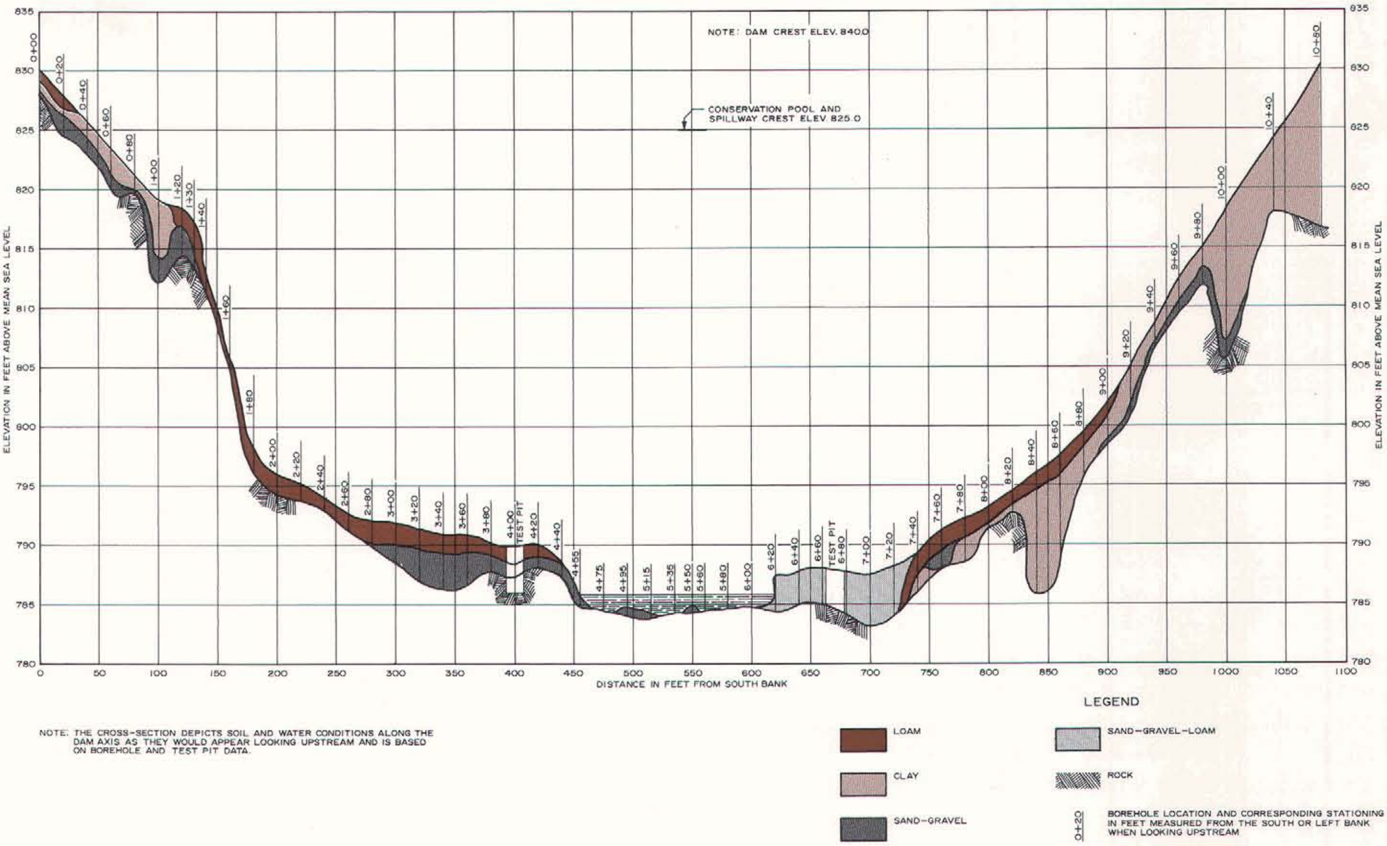
TOPOGRAPHY AND BOREHOLE LOCATIONS AT THE WAUBEKA DAM SITE ON THE MILWAUKEE RIVER AT RIVER MILE 47.0



Source: Wisconsin Public Service Commission and The Works Progress Administration.

Figure 7

VALLEY CROSS-SECTION ALONG THE AXIS OF THE PROPOSED WAUBEKA DAM ON THE MILWAUKEE RIVER AT RIVER MILE 47.0



Source: Wisconsin Public Service Commission and The Works Progress Administration.

to a conduit through the dam and discharging into the stilling basin. These outlet works would also facilitate drawdown of the reservoir surface below the spillway crest elevation of 825 in anticipation of, and to provide storage for, major flood events. A minimum of three different outlet depths would be provided between the base of the dam at Elevation 783 and the spillway crest at Elevation 825. The sluice gates would allow for the discharge of variable flow rates through each outlet and would also facilitate the operation of the outlets either individually or in combinations. A subsequent section describes the need for, and use of, the multiple-depth, gated outlet works.

The embankment portions of the dam would be earthfill having two primary zones. The inside impervious core zone would have a top width of 20 feet at Elevation 838 and extend to the stripped earth foundation at side slopes of one on two. The impervious zone would extend vertically below the earth foundation to bedrock. The outside pervious zone would have a top width of 30 feet at Elevation 840 and would extend to the stripped earth foundation at side slopes of one on three upstream and one on two and one-half downstream. Wave protection would be provided on the upstream slope by a one-foot thickness of sand and gravel bedding, overlain by two feet of rock riprap. The fill portions would be supported at the ends adjacent to the spillway by concrete retaining walls, which would be incorporated into the spillway and stilling basin end walls.

The cost of construction of the dam, spillway, outlet works, and appurtenant facilities at Waubeka, as shown in Table 19 and based upon 1969 prices, is estimated at $2,849,000.

Table 19

SCHEDULE OF ESTIMATED COSTS FOR THE WAUBEKA DAM IN THE MILWAUKEE RIVER WATERSHED

ITEM	QUANTITY	UNIT COST	TOTAL COST
FOUNDATION EXCAVATION (COMMON)	6,300 CU. YDS.	$ 2.00	$ 12,600
FOUNDATION EXCAVATION (ROCK)	3,200 CU. YDS.	5.00	16,000
FOUNDATION STRIPPING	3,900 CU. YDS.	2.00	7,800
EXCAVATION FROM BORROW	122,000 CU. YDS.	1.00	122,000
PLACE & COMPACT IMPERVIOUS EMBANKMENT	32,000 CU. YDS.	0.30	9,600
PLACE & COMPACT PERVIOUS EMBANKMENT	76,000 CU. YDS.	0.20	15,800
RIPRAP	6,500 CU. YDS.	9.00	58,500
SAND AND GRAVEL BEDDING	3,400 CU. YDS.	4.00	13,600
MASS CONCRETE IN SPILLWAY	16,610 CU. YDS.	50.00	830,000
CONCRETE STILLING BASIN FLOOR	1,610 CU. YDS.	60.00	96,500
CONCRETE WALLS, PIERS AND DECK	4,830 CU. YDS.	80.00	386,400
SPILLWAY CREST RADIAL GATES	150,000 LBS	0.65	97,500
EMBEDDED METAL FOR GATES	30,000 LBS	1.20	36,000
GATE HOISTS (15 TON)	10	7,500.00	75,000
REINFORCING STEEL	1,420,000 LBS	0.18	256,000
MOBILIZATION FOR GROUTING	--	--	10,000
DRILLING GROUT HOLES	3,700 FT	4.00	14,800
CONNECTION TO GROUT HOLES	125	12.00	1,500
CEMENT GROUT	3,700 SACKS	2.00	7,400
CARE AND DIVERSION	--	--	20,000
MULTIPLE DEPTH GATES	--	--	9,000
		SUBTOTAL	$ 2,096,000
CONTINGENCIES - 25 PERCENT			$ 523,000
ENGINEERING SERVICES			150,000
INTEREST DURING CONSTRUCTION			80,000
		SUBTOTAL	$ 753,000
TOTAL DAM COST			$ 2,849,000

SOURCE- HARZA ENGINEERING COMPANY.

Foregone Opportunities and Costs: It is assumed that the basic land value of $400 per acre for existing lands in the Waubeka reservoir site is the result of the potential of the land for the production of timber, agricultural crops, livestock, and wildlife; and, therefore, these values are automatically reflected in the economic analyses. The wildlife habitat in the reservoir area consists primarily of swamps, marshes, and upland wooded areas, which constitute about 25 percent of the total reservoir area. Although these areas do cover the entire range of habitat enjoyed by wildlife, they are limited in size and are of minor importance within the watershed as a whole. The full range of existing wildlife areas in the potential reservoir area includes 1,200, 500, and 200 acres of high-, medium-, and low-value wetland, respectively, for a total of 1,900 acres. Wildlife habitat in the Waubeka reservoir site also includes 600 and 150 acres of high- and medium-value woodland, respectively, for a total of 750 acres; and, therefore, 2,650 acres of existing wetland and woodland wildlife habitat would be eliminated by the Waubeka Reservoir.

Generally, those wildlife species that dwell in both swamp and drier types of woodlands, such as deer, rabbit, and squirrel, will be temporarily lost through reservoir construction and replaced by aquatic habitat species, such as waterfowl and shorebirds. The diversity contributed by the existing swamps, marshes, and riverine shoreline areas would be lost. None of these areas, however, are unique within the watershed nor do they support any known rare or unique species of plant or animal life. Moreover, some initial wetland, woodland, and wildlife losses would be compensated for by similar natural development on the shores of the reservoir. The elimination of wildlife habitat areas can be compensated for in part by reservation of lake shoreline areas for protection of wildlife. A portion of the reservoir shoreline would, by design, remain in a "natural state," the term "natural" referring to that state of the shoreline following the filling of the reservoir. These natural areas would include marshy areas bordering shallow water areas and would normally be located in the upper reaches of an impoundment. If these areas are protected from disturbance, they will, in time, fill in with sediment, be invaded by vegetation, and form desirable wetlands for habitation by waterfowl and other birds and for muskrats. Water levels could be managed to promote desirable stages of aquatic plant succession.

Reservoir Sedimentation Analysis: As described in Chapter VI, Volume 1, of this report, sediment yield from the Milwaukee River watershed was estimated utilizing, as a basis, actual sediment measurements made in the Milwaukee, Root, and Sheboygan Rivers. The yield values derived from these measurements were compared with published estimates of sediment yields for the nearby Baraboo, Crawfish, and Rock Rivers.[13] These comparisons indicated that the derived yield values were consistent with the published estimates of the other agencies; and it was, therefore, concluded that depletion of storage in reservoirs on the Milwaukee River system due to sediment deposition would be negligible.

The probable sediment loading in the Milwaukee River was estimated to fall within the range of 16 to 61 tons per square mile of drainage area per year. Based upon the calculated unit yields, the probable loss of storage in the proposed Waubeka Reservoir over a 50-year period may be expected

[13] *Summary of Reservoir Sediment Deposition Surveys Made in the United States through 1960, Miscellaneous Publication No. 964, Agricultural Research Service, U. S. Department of Agriculture, in cooperation with the Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources, and Draft No. 2 of Appendix G, "Fluvial Sediment in the Upper Mississippi River Basin," U. S. Department of the Army, Corps of Engineers, prepared by an Interagency Task Force on Sedimentation, March 1, 1967.*

to range from about 200 to 760 acre-feet, due to the deposition of from 325,000 to 1,240,000 tons of sediment.[14] This relatively small volume of sediment, deposited over a 50-year period, represents less than 1 percent of the volume of the proposed 155,000 acre-foot Waubeka Reservoir and would not constitute a significant problem.

Water Quality Effects Attributable to Impoundment: The present status of stream and lake water quality in the watershed is described in Chapter IX, Volume 1, of this report. Future water quality conditions within the watershed will depend, to a large degree, upon land and water management practices and whether both urban and rural development within the watershed is carefully planned and guided in the public interest or allowed to continue in a largely uncontrolled manner. Alternative measures which may be implemented to cope with the present and projected future water quality problems of the watershed are described in Chapter V, Volume 2, of this report.

Water quality affects the public health, the overall quality of the environment, and the economic and aesthetic aspects of present and potential instream and withdrawal water uses. In general, benefits accrue from a level of water quality which permits the use of water for recreational activities, public and industrial water supply, fish and wildlife propagation and conservation, and aesthetic enjoyment. Costs are incurred and benefits reduced if water quality restricts these uses; makes treatment for beneficial uses more costly; results in the necessity of substituting more remote and, therefore, possibly more expensive water-based recreational activities; or results in corrosion or scaling of domestic, transportation, and industrial equipment and facilities coming in contact with the water. Adverse water quality can also result in loss of aesthetic enjoyment and reduced land values because of excessive aquatic growths.

Multiple-depth, gated outlet works proposed for the dam, in combination with water quality sampling operations in the impoundment, are intended to facilitate management of not only the quantity but also the quality of both the water within, and the water withdrawn from, the Waubeka Reservoir. In the absence of such positive control arrangements, water quality problems may develop in, and downstream of, the impoundment due to the wide temporal and spatial variation in water quality characteristics that typically develop in a deep lake or reservoir located in a temperate climate.

Spatial water quality differences would be most pronounced in the Waubeka Reservoir during the summer because of the phenomenon of thermal stratification, characterized by the development of an upper warm zone called the epilimnion and a lower cold zone referred to as the hypolimnion, separated by an intermediate transition region. The warm epilimnion, because of its susceptibility to mixing by the wind, its contact with the atmosphere, and its penetration by solar radiation, would be well oxygenated and have the potential to support rooted plant life and algae subject to the necessary supply of nutrients.

The cold hypolimnion, because of its physical separation from the atmosphere, would not be illuminated enough to support extensive plant life and would not receive oxygen in sufficient quantities to replace that used to satisfy the existing oxygen demand. The hypolimnion will, therefore, contain lower oxygen concentrations than the epilimnion; and its lower strata may even become anaerobic, especially during the early years following filling of the reservoir, because of the oxygen-demanding organic material that will be inundated. Low oxygen levels may result in the development of hypolimnetic odor, color, low pH, and the solution of potentially troublesome materials.

Iron and manganese are typical of these, in that even in solution concentrations as small as several milligrams per liter, they can cause troublesome staining and incrustation problems throughout a water supply system or industrial process that uses water from the bottom of the impoundment by either extracting it directly from the reservoir or by withdrawing it from the river immediately downstream from the dam to which the water has been released. The hypolimnion will tend to contain larger concentrations of nut-

[14] *The estimated annual dry weight in tons of sediment accumulation in the Waubeka Reservoir was based on the conservative assumption that all suspended sediment entering the impoundment would be ultimately trapped there and was computed as the product of the 406-square mile area tributary to the dam site and the unit sediment contribution ranging from 16 to 61 tons per square mile per year. The resulting calculated annual sediment accumulation in dry weight was converted to the volume it would occupy after settling to the reservoir bottom by dividing by a unit weight of 75 pounds of dry solids per cubic of deposited sediment, which is equivalent to 1,620 tons per acre-foot.*

rients attributable to the decomposition of organic material that was originally at the reservoir site or settled to the bottom from the epilimnion. Hypolimnetic waters will probably be more turbid than the remainder of the impoundment, especially during and immediately after summer rainfall events, when inflowing turbid water, because of its greater density relative to the reservoir water, will tend to move as a discrete current along the reservoir bottom as the sediment and other material slowly settle to the reservoir bottom.

The horizontal strata positioned between the epilimnion and the hypolimnion will exhibit a gradation in water quality parameters ranging from the conditions found in the epilimnion to those that characterize the hypolimnion. Spatial water quality differences will occur not only during the summer but also at other times; however, summer variations are the most pronounced and most significant from an operational point of view, since the greatest demands, including some conflicting uses, are placed on a reservoir-river system during the summer. The wide spectrum of water quality characteristics within the impoundment, especially during the summer period, presents the opportunity to optimize the use of the available water resource by selectively withdrawing and releasing water exhibiting quality characteristics consistent with its intended use. Manipulation of reservoir releases would be accomplished by the proposed multiple-depth, gated outlet works in combination with impoundment water sampling.

For example, summer low-flow augmentation for downstream fishery enhancement requires the release of water that is relatively cold but contains a minimum oxygen concentration necessary to support fish life. Such water would be found at, and therefore withdrawn from, some intermediate depth, with the precise withdrawal depth determined by current reservoir and river water quality conditions.

If the intent of reservoir releases is to augment downstream dissolved oxygen levels for water quality enhancement, irrespective of stream temperature, then high level outlets would be used to selectively release oxygen-rich waters found at or near the reservoir surfaces. Immediately after release through the dam, supplemental oxygen would be added as the river flows over the Waubeka weir, and additional aeration potential would be provided by flow over the series of seven dams beginning in the Village of Grafton and extending downstream into the City of Milwaukee.[15] Although aeration potential at dams exists at present, the oxygen demands on the river are relatively great compared to the total oxygen in solution during periods of low flow; and, thus, oxygen-rich Waubeka reservoir releases could greatly increase the total dissolved oxygen supply in the river during these critical periods.

Operation of the Waubeka Reservoir multiple-depth, controlled outlet works would serve to reduce the marked variations in river water quality that presently occur downstream of the impoundment site due to short-term storm water runoff and long-term seasonal changes in the proportion of ground water contribution to the total flow. With a more uniform water quality, the Milwaukee River water should be better suited for certain uses than at present.

The selective withdrawal capability proposed for the Waubeka Reservoir would provide, in addition to the control of downstream water quality, the potential for enhancement of water quality within the impoundment. For example, if the lower strata of the hypolimnion along with the reservoir bottom are occasionally subjected to the influx of turbidity during severe rainfall events in quantities sufficient to interfere with the feeding and reproduction of the fish population, it would be possible to route the sediment-laden current through the reservoir by use of the gated outlets in the dam. Such an operation would, however, have to consider possible detrimental effects on the Milwaukee River downstream of the dam. Similarly, if hypolimnetic oxygen depletion threatens the fish population or produces noxious odors, the troublesome strata could be selectively withdrawn from the impoundment and discharged downstream at a time and at a rate consistent with downstream river uses.

Experience on large, moderately deep natural lakes in the watershed has shown that these bodies of water do not suffer overriding water quality problems even though, unlike the Waubeka Reservoir, they are subject to: 1) long (three or more years) residence times of water due to small

---

[15] *These dams are described in Chapter V of Volume 1 of this report, and the measured effects of existing structures on instream dissolved oxygen are documented in Chapter IX of Volume 1 of this report.*

drainage areas in relation to storage volumes; 2) effects of residential land uses with on-site sewage disposal systems located along high percentages of the lake shoreline; 3) relatively poor control of domestic sewage flows.

Of the 21 major lakes in the watershed ranging from 50 to 100 acres in surface area, 13 exhibit overabundant aquatic plant growth. This and other water quality problems, however, are generally directly traceable to nutrient contribution from domestic sewage and farm runoff. Implementation of present state standards and orders concerning wastewater treatment and adoption and implementation of the comprehensive watershed plan recommended herein would not only serve to protect and enhance the quality of water in the existing lakes but would be decisive in protecting the quality of water in the Waubeka Reservoir.

Land in the drainage area tributary to the North Branch of the Milwaukee River, above and including the main body of the proposed Waubeka Reservoir, is primarily in agricultural and open-space use. Only small communities exist in the area, with the two largest—Adell and Random Lake—being served by wastewater treatment plants. The effluent from these plants is of good quality and is normally not discharged directly to receiving streams but is first impounded in lagoons or diverted for irrigation. By the time these small effluent discharges would reach the Waubeka Reservoir, they should have very low organic and nutrient concentrations. The lower short arm of Lake Waubeka centers along five miles of the main stem of the Milwaukee River. This part of the reservoir would receive flow from the entire upper Milwaukee River watershed, including effluent from the Campbellsport, Kewaskum, West Bend, and Newburg wastewater treatment plants. If the water quality control recommendations contained in the watershed plan are implemented, all of these communities will provide high levels of removal of organics and of the nutrient phosphorus. Therefore, no oxygenation or sludge problems should develop in the Waubeka Reservoir; and, due both to the relatively low levels of nutrient discharge and an indicated reservoir-wide time of residence of less than one year, no unusual problems due to eutrophication would be expected to develop in this arm of the reservoir.[16]

[16] *During the annual wet season, inflow to this short arm of the Waubeka Reservoir would equal the volume of the stored water within a period of 30 to 60 days.*

Water quality conditions in the Waubeka Reservoir would be conducive to the development of a self-sustaining sport fishery. As indicated earlier in this chapter, the potential fishery development is determined primarily by temperature and dissolved oxygen requirements, with consideration given to the possible influx of toxic substances and the likelihood of winterkill, which is common in very shallow lakes.

Since there are no industrial, large commercial, or other significant sources of thermal and toxic pollution tributary to the Waubeka Reservoir, detrimental thermal or toxic effects from such sources should not present a problem. Daily and seasonal temperature fluctuations would occur in areas of relatively shallow water similar to those documented in Chapter IX of Volume 1 of this report, for existing impoundments. Considering the 40 feet maximum depth and the short residence time of water in the reservoir, these temperature fluctuations should not significantly affect fishery resources in the lake. The relatively great depth of the reservoir also essentially eliminates the possibility of winterkill. This excellent potential fishery resource would be best managed by, or in cooperation with, the Wisconsin Department of Natural Resources to provide maximum fishing opportunities.

It may be expected that, with carefully regulated land development and with the exercise of the water quality control elements proposed in the recommended comprehensive watershed plan, the Waubeka Reservoir would become a high-quality lake with a good balance among plant, wildlife, aquatic, and human life and uses. As already noted, the generally good condition of existing lakes in the watershed, which have poor hydrologic conditions relative to Lake Waubeka and around which land use is often intensive, indicates that the large, moderately deep reservoir should have a reasonably high level of water quality and, as such, be an asset to the watershed.

Summary of Benefits and Costs: Benefits and costs attendant to the proposed multiple-purpose Waubeka Reservoir are summarized in Table 20 for a 50-year project life and a 6 percent interest rate. The benefit-cost ratio for flood control, recreation, and low-flow augmentation and municipal water supply, but exclusive of any land enhancement benefit, is 1.33, and, including benefits for land enhancement around the reservoir site, is 1.37.

Table 20

ESTIMATED COSTS AND BENEFITS FOR THE MULTIPLE PURPOSE WAUBEKA RESERVOIR PROJECT IN THE MILWAUKEE RIVER WATERSHED[a]

SCHEDULE OF COSTS

ITEM	CAPITAL COST	PRESENT WORTH OF CAPITAL COST	ANNUAL COST: AMORTIZATION OF CAPITAL COST	ANNUAL COST: OPERATION AND MAINTENANCE	ANNUAL COST: TOTAL	PRESENT WORTH OF COSTS
RESERVOIR--LAND AQUISITION AND STRUCTURE RELOCATION	$19,000,000	$19,000,000	$ 1,205,000	$ 80,000	$ 1,285,000	$20,300,000
DAM	2,849,000	2,849,000	181,000	--[b]	181,000	2,849,000
RECREATION FACILITIES[c]	26,045,000	8,655,000	548,000	500,000[d]	1,048,000	16,500,000
TOTAL	$47,894,000	$30,504,000	$ 1,934,000	$580,000	$ 2,514,000	$39,649,000

SCHEDULE OF BENEFITS

ITEM[e]	ANNUAL BENEFIT	PRESENT WORTH OF BENEFITS
FLOOD CONTROL	$ 149,500	$ 2,350,000
RECREATION[f]	3,190,000	50,362,500
LAND ENHANCEMENT	102,500	1,615,000
TOTAL	$ 3,442,000	$54,327,500

PROJECT BENEFIT-COST RATIO--1.37
ANNUAL BENEFITS MINUS ANNUAL COSTS--$928,000

[a] ECONOMIC ANALYSES ARE BASED ON AN ANNUAL INTEREST RATE OF SIX PERCENT AND ASSUME THAT THE PROJECT WOULD BE INITIATED IN 1970 AND WOULD HAVE A 50 YEAR LIFE.

[b] DAM OPERATION AND MAINTENANCE ARE INCLUDED IN THE ANNUAL RESERVOIR OPERATION AND MAINTENANCE COST.

[c] INCLUDES AN INITIAL RECREATION FACILITY COST OF $4,745,000 (SEE TABLE D-5) AND REPLACEMENT OF AND ADDITION TO THOSE FACILITIES IN 1995 AND 2015 AT COSTS OF $8,600,000 AND $12,700,000, RESPECTIVELY.

[d] AVERAGE VALUE FOR THE PROJECT LIFE BASED ON A UNIT COST OF $0.20 PER VISITATION.

[e] AS DESCRIBED IN APPENDIX D, THE PRESENCE OF RESERVOIR RECREATION OPPORTUNITIES WOULD STIMULATE RETAIL TRADE SUCH THAT NET LOCAL INCOME WOULD INCREASE BY ABOUT $3,000,000 ANNUALLY. THIS SECONDARY BENEFIT IS NOT INCLUDED IN THE TABLE SINCE THE ECONOMIC ANALYSIS DOES NOT INCLUDE THE CAPITAL COSTS THAT WOULD BE REQUIRED TO EXPAND EXISTING BUSINESSES AND TO ESTABLISH NEW ONES IN ORDER TO ACCOMMODATE THE INFLUX OF RECREATIONISTS. LOW FLOW AUGMENTATION COULD YIELD FISHERY, RECREATION, WATER SUPPLY AND AESTHETIC BENEFITS DOWNSTREAM OF THE PROPOSED IMPOUNDMENT SITE. HOWEVER, THE UNPREDICTABLE NATURE OF THE DEMAND FOR THESE BENEFITS AND THEIR INTANGIBLE MONETARY VALUE PRECLUDES ASSIGNMENT OF A DOLLAR VALUE TO THE LOW FLOW AUGMENTATION CAPABILITY OF THE RESERVOIR.

[f] INCLUDES ANNUAL FISHERY BENEFITS OF $850,500 HAVING A PRESENT WORTH OF $13,405,500.

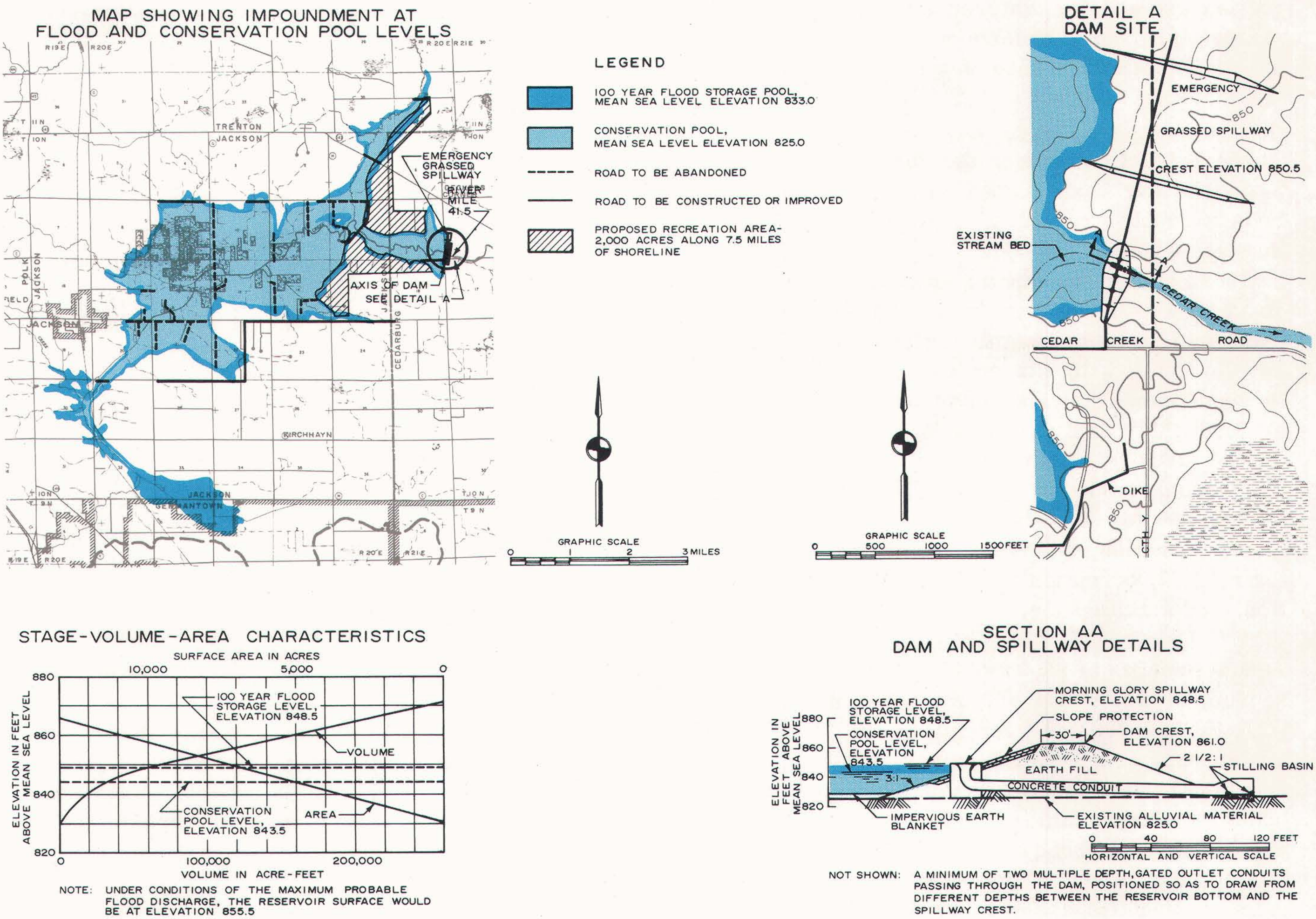
SOURCE- HARZA ENGINEERING COMPANY.

This plan element would serve to assist in meeting certain important watershed land use development objectives, including those relating to recreational uses, as well as the watershed flood control and water quality control objectives. As already noted, flood peaks and associated flood damages would be entirely eliminated along the entire main stem of the Milwaukee River from the structure to the City of Milwaukee for all floods up to and including the 100-year recurrence interval event. The proposed reservoir may be expected to lower the high water elevation of the 100-year recurrence interval flood on the Milwaukee River approximately 4 feet at the Kletzsch Park Dam, 3 feet at Thiensville, 5 feet at Grafton, 10 feet at Saukville and 4 feet at Waubeka. The flood control provided by the reservoir could be of inestimable value to the City of Milwaukee which, though it should not suffer damage during a 100-year flood event, could be expected to sustain damages during larger floods if no upstream control is provided.

Horns Corners Reservoir: The initial screening process indicated that the Horns Corners Reservoir was one of the four practicable reservoir sites remaining in the watershed and deserving more detailed study. Figure 8 illustrates the essential features of the impoundment and the dam, showing, in particular, the horizontal extent of the reservoir when the water surface is at both the conservation and flood pool level; impound-

Figure 8

HYDROGRAPHIC AND STRUCTURAL FEATURES OF A POTENTIAL MULTIPLE-PURPOSE HORNS CORNERS RESERVOIR ON CEDAR CREEK IN THE MILWAUKEE RIVER WATERSHED



Source: Harza Engineering Company.

ment volume and surface area as a function of pool stage; and the structural aspects of the dam and its spillway, including key elevations.

The impounding structure would be an earthfill dam, rising 36 feet above the alluvial foundation in the stream bed of Cedar Creek at a site in Section 7, Town 10 North, Range 21 East, about eight miles upstream from the City of Cedarburg. The proposed reservoir would center along Cedar Creek for a distance of about eight miles from Horns Corners to the Village of Jackson. The proposed reservoir would have a surface area of 5,000 acres at Elevation 843.5, the proposed conservation pool level. Average lake depth would be about 6 feet, with a maximum depth of 18 feet. Storage at the conservation pool level would be 35,000 acre-feet; and the entire 30,000 acre-foot volume of a 100-year recurrence interval flood on the Cedar Creek subwatershed area tributary to the Horns Corners site could be stored in the 30,000 acre-foot flood storage volume between Elevations 843.5 and 848.5. At Elevation 848.5 the area of the lake would grow to 7,000 acres. The storage potential in the conservation pool represents 110 percent of the annual yield from the 63,000-acre drainage area, based on six inches of runoff for a year of average wetness; and, thus, the reservoir could be expected to fill in about two years.

In addition to providing for flood abatement, the reservoir could perform streamflow augmentation and water supply functions, with some fluctuation of the lake level. Due to its size, the lake would afford good opportunities for water-oriented recreation use and for water-related recreation and residential land development in an area within easy commuting distance of the Milwaukee urbanized area.

The construction cost of the dam is estimated at \$623,000; the cost of acquisition of the lands and relocation of structures, utilities, and roads in the reservoir, at about \$15,993,000; and the development of attendant recreation facilities, at about \$6,160,000. This latter cost represents the estimated initial capital outlay for recreation development, with staged construction projected to require additional expenditures of \$12,600,000 by about the year 1995 and \$18,700,000 additional expenditures by about the year 2015. The average annual costs total \$2,539,600 and would be \$1,134,600 for the dam and reservoir development, operation, and maintenance and \$1,405,000 for related recreation facility development, operation, and maintenance.

Annual benefits of \$3,053,000 could be expected to accrue, of which \$54,500 would be for flood control; \$2,950,000 for recreation; and \$48,500 for the enhancement of land values. These primary and identifiable benefits would result in a project benefit-to-cost ratio of 1.20. No economically viable potential presently exists for the production of electrical power at this site. In addition to the primary benefits assigned monetary values, significant secondary benefits could be expected to accrue to which no monetary values were assigned. These include, among others, the economic stimulation engendered through construction of the dam and supporting facilities and development of recreational and recreation-related residential land uses in the vicinity of the reservoir.

The costs of opportunities foregone were not directly identified but were assumed to be included in the costs of land. A potential presently exists to support hunting and fishing in woodland and wetland areas of the proposed reservoir site. The potential for these types of recreational activities and for additional water-oriented recreation activities that would be created by the development of the reservoir are, however, only marginally greater than those supplanted. Certain valuable elements of the natural resource base would be lost, the most important of which is the Jackson Marsh, an important existing state-owned wetland. An equivalent area could not be established anywhere else within the watershed. Some of the loss could be offset by the creation of new wetland areas along certain portions of the shoreline of the reservoir; by reforestation of other reaches of the shoreline; and by the creation of waterfowl habitat, particularly for spring and fall migrants.

Flood Control Operation and Resulting Benefits: Application of the flood-flow simulation model indicated that a 100-year recurrence interval flood event for the area tributary to the Horns Corners site will generate a peak discharge of about 6,000 cfs and a corresponding flood volume of approximately 30,000 acre-feet that would require seven days for its passage. A 10-year flood event at Horns Corners would generate a peak discharge of about 3,100 cfs, a volume of 14,000 acre-feet, and have a time base of seven days.[17] The stage-volume curve for the proposed impoundment shown in Figure 8 indicates that 31,000 acre-feet of water, or all of the 100-year flood volume entering the impoundment, could be stored between the conservation pool level at Elevation 843.5 and the flood stage pool level at Elevation 848.5.

Although major floods on the Milwaukee River can occur in any season of the year, as described in Chapter IV, Volume 1, of this report, such floods are more likely to occur in early spring. Since recreation activity would be at a minimum during this period and there would be no need for flow augmentation during the spring, it would be possible to draw down the reservoir level to an elevation several feet below the conservation pool level during the winter in preparation for storage of spring floodwaters and, thus, completely contain runoff from floods even more severe than the 100-year flood event. The amount of drawdown would be related to the accumulated snowpack on the Cedar Creek subwatershed. If the snowpack were light, only a minor drawdown would be made, while if the snowpack were deep in terms of its water equivalent, a greater drawdown would be made.

---

[17] *For a watershed-wide 100-year recurrence interval flood event, the peak discharge at the Horns Corners site would be 3,120 cfs and the volume, 21,000 acre-feet, while the 10-year recurrence interval watershed-wide flood event would have a peak discharge of 1,680 cfs and a volume of 10,000 acre-feet.*

The potential benefits that would accrue to the reservoir for flood control were estimated by operating the flood-flow simulation model for the 10-year and the 100-year recurrence interval watershed-wide floods with all flows originating upstream from the dam being stored in the Horns Corners Reservoir. The reduction to the flood damages, as estimated in Chapter VIII, Volume 1, of this report, was then calculated utilizing the revised flood profiles. With the Horns Corners Reservoir operated as described above, there would be very little abatement of damage under conditions of uncontrolled land use development during a 100-year recurrence interval flood on the entire Milwaukee River watershed and only a 55 percent reduction during a 10-year recurrence interval watershed-wide flood event.

Flow Augmentation and Water Supply Consideration: A study was made to determine the potential of the Horns Corners Reservoir for stabilizing seasonal stream discharge by regulation of low flows experienced along Cedar Creek and the Milwaukee River and to determine the additional effect of releasing water from storage to augment the regulated low flows. This regulation and augmentation of low streamflows would be beneficial to fish life and recreational water uses; would enhance water quality by dilution and flushing; and could serve as a source of municipal and industrial water supply. At present, dissolved oxygen levels in Cedar Creek below the Horns Corners reservoir site are often critically low for the maintenance of a healthy fishery and would be significantly enhanced by flow augmentation. With reservoir releases, canoeing and other forms of water-oriented recreation would be possible, even in low-flow periods.

As discussed earlier in this chapter, low-flow augmentation is presently practiced within the watershed only in the City of Milwaukee, where a flushing tunnel pumps water from a point on the Lake Michigan shoreline inside the harbor breakwater to a point on the Milwaukee River immediately downstream of the North Avenue Dam. The tunnel is relatively ineffective in flushing noxious aquatic vegetation, oil slicks, turbidity, and floating debris from the estuarine portion of the Milwaukee River downstream of the North Avenue Dam. Supplemental flow augmentation equivalent to several multiples of that provided by the flushing tunnel would be needed to generate river velocities high enough to completely eliminate noxious floating materials and thereby markedly improve the appearance of the lower river. The Horns Corners Reservoir could not continuously supply such large flow augmentation discharges, particularly during the summer period when most needed, without excessive drawdowns and attendant resulting conflicts with recreational uses and aesthetic enjoyment of the impoundment.[18] Smaller flow augmentation releases could, however, be provided continuously by the reservoir; and these, with occasional, short-term larger discharges, might, in combination with the flushing tunnel, be effective in improving the appearance of the river as it flows through the Milwaukee business district.

As described in Chapter XI, Volume 1, of this report, ground water and withdrawals from Lake Michigan are, at present, the two principal sources for water supply in the watershed. The Horns Corners Reservoir would establish a possible modest third alternative, with water supplies being provided directly from the reservoir or from Cedar Creek and the Milwaukee River following release from the reservoir.

The potential for streamflow regulation and augmentation from the Horns Corners Reservoir was quantified on the basis of monthly flows tabulated in the USGS Water Supply Papers for the 1914 to 1966 period as recorded at Estabrook Park on the Lower Milwaukee River and for the 1930 to 1966 period as measured at the Cedarburg gage on Cedar Creek.

An analysis was made to determine the average flows that could have been maintained along Cedar Creek and the lower Milwaukee River during 1932 and 1934, the most critical years of record, with a release of one to five feet of storage from a full conservation pool in the Horns Corners Reservoir. More than two feet of drawdown may not be acceptable for recreation use and aesthetic enjoyment of this reservoir, as the surface area would be reduced by about 40 percent with a five-foot drawdown and by about 25 percent with a three-foot drawdown. A two-foot drawdown from the conservation pool elevation of 843.5 to Elevation

---

[18] *For example, if the Horns Corners Reservoir were to supply, in addition to the average streamflow that presently occurs without the reservoir, a discharge equal to the maximum rate of discharge of the flushing tunnel (420 cfs), the 35,000 acre-feet of water stored below the conservation pool level would be exhausted in about 40 days; that is, the reservoir would be completely emptied.*

841.5 would decrease the reservoir surface area by about 17 percent and provide about 7,000 acre-feet of water, while a one-foot drawdown to Elevation 842.5 would yield about 3,500 acre-feet of water, with an attendant 8 percent reduction in lake area.

During the year 1934, the minimum mean monthly flow at Cedarburg on Cedar Creek was 1.5 cfs in August, while the May through September average was 5 cfs. The comparable flows on the Milwaukee River at Estabrook Park were 19 and 54 cfs, respectively. With a one-foot drawdown of the Horns Corners Reservoir, the flow throughout this six-month period could have been maintained at 15 cfs along Cedar Creek, equivalent to 0.84 inch of runoff from the Cedar Creek subwatershed tributary to the gaging station at Cedarburg; and the resulting minimum monthly flow along the Milwaukee River would have been 32.5 cfs, equivalent to 0.32 inch of runoff from the entire Milwaukee River watershed tributary to the Estabrook Park gaging station. With two feet of drawdown, the flows could have been maintained at 25 and 42.5 cfs, respectively, equivalent to 1.4 inches of runoff at the Cedarburg gaging station and 0.42 inch of runoff at the Estabrook Park gaging station, respectively.

It is not necessary that augmentation discharges be released uniformly. In fact, it is considered beneficial to fish life to have varying flows in a stream. Also, it may be desirable to make occasional large releases to maintain water quality conditions at critical times; to meet unusual water supply needs; or to provide for certain forms of water-related recreation, such as canoeing.

As noted above, it would be possible to maintain a flow of 32 to 42 cfs in the river at Estabrook Park even during a year similar to the most critical year in the period of record and with only one to two feet of drawdown. The full drawdown would not have occurred in 1934 until the end of September, which is after the close of the lake-oriented recreation season in southeastern Wisconsin. It would be possible to refill the reservoir during the subsequent fall-winter-spring period by proper operation.

The analyses described above were intended solely to demonstrate the potential of the Horns Corners Reservoir to augment low streamflows on Cedar Creek and along the Lower Milwaukee River. No attempt was made to determine or recommend a level at which the low flows should be maintained. Low-flow augmentation requirements will vary with demand conditions and time and would have to be determined in the preparation of an operational plan for the reservoir, should the reservoir be constructed. Although low-flow augmentation would yield fishery, recreation, water supply, and aesthetic benefits on Cedar Creek and the Lower Milwaukee River downstream of its confluence with Cedar Creek, the unpredictable nature of the demand for those benefits and their intangible monetary value precludes assignment of a dollar benefit to the low-flow augmentation that would be possible with the development of the Horns Corners Reservoir. Therefore, in the subsequent economic analysis of the reservoir, low-flow augmentation benefits are conservatively valued at zero.

Recreation Development: As indicated earlier in this chapter, studies made by the Wisconsin Department of Natural Resources and published in a 1968 report establish the need for additional water-oriented recreational facilities within the Region. An evaluation of the capacity of a reservoir to satisfy a portion of this need and the benefits and costs that would accrue to reservoir-recreation development, along with an evaluation of land enhancement that could be expected to take place after a dam and reservoir were built in the watershed, are analyzed and described in Appendix D of Volume 2 of this report. Appendix D indicates that, after a reservoir is constructed, the present worth of the benefits from development of public recreation facilities can be expected to be twice the present worth of the recreation facility development and operation costs.

The expected annual visitation to recreation sites is the basis for development of costs of recreation facilities and recreation-user benefits. The demand curve method of analysis, which is determined on a supply-and-demand market basis, was used for evaluation of specific sites. The potential for enhancement of basic land values through residential and commercial development and the economic impact of a reservoir project on the nearby area are also described in Appendix D.

It is estimated that initial (1970) use of recreation facilities at Horns Corners Lake would total 2,340,000 visitations yearly and that recreation use would increase to 3,480,000 annual visitations by 1990 and to over 5 million visitations within a period of 50 years. Developed recreation areas would encompass 2,000 acres of land, as shown in Figure 8, with land and facilities required to support the initial levels of use estimated to cost $6,160,000, with additional expenditures of $12,600,000 projected for the year 1995 and $18,700,000 projected for the year 2015. Annual net benefits from recreation use were estimated to total $2,420,000 and $3,280,000, respectively, for the initial and 1990 use levels at Horns Corners. For a project with a 50-year life and a discount rate of 6 percent, the present worth of all recreation benefits is $46,467,000, for an average annual benefit of $2,940,000, while the present worth of the recreation capital and operation and maintenance costs is $22,200,000. Therefore, the benefit-to-cost ratio is 2.10. It should be noted that the costs for recreation development around Horns Corners Lake are exclusive of allocated reservoir and dam costs.

Enhancement of Land Value and Local Income: Many people have a preference for residential building sites on or near a lakeshore and are willing to pay additional sums of money to satisfy this preference. The resulting increase in the value of land due to the proximity to a water area is an added benefit of a reservoir project. The evaluation of land enhancement benefits was based on the assumption that about 2,400 lots on 1,757 acres adjacent to 53,000 feet of the lakeshore would be sold over a period of 20 years, following development of the reservoir. Land enhancement value, defined as the difference between the present worth of the market value of the developed land minus the present worth of the development costs, is, as calculated in Appendix D of Volume 2 of this report and summarized in Tables D-11 and D-12 of that appendix, $765,000, or $435 per acre. Development costs include expenditures for land, sanitary sewers and sewage treatment facilities, water treatment and distribution facilities, street improvements, site preparation, beach and private recreation facilities, planning and engineering services, advertising, sales commissions, and financing. In alternative agricultural use, the land is presently (1969) worth about $1,400,000, or $800 per acre, including structures; and, therefore, residential development on about 45 percent of the periphery of the Horns Corners Reservoir would enhance the present worth of the land by $765,000, for an increase of approximately 50 percent over its present worth as agricultural land.

Additional evaluations of the impact of a reservoir on the tax base and of the general economy of areas nearby are described in Appendix D of Volume 2 of this report. It is estimated that the gross local income would increase about $4,600,000 annually as a result of the development of the Horns Corners Reservoir. As indicated in Appendix D, a temporary decrease in taxable real estate value would probably occur initially; however, in the long run, the municipalities would experience gains more than offsetting such initial losses.

Hydroelectric Power Evaluation: A power head of less than 20 feet could be developed with the installation of a powerhouse at the Horns Corners site discharging to Cedar Creek. This low head, combined with the flow characteristics of Cedar Creek, makes conventional hydroelectric power generation at the Horns Corners Dam economically unattractive.

Land and Relocation Considerations and Cost: As shown in Table 21, the cost for the purchase and preparation of land; the relocation of houses, other buildings, roads, and bridges in the reservoir site; and piping the Jackson sewage treatment plant effluent to Cedar Creek downstream of the dam site is estimated to total about $15,993,000 and would constitute the largest capital investment

Table 21

ESTIMATED LAND AND RELOCATION COSTS FOR THE HORNS CORNERS RESERVOIR IN THE MILWAUKEE RIVER WATERSHED

ITEM	QUANTITY	UNIT COST	TOTAL COST
ACQUISITION OF LAND (EXCLUSIVE OF IMPROVEMENTS)	10,500 ACRES[a]	$400/ACRE	$ 4,200,000
LAND CLEARING AND PREPARATION (EXCLUSIVE OF STRUCTURE REMOVAL)	2,500 ACRES	500/ACRE	1,250,000
ACQUISITION OF RESIDENTIAL STRUCTURES[b]	90	25,000	2,250,000
ACQUISITION OF OTHER BUILDINGS[b]	130	5,000	650,000
RELOCATION OF ROADS AND BRIDGES	--	--	1,800,000
RELOCATION OF ELECTRICAL TRANSMISSION LINE	--	--	1,010,000
RELOCATION OF JACKSON SEWAGE TREATMENT PLANT EFFLUENT PIPELINE[c]	--	--	333,000
FLOODPROOFING OF GAS PIPELINE	--	--	300,000
		SUBTOTAL	$11,793,000
CONTINGENCIES - 25 PERCENT			$ 2,950,000
ENGINEERING SERVICES			800,000
INTEREST DURING CONSTRUCTION			450,000
		SUBTOTAL	$ 4,200,000
TOTAL RESERVOIR LAND RELOCATION COSTS			$15,993,000

[a]INCLUDES 3,500 ACRES IN EXCESS OF THE AREA THAT WILL BE INUNDATED WHEN THE RESERVOIR SURFACE IS AT THE 100-YEAR RECURRENCE INTERVAL FLOOD STORAGE ELEVATION OF 848.5 FEET, MSL. INCLUSION OF THIS ADDITIONAL LAND IN THE ECONOMIC ANALYSIS IS PRIMARILY INTENDED TO ACCOUNT FOR THE IRREGULAR SHAPE OF REAL PROPERTY BOUNDARY LINES AND THUS THE NECESSITY TO PURCHASE LANDS IN EXCESS OF THAT ACTUALLY REQUIRED TO CONTAIN THE RESERVOIR.

[b]DEMOLITION OR REMOVAL COSTS ARE ASSUMED TO BE EQUAL TO SALVAGE VALUE.

[c]THIS ITEM IS FOR THE COST OF PIPING EFFLUENT FROM THE JACKSON SEWAGE TREATMENT PLANT TO CEDAR CREEK AT A POINT DOWNSTREAM OF THE HORNS CORNERS DAM SITE PRIMARILY TO REDUCE THE DIRECT INTRODUCTION OF NUTRIENTS AND ORGANIC MATERIAL INTO THE RESERVOIR.

SOURCE- HARZA ENGINEERING COMPANY.

incurred in the development of the Horns Corners Reservoir. This cost was estimated by assuming that land would be purchased up to the 858.5-foot contour. About 10,500 acres of land are enclosed by the 858.5-foot contour, 3,500 acres more than the area covered during storage of the 100-year watershed-wide flood event, at which time the reservoir surface would be at Elevation 848.5. Although this represents a conservatively high estimate of the land requirement, it is considered reasonable for cost estimating purposes at the general planning stage, since taking lines for actual land purchases will have to follow or be otherwise properly related to real property boundary lines rather than following topographic contours. The amount of land included in the estimates is enough to contain the dam and reservoir, with 2,000 acres in the flood pool (Elevation 843.5 to Elevation 848.5) available for limited use and an additional 3,500 acres between Elevations 848.5 and 858.5 available for less restricted use. The aforementioned land acquisition requirements are only for control of floodwaters contributed by that portion of the Cedar Creek subwatershed tributary to the Horns Corners dam site. Supplemental flood control achieved by diversion of Milwaukee River flows to the Horns Corners impoundment would necessitate additional land acquisition, as discussed in a subsequent section of this chapter.

A survey of property values in the Milwaukee River watershed was made by reviewing classified advertisements appearing in newspapers of local circulation from April of 1968 through March of 1969. Five tracts of land suited to agricultural use within or near the Horns Corners reservoir area were selected for analysis. The tracts ranged in size from 40 acres to 120 acres, which areas appeared to be reasonably representative of landholdings within the project area. In general, tracts where a major portion of the cost was in buildings were not selected; and costs for those selected tracts with buildings were adjusted downward by the estimated value of the buildings. Tracts with large areas of wooded and marshy lowlands were also excluded. A weighted average of the owner's asking price per acre was computed for the selected tracts, after deletion of the highest and lowest values. The weighted average was reduced by 5 percent, on the assumption that the asking price is normally about 5 percent higher than the selling price. The adjusted price for the five tracts of land ranged from $171 per acre to $717 per acre, exclusive of buildings; and the adjusted average price per acre was $420. Based on the results of this survey, a purchase price of $400 per acre, exclusive of structures, was used in the economic analysis of the Horns Corners reservoir development.

The value of 90 private homes and 130 other buildings located within the reservoir site was estimated separately from the land values. Average prices of $25,000 per home and $5,000 for each outbuilding were used. Total building counts and estimates of wooded acres which would require clearing within the reservoir site were made based on 1967 aerial photographs. A total of about 2,500 acres of land would require clearing and preparation prior to inundation.

Road and bridge relocation requirements were analyzed from 1967 aerial photographs. Based on the need to relocate eight miles of two-lane roads and bridges, as shown in Figure 8, the road and bridge relocation cost was estimated at $1,800,000.

Three electric power transmission lines traverse the reservoir site and would require relocation at a net cost of about $1 million. This cost includes both the cost of reconstructing and purchasing right-of-way for about nine miles of 345 kV double circuit line and for about nine miles of 138 kV single circuit line.

A 24-inch gas pipeline crosses a finger of the Horns Corners reservoir site; however, the reservoir will be shallow and narrow at the crossing point so that it should not be necessary to relocate the pipeline. Costs are included in the estimate for any expenditures necessary to anchor the pipe to keep it from floating and for dewatering the area in the event repair work is necessary after the reservoir is filled.

Effluent from the existing sewage treatment plant serving the Village of Jackson would be conveyed from the west end of the Horns Corners reservoir site to the east end so as to discharge into Cedar Creek downstream of the dam, thus reducing the direct introduction of nutrients and organic material into the impoundment. The necessary conveyance works are estimated to cost about $333,000.

Dam and Outlet Works Design and Costs: The required dam could be built on Cedar Creek at River Mile 41.5 approximately eight miles upstream from the City of Cedarburg, as shown in Figure 8. The dam and its spillways would consist of a 700-foot-long earth embankment located across the creek channel, a morning-glory spillway, and an emergency 1,000-foot-wide grassed spillway on the left bank. A morning-glory spillway would be located in the reservoir pool and, as shown in Figure 8, is shaped like an inverted cone, with the circular fixed top set at the conservation pool level. Floodwater enters the spillway around the periphery of the circular top and passes vertically downward to a 10-foot diameter conduit which passes water through the embankment to the downstream channel.

The dam would rest on the existing alluvial channel bottom at Elevation 825 and rise 36 feet to a dam crest elevation of 861. The impounding structure and attendant outlet works could be readily expanded to control an additional 24,000 acre-feet of floodwater which could be diverted to Cedar Creek from the upper Milwaukee River during flood periods. Incremental costs for structural additions required to accommodate the diverted floodwater would be less than 1 percent of the total cost of the Horns Corners project.

Site Foundation Characteristics

The dam site is located in a reach of Cedar Creek immediately upstream from Ozaukee County Trunk Highway Y, where the side slopes of the riverine area are moderately steep, offering the potential for locating an emergency spillway on either abutment. Soils maps for the reservoir site were available from the detailed operational soil survey conducted for the Commission by the U. S. Soil Conservation Service; and some foundation condition data were available from the Wisconsin Department of Transportation, Division of Highways, for six boreholes located in the river bed. The logs of the boreholes were analyzed and used to prepare two geologic sections of the dam site.

The soil types mapped on the left abutment are Hochheim-Sisson-Casco loams, locally underlain by stratified sands and gravels. These general foundation characteristics indicated by these soil types were confirmed by inspection of data from the boreholes, which show permeable horizons of sand and gravel to depths of at least 14 feet between and within the dam abutments. The alluvial soil of the river bottom is probably relatively impermeable. The Casco subsoil forming the right abutment is mapped as thick loamy outwash overlying calcareous sand and gravel. This material is highly permeable, and seepage control would be required within the right abutment foundation.

The analyses of the available soils data, supported by the results of a field reconnaissance survey conducted by geologists and foundations engineers at the Harza Engineering Company, indicate that, other than the need for seepage control, no unusual foundation problems or costs should be encountered in the construction of either the dam or the emergency spillway.

Dam and Spillway Configuration

A preliminary project layout, as described below, was made for the purpose of establishing the project features necessary for the preparation of cost estimates. The proposed layout of the dam, spillway, and outlet works, based upon analyses of the information collected by the geologists and engineers of the Harza Engineering Company during the site inspection; upon information obtained in previous investigations of the topographic and subsurface conditions at the site; and upon analyses of the hydrologic, hydraulic, and foundation conditions at the site is shown in Figure 8.

Since the subsurface geology at the site indicates that no impervious stratum exists within a reasonable depth below the surface, an impervious earth blanket extending upstream from the dam heel was adopted as a seepage-reducing measure. The blanket would have an average thickness of three feet and extend upstream from the dam approximately 15 times the maximum water depth.

The spillway would consist of two structures: a morning-glory structure already described which will pass normal flood flows and an emergency grassed spillway which will operate only during floods greater than a 100-year event. The morning-glory inlet is ungated and controls a 10-foot diameter reinforced concrete cylinder pipe conduit extending through the dam. The conduit terminates at a hydraulic jump-type stilling basin. The inlet elevation of the morning-glory structure is set at the proposed conservation pool elevation of 843.5. The morning-glory spillway will pass the 30,000 acre-feet of a 100-year flood on Cedar Creek during a period of about three weeks.

The emergency grassed spillway would be located about 700 feet north of the left abutment of the dam and has a gross width of about 1,000 feet. The crest of the spillway is at Elevation 850.5, and the spillway is divided longitudinally by earthbanks to keep flow from becoming concentrated in one channel if uneven erosion should occur. The combined spillway capacity is equal to the maximum probable flood of 21,000 cfs, with a rise of the reservoir to Elevation 855.5; however, the emergency spillway crest is positioned so as to become operable only when passing peak discharges with frequencies in excess of 100 years. The height from the alluvial foundation to the dam crest would be 36 feet.

Downstream low-flow augmentation and water supply quality and quantity requirements would be met with multiple-depth, gated outlet works in the dam, each consisting of a sluice gate mounted in the upstream face of the concrete spillway section connecting to a short conduit, which would be, in turn, hydraulically connected to the 10-foot diameter conduit passing through the dam and leading to the stilling basin. These outlet works would also facilitate drawdown of the reservoir surface below the spillway crest elevation of 843.5 in anticipation of, and to provide storage for, major flood events. A minimum of two different outlet depths would be provided between the base of the dam at Elevation 825 and the morning-glory spillway crest at Elevation 843.5. The sluice gates would allow for the discharge of variable flow rates through each outlet and would also facilitate the operation of the outlets either individually or in combinations. A subsequent section describes the need for, and use of, the multiple-depth, gated outlet works.

The dam superstructure would be a homogeneous earthfill with a top width of 30 feet at Elevation 861 and extend to the stripped earth foundation at slopes of one vertical to three horizontal on the upstream face and one vertical to two and one-half horizontal on the downstream face. Wave protection would be provided on the upstream slope by a one-foot thickness of sand and gravel bedding, overlain by two feet of rock riprap. A small dike about eight feet high and 1,200 feet long would be required to close a topographic saddle which is located about 1,000 feet south of the right abutment.

Estimated costs for construction of the dam, spillways, outlet works, and appurtenant facilities at Horns Corners, as shown in Table 22 and based upon 1969 prices, are $623,000.

Foregone Opportunities and Costs: It is assumed that the basic land value of $400 per acre for existing lands in the Horns Corners site is the result of the potential of the land for the production of timber, agricultural crops, livestock, and wildlife; and, therefore, these values are automatically reflected in the economic analyses. The wildlife habitat in the reservoir area consists primarily of swamps, marshes, and upland wooded areas, which constitute about 40 percent of the total reservoir area. The full range of existing wildlife areas in the potential reservoir area includes 1,350 and 25 acres of high- and medium-value wetland, respectively, for a total of 1,375 acres. Wildlife habitat in the Horns Corners reservoir site also includes 400 and 250 acres of high- and medium-value woodland, respectively, for a total of 650 acres; and, therefore, 2,025

Table 22

SCHEDULE OF ESTIMATED COSTS FOR THE HORNS CORNERS DAM IN THE MILWAUKEE RIVER WATERSHED

ITEM	QUANTITY	UNIT COST	TOTAL COST
EMERGENCY SPILLWAY EXCAVATION (COMMON)	237,000 CU. YDS.	$ 1.00	$ 237,000
FOUNDATION STRIPPING	10,000 CU. YDS.	2.00	20,000
EXCAVATION FROM BORROW	30,000 CU. YDS.	1.00	30,000
PLACE AND COMPACT DAM EMBANKMENT	56,500 CU. YDS.	0.20	11,000
PLACE AND COMPACT IMPERVIOUS BLANKET	19,000 CU. YDS.	0.20	3,800
PLACE AND COMPACT DIKE FILL	9,000 CU. YDS.	0.30	2,700
FURNISH AND PLACE TOE DRAIN BLANKET	2,000 CU. YDS.	4.00	8,000
FURNISH AND PLACE SAND BEDDING	1,700 CU. YDS.	4.00	6,800
RIPRAP	3,400 CU. YDS.	9.00	30,600
OUTLET WORKS CONCRETE	415 CU. YDS.	80.00	33,200
REINFORCED CONCRETE PIPE (120 INCH DIAMETER)	140 FT	220.00	30,800
REINFORCING STEEL	42,000 LBS	0.18	7,600
TRASH RACKS	10,000 LBS	0.50	5,000
STRUCTURAL EXCAVATION	900 CU. YDS.	2.00	1,800
COMPACTED STRUCTURAL BACKFILL	900 CU. YDS.	3.00	2,700
CARE & DIVERSION	--	--	20,000
MULTIPLE DEPTH GATES	--	--	6,000
		SUBTOTAL	$ 457,000
CONTINGENCIES - 25 PERCENT			$ 114,000
ENGINEERING SERVICES			32,000
INTEREST DURING CONSTRUCTION			20,000
		SUBTOTAL	$ 166,000
TOTAL DAM COST			$ 623,000

SOURCE- HARZA ENGINEERING COMPANY.

acres of existing wetland and woodland wildlife habitat would be eliminated by the Horns Corners Reservoir. A major disadvantage of the site is the inclusion of the Jackson Marsh in the area to be inundated. The Marsh is a large wetland conservancy area owned by the State of Wisconsin, and, as already noted, could not be replaced anywhere in the watershed.

Some of the initial wetland, woodland, and wildlife losses would be compensated for by the allocation of certain shoreland areas to similar natural uses. The elimination of wildlife habitat areas can be compensated for in part by the reservation of lake shoreline areas for protection of wildlife. At each potential reservoir, shoreline would be selected to remain in a "natural state." "Natural," as defined herein, refers to that state of the shoreline following the filling of the reservoir. Portions of these areas are preferably the marshy or shallow water areas, which usually are found in the upper reaches of an impoundment. If these areas are protected from disturbance, they will, in time, fill in with sediment, be invaded by vegetation, and form desirable wetlands for habitation by waterfowl and other birds and for muskrats. Water levels could be managed to promote desirable stages of aquatic plant succession. Although these areas would in total probably be equivalent in acreage to the Jackson Marsh, no single area would be as large as the Jackson Marsh, since it is more likely that natural areas would be established at several locations on the lakeshore and would lack the potential advantages of the unified area.

Reservoir Sedimentation Analysis: As described in Chapter VI, Volume 1, of this report, sediment yield from the Milwaukee River watershed was estimated utilizing, as a basis, actual sediment measurements made in the Milwaukee, Root, and Sheboygan Rivers. The yield values derived from these measurements were compared with published estimates of sediment yields for the nearby Baraboo, Crawfish, and Rock Rivers.[19] These comparisons indicated that the derived yield values were consistent with the published estimates of the other agencies; and it was, therefore, concluded that depletion of storage in the Horns Corners Reservoir on Cedar Creek due to sediment deposition would be negligible.

[19] *Ibid., Footnote 13.*

The probable sediment loading on Cedar Creek was estimated to fall, like the sediment loading on the Milwaukee River, within the range of 16 to 61 tons per square mile of drainage area per year. Based upon these unit yields, the probable loss of storage in the proposed Horns Corners Reservoir over a 50-year period may be expected to range from about 48 to 180 acre-feet, due to the deposition of from 79,000 to 300,000 tons of sediment.[20] This relatively small volume of sediment, deposited over a 50-year period, represents less than 1 percent of the volume of the proposed 35,000 acre-foot Horns Corners Reservoir and would not constitute a significant problem.

Water Quality Effects Attributable to Impoundment: The present status of stream and lake water quality in the watershed is described in Chapter IX, Volume 1, of this report. Future water quality conditions within the watershed will depend, to a large degree, upon land and water management practices and whether both urban and rural development within the watershed is carefully planned and guided in the public interest or allowed to continue in a largely uncontrolled manner. Alternative measures which may be implemented to cope with the present and projected future water quality problems of the watershed are described in Chapter V, Volume 2, of this report.

Water quality affects the public health, the overall quality of the environment, and the economic and aesthetic aspects of present and potential instream and withdrawal water uses. In general, benefits accrue from a level of water quality which permits the use of water for recreational activities, public and industrial water supply, fish and wildlife propagation and conservation, and aesthetic enjoyment. Costs are incurred and benefits reduced if water quality restricts these uses; makes

[20] *The estimated annual dry weight in tons of sediment accumulation in the Horns Corners Reservoir was based on the conservative assumption that all suspended sediment entering the impoundment would be ultimately trapped there and was computed as the product of the 99-square mile area tributary to the dam site and the unit sediment contribution ranging from 16 to 61 tons per square mile per year. The resulting calculated annual sediment accumulation in dry weight was converted to the volume it would occupy after settling to the reservoir bottom by dividing by a unit weight of 75 pounds of dry solids per cubic foot of deposited sediment which is equivalent to 1,620 tons per acre-foot.*

treatment for beneficial uses more costly; results in the necessity of substituting more remote and, therefore, possibly more expensive water-based recreational activities; or results in corrosion or scaling of domestic, transportation, and industrial equipment and facilities coming in contact with the water. Adverse water quality can also result in loss of aesthetic enjoyment and reduced land values because of excessive aquatic growths.

Multiple-depth, gated outlet works proposed for the dam, in combination with water sampling in the impoundment, are intended to facilitate management of not only the quantity but also the quality of the water within, and withdrawn from, the Horns Corners Reservoir. In the absence of positive control arrangements, water quality problems may develop in, and downstream of, the impoundment due to the temporal and spatial variation in reservoir water quality characteristics.

Spatial water quality differences would not be as striking and, therefore, as significant, from a water quality management perspective, as those that would occur in the Waubeka Reservoir, since the causative phenomenon of summer thermal stratification, characterized by the development of an upper warm zone called the epilimnion and a lower cold zone referred to as the hypolimnion, is unlikely because of the relatively shallow condition of the Horns Corners Reservoir. The impoundment would have an average depth of six feet, 75 percent of the reservoir area would be less than 10 feet deep, and the maximum depth would be 18 feet. Data for 66 existing lakes with areas in excess of 50 acres in the Fox and Milwaukee River watersheds of southeastern Wisconsin indicate that summer thermal stratification and its attendant water quality stratification generally require a maximum depth greater than 15 to 20 feet.

Although spatial water quality variations would generally be small, they may occasionally be significant. For example, a series of hot, calm summer days may produce a temporary thermal stratification characterized by a shallow warm stratum lying over the reservoir. The lower portion of the impoundment will, even in the absence of a well-defined thermal stratification, tend to contain larger concentrations of nutrients attributable to the decomposition of organic material that was originally at the reservoir site or settled to the bottom. Lower strata will probably be more turbid than the remainder of the impoundment, especially during, and immediately after, rainfall events, when inflowing turbid water, because of its greater density relative to the reservoir water, will tend to move as a discrete current along the reservoir bottom as the sediment and other material slowly settle to the reservoir bottom.

These small, but potentially significant, variations in water quality with spatial location warrant the installation of a minimum of two gated outlet works positioned at two depths between the reservoir bottom and the crest of the morning-glory spillway in order to provide the opportunity to manipulate the quality and quantity of water within, and withdrawn from, the reservoir in the event that such control would be necessary. For example, if the lower strata of the impoundment, along with the reservoir bottom, are occasionally subjected to the influx of turbidity during severe rainfall events in quantities sufficient to interfere with the feeding and reproduction of the anticipated modest fish population, it would be possible to route the sediment-laden current through the reservoir by use of the gated outlets in the dam. Such an operation would, however, have to consider possible detrimental effects on Cedar Creek downstream of the dam. The incremental cost of the multiple-depth, gated outlet works is approximately 1 percent of the total dam cost and is, therefore, small relative to the water quality control potential that would be available.

At the present time, streamflows in Cedar Creek frequently drop to near zero during the late summer months. Daily flows of less than 1 cfs occur on the average of once in five years, and flows of less than 5 cfs occur on the average of twice in three years. The potential for water quality improvement along Cedar Creek through flow augmentation is great in that the assimilative capacity of the stream would be significantly increased. Water released from the reservoir would be aerated as it would move along Cedar Creek and the Lower Milwaukee River channel, with conditions approaching saturation at each of the nine existing downstream dams on Cedar Creek and the Lower Milwaukee River.[21] Although aeration potential at dams exists at present, the oxygen demands on the streams are relatively great com-

---

[21] *These dams are described in Chapter V of Volume 1 of this report, and the measured effects of existing structures on instream dissolved oxygen are documented in Chapter IX of Volume 1 of this report.*

pared to total oxygen in solution during periods of low streamflow. Horns Corners Reservoir releases would increase low flows severalfold and would greatly increase the total dissolved oxygen supply in Cedar Creek and the Lower Milwaukee River during periods of low streamflow.

Operation of the Horns Corners Reservoir could serve to reduce the marked variations in river water quality that presently occur downstream of the impoundment site due to short-term storm water runoff and long-term seasonal changes in the proportion of ground water contribution to the total flow. With a more uniform water quality, Cedar Creek and, to a lesser extent, the Lower Milwaukee River, would be better suited for certain uses than at present.

Extensive areas of rooted vegetation, not necessarily detrimental to water quality, may develop in the Horns Corners Reservoir because much of the impoundment would be relatively shallow. Approximately 25 percent of the reservoir area would be less than three feet deep and another 25 percent would be only three to six feet deep. The extensive areas with water depths less than three feet would be subject to growth of emergent vegetation, such as cattails and bulrushes. The areas with water depths ranging from three to six feet would be subject to extensive growths of submergent rooted vegetation.

Experience on large, moderately deep natural lakes in the watershed has shown that these bodies of water do not suffer overriding water quality problems, even though, unlike the Horns Corners Reservoir, they are subject to: 1) long (three or more years) residence times of water due to small drainage areas in relation to storage volumes; 2) effects of residential land uses with on-site sewage disposal systems located along high percentages of the lake shoreline; and 3) relatively poor control of domestic sewage flows.

Of the 21 major lakes in the watershed ranging from 50 to 100 acres in surface area, 13 exhibit overabundant aquatic plant growth. This and other water quality problems, however, are generally directly traceable to nutrient contribution from domestic sewage and farm runoff. Implementation of present state standards and orders concerning waste-water treatment and adoption and implementation of the comprehensive watershed plan recommended herein would not only serve to protect and enhance the quality of water in the existing lakes but would be decisive in protecting the quality of water in the Horns Corners Reservoir.

Land in the drainage area tributary to Cedar Creek, above and including the main body of the proposed Horns Corners Reservoir, is in primarily agricultural and open-space use. The Village of Jackson, the largest community in the drainage area, is served by a sewage treatment plant. Cost estimates for the reservoir development include a cost for piping and discharging the effluent from this plant to Cedar Creek at a location downstream from the Horns Corners Dam. There are no other sizable urban communities in the drainage area; and, therefore, no oxygenation or sludge problems due to domestic sewage discharges should develop in the Horns Corners Reservoir.

The Horns Corners Reservoir would not have the potential for development of a large, self-sustaining sport fishery because of several factors, all of which are related to its shallow depth. The water would tend to become very warm in the summer season, perhaps as much as 30°C (86°F) at the surface. This high temperature, in combination with the aforementioned expected extensive aquatic vegetation, would create conditions favorable to the maintenance of large populations of carp and other undesirable fish. Fishery management for more desirable species would be both difficult and expensive. Winterkill, a phenomenon common to shallow lakes, would inhibit development of a self-sustaining fishery. The high probability of a carp-dominated fishery, the turbidity of the waters resulting from the disturbance of sediments by feeding carp, the high water temperatures created by extensive shallow areas, and the likelihood of extensive weed growths and the regular occurrence of winterkill would detract from the overall quality of the reservoir waters for uses in general and particularly for fishery development.

It may be expected that, with carefully regulated land development and with the exercise of the water quality management elements proposed in the recommended comprehensive watershed plan, the Horns Corners Reservoir would be well protected from high levels of nutrient and organic inputs due to the activity of man. However, these measures would not assure that the Horns Corners Reservoir would be a high-quality lake with a good balance among plant, wildlife, aquatic, and human life and uses. Thus, the Horns Corners alternative for a multiple-purpose development in the watershed is, for reasons of water quality management and maintenance, as well as for its shallow nature, far less attractive than the proposed Waubeka Reservoir.

Summary of Benefits and Costs: Benefits and costs attendant to the proposed multiple-purpose Horns Corners Reservoir are summarized in Table 23 for a 50-year project life and a 6 percent interest rate. The benefit-cost ratio for flood control, recreation, and low-flow augmentation and municipal water supply, but exclusive of any land enhancement benefit, is 1.19 and, including benefits for land enhancement around the reservoir site, is 1.20.

This plan element would serve to assist in meeting certain watershed land use development objectives, including those relating to recreational uses, as well as the watershed flood control and water quality control objectives. As already noted, flood peaks and associated flood damages would be only partially abated along the main stem of the Milwaukee River from the junction with Cedar Creek to the City of Milwaukee. The proposed reservoir may be expected to lower the high water elevation of the 100-year recurrence interval

Table 23

ESTIMATED COSTS AND BENEFITS FOR THE MULTIPLE PURPOSE HORNS CORNERS RESERVOIR PROJECT IN THE MILWAUKEE RIVER WATERSHED[a]

SCHEDULE OF COSTS

ITEM	CAPITAL COST	PRESENT WORTH OF CAPITAL COST	ANNUAL COST: AMORTIZATION OF CAPITAL COST	ANNUAL COST: OPERATION AND MAINTENANCE	ANNUAL COST: TOTAL	PRESENT WORTH OF COSTS
RESERVOIR--LAND AQUISITION AND STRUCTURE RELOCATION	$15,993,000	$15,993,000	$ 1,015,000	$ 80,000	$ 1,095,000	$17,250,000
DAM	623,000	623,000	39,600	--b	39,600	623,000
RECREATION FACILITIES[c]	37,460,000	11,910,000	755,000	650,000[d]	1,405,000	22,200,000
TOTAL	$54,076,000	$28,526,000	$ 1,809,600	$730,000	$ 2,539,600	$40,073,000

SCHEDULE OF BENEFITS

ITEM[e]	ANNUAL BENEFIT	PRESENT WORTH OF BENEFITS
FLOOD CONTROL	$ 54,500	$ 858,000
RECREATION	2,950,000	46,467,000
LAND ENHANCEMENT	48,500	765,000
TOTAL	$ 3,053,000	$48,090,000

PROJECT BENEFIT-COST RATIO--1.20
ANNUAL BENEFITS MINUS ANNUAL COST--$513,400

[a]ECONOMIC ANALYSES ARE BASED ON AN ANNUAL INTEREST RATE OF SIX PERCENT AND ASSUME THAT THE PROJECT WOULD BE INITIATED IN 1970 AND WOULD HAVE A 50 YEAR LIFE.

[b]DAM OPERATION AND MAINTENANCE ARE INCLUDED IN THE ANNUAL RESERVOIR OPERATION AND MAINTENANCE COST.

[c]INCLUDES AN INITIAL RECREATION FACILITY COST OF $6,160,000 (SEE TABLE D-5) AND REPLACEMENT OF AND ADDITION TO THOSE FACILITIES IN 1995 AND 2015 AT COSTS OF $12,600,000 AND $18,700,000, RESPECTIVELY.

[d]AVERAGE VALUE FOR THE PROJECT LIFE BASED ON A UNIT COST OF $0.20 PER VISITATION.

[e]AS DESCRIBED IN APPENDIX D, THE PRESENCE OF RESERVOIR RECREATION OPPORTUNITIES WOULD, STIMULATE RETAIL TRADE SUCH THAT NET LOCAL INCOME WOULD INCREASE BY ABOUT $4,570,000 ANNUALLY. THIS SECONDARY BENEFIT IS NOT INCLUDED IN THE TABLE SINCE THE ECONOMIC ANALYSIS DOES NOT INCLUDE THE CAPITAL COSTS THAT WOULD BE REQUIRED TO EXPAND EXISTING BUSINESSES AND TO ESTABLISH NEW ONES IN ORDER TO ACCOMMODATE THE INFLUX OF RECREATIONISTS. LOW FLOW AUGMENTATION COULD YIELD FISHERY, RECREATION, WATER SUPPLY AND AESTHETIC BENEFITS DOWNSTREAM OF THE PROPOSED IMPOUNDMENT SITE. HOWEVER, THE UNPREDICTABLE NATURE OF THE DEMAND FOR THESE BENEFITS AND THEIR INTANGIBLE MONETARY VALUE PRECLUDES ASSIGNMENT OF A DOLLAR VALUE TO THE LOW FLOW AUGMENTATION CAPABILITY OF THE RESERVOIR.

SOURCE- HARZA ENGINEERING COMPANY.

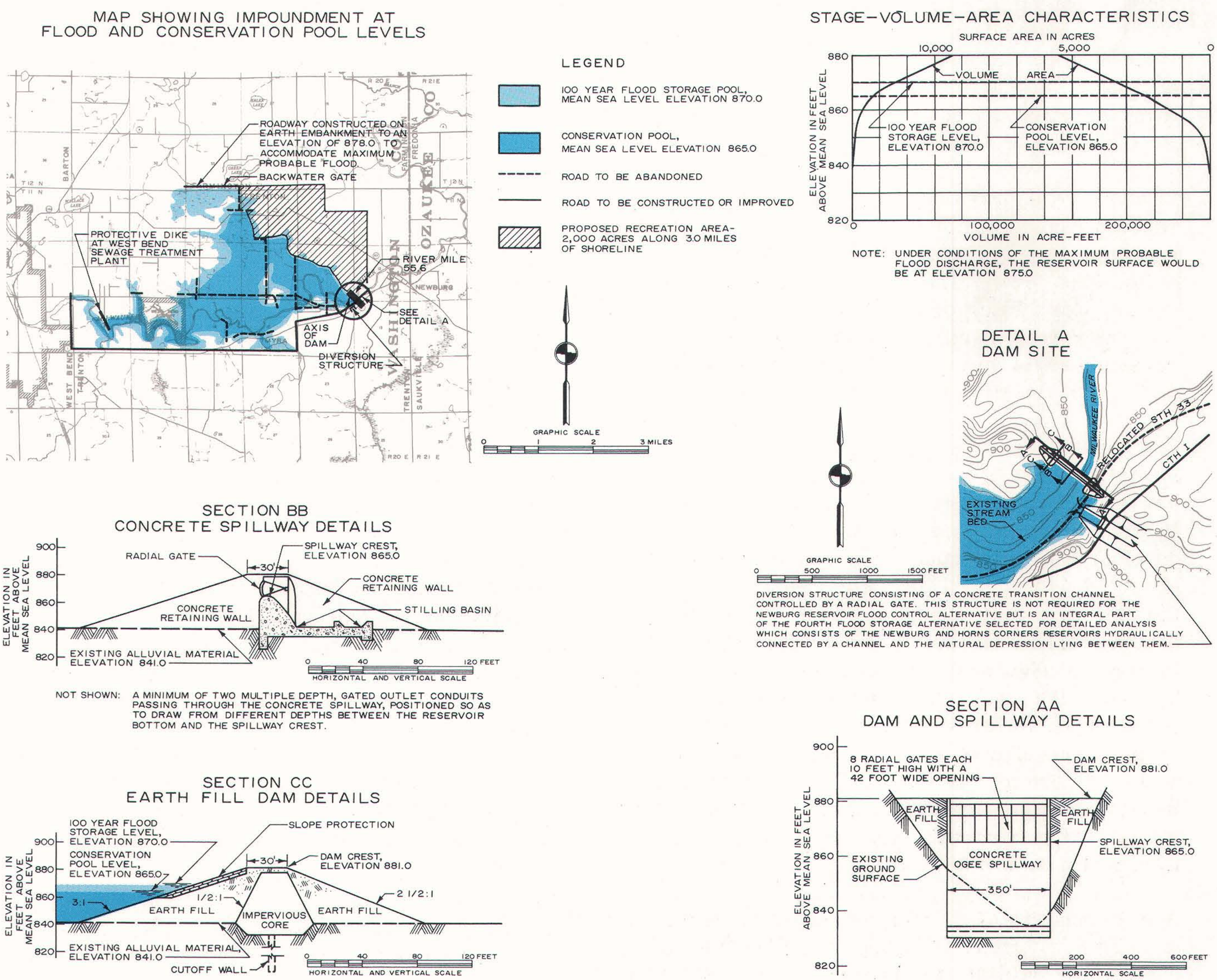
watershed-wide flood event approximately 0.7 foot at the Kletzsch Park Dam and 0.8 foot at the Thiensville Dam on the Lower Milwaukee River and 0.7 foot at the confluence of Cedar Creek with the Milwaukee River. The reduction of average annual flood damages would be about $54,500, or about 36 percent of the projected damages for conditions occurring under uncontrolled land use development.

<u>Newburg Reservoir:</u> The initial screening process indicated that the Newburg Reservoir was one of the four practicable reservoir sites remaining in the watershed and deserving more detailed study. Figure 9 illustrates the essential features of the impoundment and the dam, showing, in particular, the horizontal extent of the reservoir when the water surface is at both the conservation and flood pool level; impoundment volume and surface area as a function of pool stage; and the structural aspects of the dam and its spillway, including key elevations.

The impounding structure would be a concrete and earthfill dam, rising 51 feet above the alluvial foundation and 40 feet above the existing stream

Figure 9

HYDROGRAPHIC AND STRUCTURAL FEATURES OF A POTENTIAL MULTIPLE-PURPOSE NEWBURG RESERVOIR ON THE MILWAUKEE RIVER



Source: Harza Engineering Company.

bed of the Milwaukee River at a site in Section 13, Town 11 North, Range 20 East, about one mile upstream from the community of Newburg. The proposed reservoir would center along the Milwaukee River for a distance of about 10 miles, extending upstream to the sewage treatment plant at West Bend. The proposed reservoir would have a surface area of 2,300 acres at Elevation 865.0, the proposed conservation pool level. Average lake depth would be about 7 feet, with a maximum depth of about 25 feet. Storage at the conservation pool level would be 16,000 acre-feet; and, for a 100-year recurrence interval watershed-wide flood, less than one-third of the 54,000 acre-foot volume at the Newburg site could be stored in the 16,000 acre-foot flood storage volume between Elevation 865.0 and 870.0. At Elevation 870.0 the area of the lake would grow to 3,600 acres. The storage potential in the conservation pool represents 20 percent of the annual yield from the 163,000-acre drainage area, based on six inches of runoff, for a year of average wetness; and, thus, the reservoir could be expected to fill during the first year of operation.

In addition to providing for flood abatement, the reservoir could perform streamflow augmentation and water supply functions, with some fluctuation of the lake level. The lake would afford opportunities for water-oriented recreation use and for water-related recreation and residential land development in an area within easy commuting distance of the Milwaukee urbanized area.

The construction cost of the dam is estimated at $2,554,800; the cost of acquisition of the lands and relocation of structures, utilities, and roads in the reservoir, at about $12,515,000; and the development of attendant recreation facilities, at about $4,615,000. This latter cost represents the estimated initial capital outlay for recreation development, with staged construction projected to require additional expenditures of $8,500,000 by about the year 1995 and $12,600,000 additional expenditures by about the year 2015. The average annual costs total $2,074,000 and would be $1,036,000 for the dam and reservoir development, operation, and maintenance and $1,038,000 for related recreation facility development, operation, and maintenance.

Annual benefits of $2,432,300 could be expected to accrue, of which $59,000 would be for flood control; $2,340,000 for recreation; and $33,300 for the enhancement of land values. These primary and identifiable benefits would result in a project benefit-to-cost ratio of 1.17. No economically viable potential presently exists for the production of electrical power at this site. In addition to the primary benefits assigned monetary values, significant secondary benefits could be expected to accrue to which no monetary values were assigned. These include, among others, the economic stimulation engendered through construction of the dam and supporting facilities and development of recreation land uses in the vicinity of the reservoir.

The costs of opportunities foregone were not directly identified but were assumed to be included in the costs of land. A potential presently exists to support hunting and fishing in woodland and wetland areas of the proposed reservoir site. The potential for these types of recreational activities and for additional water-oriented recreation activities that would be created by the development of the reservoir are, however, only marginally greater than those supplanted. Although certain valuable elements of the natural resource base would be eliminated, some of these could be offset by the creation of new wetland areas along certain portions of the shoreline of the reservoir; by reforestation of other reaches of the shoreline; and by the creation of waterfowl habitat, particularly for spring and fall migrants.

Flood Control Operation and Resulting Benefits: Application of the flood-flow simulation model indicated that a 100-year recurrence interval watershed-wide[22] flood event will have a peak discharge at Newburg of 6,600 cfs and a corresponding flood volume of approximately 54,000 acre-feet that would require nine days for its passage. The stage-volume curve for the proposed impoundment shown in Figure 9 indicates that 16,000 acre-feet of water, or about 30 percent of the 100-year flood volume entering the impoundment, could be stored between the conservation pool level at Elevation 865.0 and the flood storage pool level at Elevation 870.0. Criteria adopted for this study would permit the reservoir to rise to Elevation 870 during the 10-year or 100-year recurrence interval flood events and as high as Elevation 875 in case of a maximum

[22]*The peak discharge at the Newburg site for a 100-year recurrence interval flood event for the area tributary to the Newburg site would generate a peak discharge of about 9,475 cfs, and a similar 10-year event would have a peak discharge of 5,320 cfs.*

probable flood. It would be necessary to construct a dike on a topographic divide located southwest of Green Lake so as to increase the minimum elevation there from the existing Elevation 870 to Elevation 878 (see Figure 9).

Although major floods on the Milwaukee River can occur in any season of the year, as described in Chapter IV, Volume 1, of this report, such floods are more likely to occur in early spring. Since recreation activity would be at a minimum during this period and there would be no need for flow augmentation during the spring, it would be possible to draw down the reservoir level to an elevation several feet below the conservation pool level during the winter in preparation for storage of spring floodwaters. For example, the pool could be lowered five feet below the conservation pool level to Elevation 860, and an additional 8,000 acre-feet of storage would be available. The amount of drawdown would be related to the accumulated snowpack on the upper Milwaukee River watershed. If the snowpack were light, only a minor drawdown would be made, while if the snowpack were deep in terms of its water equivalent, a greater drawdown be made.

The potential benefits that would accrue to the reservoir for flood control were estimated by operating the flood-flow simulation model for the 10-year and the 100-year recurrence interval watershed-wide floods, with two-thirds of the volume of the 10-year watershed-wide flood originating upstream from the dam being stored in the Newburg Reservoir and with retention of one-third of the 100-year flood volume. The reduction to the flood damages, as estimated in Chapter VIII, Volume 1, of this report, was then calculated utilizing the revised flood profiles. With the Newburg Reservoir operated as described above, about $113,000, or 34 percent of the flood damages from a 10-year recurrence interval flood event under conditions of uncontrolled land use development, would be eliminated, while the available flood storage would eliminate about $706,000, or 38 percent of the damages from a 100-year recurrence interval flood event.

Flow Augmentation and Water Supply Consideration: A study was made to determine the potential of the Newburg Reservoir for stabilizing seasonal stream discharge by regulation of low flows experienced along the Milwaukee River and to determine the additional effect of releasing water from storage to augment the regulated low flows. This regulation and augmentation of low streamflows would be beneficial to fish life and recreational water uses; would enhance water quality by dilution and flushing; and would serve as a source of municipal and industrial water supply. At present, dissolved oxygen levels in the Milwaukee River below the Newburg Reservoir site are often critically low for the maintenance of a healthy fishery and would be significantly enhanced by flow augmentation. With reservoir releases, canoeing and other forms of water-oriented recreation would be possible, even in low-flow periods.

As discussed earlier in this chapter, low-flow augmentation is presently practiced within the watershed only in the City of Milwaukee, where a flushing tunnel pumps water from a point on the Lake Michigan shoreline inside the harbor breakwater to a point on the Milwaukee River immediately downstream of the North Avenue Dam. The tunnel is relatively ineffective in flushing noxious aquatic vegetation, oil slicks, turbidity, and floating debris from the estuarine portion of the Milwaukee River downstream of the North Avenue Dam. Supplemental flow augmentation equivalent to several multiples of that provided by the flushing tunnel would be needed to generate river velocities high enough to completely eliminate noxious floating materials and thereby markedly improve the appearance of the lower river. The Newburg Reservoir could not continuously supply such large flow augmentation discharges, particularly during the summer period when it is most needed, without excessive drawdowns and attendant resulting conflict with recreational uses and aesthetic enjoyment of the impoundment.[23] Smaller flow augmentation releases could, however, be provided continuously by the reservoir; and these, with occasional, short-term large discharges, might, in combination with the flushing tunnel, be effective in improving the appearance of the river as it flows through the Milwaukee business district.

As described in Chapter XI, Volume 1, of this report, ground water and withdrawals from Lake Michigan are, at present, the two principal sources

[23] *For example, if the Newburg Reservoir were to supply, in addition to the average streamflow that presently occurs without the reservoir, a discharge equal to the maximum rate of discharge of the flushing tunnel (420 cfs), the 16,000 acre-feet of water stored below the conservation pool level would be exhausted in about 19 days; that is, the reservoir would be completely emptied.*

for water supply in the watershed. The Newburg Reservoir would establish a possible modest third alternative, with water supplies being provided directly from the reservoir or from the Milwaukee River following release from the reservoir.

The potential for streamflow regulation and augmentation from the Newburg Reservoir was quantified on the basis of monthly flows tabulated in the USGS Water Supply Papers for the 1914 to 1966 period, as recorded at Estabrook Park on the Lower Milwaukee River.

An analysis was made to determine the average flows that could have been maintained along the Lower Milwaukee River during 1932 and 1934, the most critical years of record, with release of one to five feet of storage from a full conservation pool in the Newburg Reservoir. More than two feet of drawdown may not be acceptable for recreation use and aesthetic enjoyment of this reservoir, as the surface area would be reduced by more than 40 percent with a five-foot drawdown and by about one-third with a three-foot drawdown. A two-foot drawdown from the conservation pool elevation of 865.0 to Elevation 863.0 would decrease the reservoir surface area by about 14 percent and provide about 3,000 acre-feet of water, while a one-foot drawdown to Elevation 864.0 would yield about 2,000 acre-feet of water with an attendant 5 percent reduction in lake area.

During the year 1934, the minimum mean monthly flow at Estabrook Park on the Milwaukee River was 19 cfs in August, while the May through October average was 55 cfs. With a one-foot drawdown of the Newburg Reservoir, the flow throughout this six-month period could have been maintained at 60 cfs, equivalent to 0.49 inch of runoff from the entire Milwaukee River watershed tributary to the gaging station, while a two-foot drawdown would have maintained an average discharge of 64 cfs, or 0.53 inch of runoff.

It is not necessary that augmentation discharges be released uniformly. In fact, it is considered beneficial to fish life to have varying flows in a stream. Also, it may be desirable to make occasional large releases to maintain water quality conditions at critical times; to meet unusual water supply needs; or to provide for certain forms of water-related recreation, such as canoeing.

As noted above, it would be possible to maintain a flow of 60 to 64 cfs in the river at Estabrook Park, even during a year similar to the most critical year in the period of record and with only one to two feet of drawdown. The full drawdown would not have occurred in 1934 until the end of September, which is after the close of the lake-oriented recreation season in southeastern Wisconsin. It would be possible to refill the reservoir during the subsequent fall-winter-spring period by proper operation.

The analyses described above were intended solely to demonstrate the potential of the Newburg Reservoir to augment low streamflows along the Lower Milwaukee River. No attempt was made to determine or recommend a level at which the low flows should be maintained. Low-flow augmentation requirements will vary with demand conditions and time and would have to be determined in the preparation of an operational plan for the reservoir, should the reservoir be constructed. Although low-flow augmentation would yield fishery, recreation, water supply, and aesthetic benefits on the Lower Milwaukee River downstream of its confluence with Cedar Creek, the unpredictable nature of the demand for those benefits and their intangible monetary value precludes assignment of a dollar benefit to the low-flow augmentation that would be possible with the development of the Newburg Reservoir. Therefore, in the subsequent economic analysis of the reservoir, low-flow augmentation benefits are conservatively valued at zero.

Recreation Development: As indicated earlier in this chapter, studies made by the Wisconsin Department of Natural Resources and published in a 1968 report establish the need for additional water-oriented recreational facilities within the Region. An evaluation of the capacity of a reservoir to satisfy a portion of this need and the benefits and costs that would accrue to reservoir-recreation development, along with an evaluation of land enhancement that could be expected to take place after a dam and reservoir were built in the watershed, are analyzed and described in Appendix D of Volume 2 of this report. Appendix D indicates that, after a reservoir is constructed, the present worth of the benefits from development of public recreation facilities can be expected to be twice the present worth of the recreation facility development and operation costs.

The expected annual visitation to recreation sites is the basis for development of costs of recreation facilities and recreation-user benefits. The demand curve method of analysis, which is determined on a supply-and-demand market basis, was used for evaluation of specific sites. The potential for enhancement of basic land values through residential and commercial development and the economic impact of a reservoir project on the nearby area are also described in Appendix D.

It is estimated that initial (1970) use of recreation facilities at Newburg Lake would total 1,560,000 visitations yearly and that recreation use would increase to 2,354,000 annual visitations by 1990 and to nearly 4 million visitations within a period of 50 years. Developed recreation areas would encompass 2,000 acres of land, as shown in Figure 9, with land and facilities required to support the initial levels of use estimated to cost $4,615,000, with additional expenditures of $8,500,000 projected for the year 1995 and $12,600,000 projected for the year 2015. Annual net benefits from recreation use were estimated to total $1,602,000 and $2,466,000, respectively, for the initial and 1990 use levels at Newburg. For a project with a 50-year life and with a discount rate of 6 percent, the present worth of all recreation benefits is $36,957,000, for an average annual benefit of $2,340,000, while the present worth of the recreation capital and operation and maintenance costs is $16,400,000. Therefore, the benefit-to-cost ratio is 2.25. It should be noted that the costs for recreation development around Newburg Lake are exclusive of allocated reservoir and dam costs.

Enhancement of Land Value and Local Income: Many people have a preference for residential building sites on or near a lakeshore and are willing to pay additional sums of money to satisfy this preference. The resulting increase in the value of land due to the proximity to a water area is an added benefit of a reservoir project. The evaluation of land enhancement benefits was based on the assumption that about 1,740 lots on 1,255 acres adjacent to 42,000 feet of the lakeshore would be sold uniformly over a period of 20 years, following development of the reservoir. Land enhancement value, defined as the difference between the present worth of the market value of the developed land minus the present worth of the development costs, is, as calculated in Appendix D of Volume 2 of this report and summarized in Tables D-11 and D-12 of that appendix, $526,000, or $420 per acre. Development costs include expenditures for land, sanitary sewers and sewage treatment facilities, water treatment and distribution facilities, street improvements, site preparation, beach and private recreation facilities, planning and engineering services, advertising, sales commissions, and financing. In alternative agricultural use, the land is presently (1969) worth about $1,000,000, or $800 per acre, including structures; and, therefore, residential development on about 45 percent of the periphery of the Newburg Reservoir would enhance the present worth of the land by $526,000, for an increase of approximately 50 percent over its present worth as agricultural land.

Additional evaluations of the impact of a reservoir on the tax base and of the general economy of areas nearby are described in Appendix D of Volume 2 of this report. It is estimated that the gross local income would increase about $3,100,000 annually as a result of the development of the Newburg Reservoir. As indicated in Appendix D, a temporary decrease in taxable real estate value would probably occur initially; however, in the long run, the municipalities would experience gains more than offsetting such initial losses.

Hydroelectric Power Evaluation: A power head of less than 20 feet could be developed with the installation of a powerhouse at the Newburg site discharging to the Milwaukee River. This low head, combined with the flow characteristics of the Milwaukee River, makes conventional hydroelectric power generation at the Newburg Dam economically unattractive.

Land and Relocation Consideration and Cost: As shown in Table 24, the cost for purchase and preparation of land; the relocation of houses, other buildings, roads, and bridges in the reservoir site; piping the West Bend sewage treatment plant effluent to the Milwaukee River downstream of the dam site; the construction of a protective dike at the sewage treatment plant; and floodproofing of a gas pipeline is estimated to total about $12,515,000 and would constitute the largest capital investment incurred in the development of the Newburg Reservoir. This cost was estimated by assuming that land would be purchased up to the 880-foot contour. About 6,500 acres of land are enclosed by the 880-foot contour, 2,900 acres more than would be inundated when the impoundment rises to the design elevation of

Table 24

ESTIMATED LAND AND RELOCATION COSTS FOR THE NEWBURG RESERVOIR IN THE MILWAUKEE RIVER WATERSHED

ITEM	QUANTITY	UNIT COST	TOTAL COST
ACQUISITION OF LAND (EXCLUSIVE OF IMPROVEMENTS)	6,500 ACRES[a]	$550/ACRE	$ 3,570,000
LAND CLEARING AND PREPARATION (EXCLUSIVE OF STRUCTURE REMOVAL)	1,000 ACRES	500/ACRE	500,000
ACQUISITION OF RESIDENTIAL STRUCTURES[b]	100	25,000	2,500,000
ACQUISITION OF OTHER BUILDINGS[b]	50	5,000	250,000
RELOCATION OF ROADS AND BRIDGES	--	--	1,240,000
RELOCATION OF WEST BEND SEWAGE TREATMENT PLANT EFFLUENT PIPELINE[c]	--	--	780,000
CONSTRUCTION OF DIKE AT WEST BEND SEWAGE TREATMENT PLANT	110,000 CU. YDS.	1.50/CU. YD.	165,000
FLOODPROOFING OF GAS PIPELINE	--	--	200,000
		SUBTOTAL	$ 9,205,000
CONTINGENCIES - 25 PERCENT			$ 2,300,000
ENGINEERING SERVICES			650,000
INTEREST DURING CONSTRUCTION			360,000
		SUBTOTAL	$ 3,310,000
TOTAL RESERVOIR LAND AND RELOCATION COSTS			$12,515,000

[a] INCLUDES 2,900 ACRES IN EXCESS OF THE AREA THAT WILL BE INUNDATED WHEN THE RESERVOIR SURFACE IS AT ELEVATION 870 FEET, MSL, THE MAXIMUM DESIGN STAGE FOR PASSAGE OF THE 100-YEAR RECURRENCE INTERVAL WATERSHEDWIDE FLOOD. INCLUSION OF THIS ADDITIONAL LAND IN THE ECONOMIC ANALYSIS IS INTENDED TO ACCOUNT FOR THE IRREGULAR SHAPE OF REAL PROPERTY BOUNDARY LINES NECESSITATING THE PURCHASE OF LANDS IN EXCESS OF THAT ACTUALLY REQUIRED TO CONTAIN THE RESERVOIR.

[b] DEMOLITION OR REMOVAL COSTS ARE ASSUMED TO BE EQUAL TO SALVAGE VALUE.

[c] THIS ITEM IS FOR THE COST OF PIPING EFFLUENT FROM THE WEST BEND SEWAGE TREATMENT PLANT TO THE MILWAUKEE RIVER AT A POINT DOWNSTREAM OF THE NEWBURG DAM SITE PRIMARILY TO REDUCE THE DIRECT INTRODUCTION OF NUTRIENTS AND ORGANIC MATERIAL INTO THE RESERVOIR.

SOURCE- HARZA ENGINEERING COMPANY.

870 to temporarily store a portion of the 100-year watershed-wide flood event. Although this represents a conservatively high estimate of the land requirement, it is considered reasonable for cost estimating purposes at the general planning stage, since taking lines for actual land purchases will have to follow or be otherwise properly related to real property boundary lines rather than following topographic contours. The additional acreage would also reserve lands subject to inundation by flood events more severe than the 100-year flood. For example, during passage of the maximum probable flood discharge, the impoundment water surface would rise to Elevation 875. The amount of land included in the estimates is enough to contain the dam and reservoir, with 1,300 acres in the flood pool (Elevation 865.0 to Elevation 870.0) available for limited use and an additional 2,900 acres between Elevations 870.0 and 880.0 available for less restricted use.

A survey of property values in the Milwaukee River watershed was made by reviewing classified advertisements appearing in newspapers of local circulation from April of 1968 through March of 1969. Seventeen tracts of land suited to agricultural use within or near the Newburg reservoir area were selected for analysis. The tracts ranged in size from 10 acres to 159 acres, which areas appeared to be reasonably representative of landholdings within the project area. In general, tracts where a major portion of the cost was in buildings were not selected; and costs for those selected tracts with buildings were adjusted downward by the estimated value of the buildings. Tracts with large areas of wooded and marshy lowlands were also excluded. A weighted average of the owner's asking price per acre was computed for the selected tracts, after deletion of the highest and lowest values. The weighted average was reduced by 5 percent, on the assumption that the asking price is normally about 5 percent higher than the selling price. The adjusted price for the 17 tracts of land ranged from $181 per acre to $1,750 per acre, exclusive of buildings, and the adjusted average price per acre was $662. Based on the results of this survey, a purchase price of $550 per acre for all lands, including those not cultivable, exclusive of structures, was used in the economic analysis of the Newburg reservoir development.

The value of 100 private homes and 50 other buildings located within the reservoir site was estimated separately from the land values. Average prices of $25,000 per home and $5,000 for each outbuilding were used. Total building counts and estimates of wooded acres which would require clearing within the reservoir site were made based on 1967 aerial photographs. A total of about 1,000 acres of land would require clearing and preparation prior to inundation.

Road and bridge relocation requirements were analyzed from 1967 aerial photographs. Based on the need to relocate eight miles of two-lane roads and bridges, as shown in Figure 9, the road and bridge relocation cost was estimated at $1,240,000.

The West Bend sewage treatment plant is located on the Milwaukee River about 1.5 miles downstream from the Woolen Mills Dam and would be subjected to inundation by the Newburg Reservoir during floodwater storage periods. Therefore, the cost estimates include provision for a protective dike on three sides of the plant. Effluent from the sewage treatment plant would be conveyed from the west end of the Newburg reservoir site about five miles to the east end so as to discharge into the Milwaukee River downstream of the dam, thus reducing the direct introduction of nutrients and organic material into the impoundment. The necessary conveyance works are estimated to cost $780,000.

A 24-inch gas pipeline crosses a finger of the Newburg Reservoir; however, the reservoir will be shallow and narrow at the crossing point so that it should not be necessary to relocate the pipeline on an alignment around the reservoir. Costs are included in the estimate for any expenditures necessary to anchor the pipe to keep it from floating and for dewatering the area in the event repair work is necessary after the reservoir is filled.

Dam and Outlet Works Design and Costs: The required dam would be built on the Milwaukee River at River Mile 55.6, approximately one mile upstream from the existing Newburg weir, as shown in Figure 9. The dam and spillway would consist of an 850-foot-long earth embankment, with a concrete weir and gated control located in the middle portion of the structure. The dam superstructure would rest on an alluvial foundation at Elevation 830 and rise 51 feet to a dam crest elevation of 881. The concrete ogee spillway would pass the maximum probable flood discharge of 38,000 cfs, with the reservoir surface at Elevation 875. The ogee spillway would have a total width of 350 feet, a crest elevation of 865, and would be surmounted by a system of 10-foot-high radial gates.

Site Foundation Characteristics

Soils maps for the reservoir site and environs were available from the detailed operational soil survey conducted for the Commission by the U. S. Soil Conservation Service. Geologists and foundations engineers of the Harza Engineering Company made a reconnaissance survey of the surficial geologic and topographic features at the dam site in order to more thoroughly evaluate requirements for foundation preparation and treatment. Sources of construction materials were also identified during the inspection.

The soil types mapped on the right abutment are Casco-Rodman loams underlain by loose sand and gravel. This material, observed in a right abutment road cut, is coarse sand to gravel size, highly permeable, necessitating seepage control. The left abutment is mapped as Hochheim-Sisson-Casco loams, containing no gravel. These loams are classified as only moderately permeable but do contain significant areas of permeable sandy loam underlain by loose sand and gravel.

Foundation conditions at this site were rated below those of the Waubeka and Horns Corners sites because of the widespread presence of known permeable materials. However, there should be no technical insurmountable problems encountered in constructing a dam and spillway at this site.

Dam and Spillway Configuration

A preliminary project layout, as described below, was made for the purpose of establishing the project features necessary for the preparation of cost estimates. The proposed layout of the dam, spillway, and outlet works based upon the analyses of information collected by the geologists and engineers of the Harza Engineering Company during the site inspection; upon information obtained in previous investigations of the topographic and subsurface conditions at the site; and upon analyses of the hydrologic, hydraulic, and foundation conditions at the site is shown in Figure 9.

Because the subsurface information available for the site was limited, it was assumed that rock is quite deep; and overlying material is quite permeable. These assumptions, together with structure cost considerations, led to the conclusion that a slurry trench cutoff would be the best method of protecting the structure against seepage. The slurry trench would extend the length of the dam and be 60 feet deep. Although these dimensions could be altered based on better subsurface information, this conservative estimate for foundation construction represents only about 12 percent of the structure cost and less than 2 percent of the project costs.

The spillway crest elevation was set at the proposed conservation pool level of 865. This would permit storage of approximately 30 percent of the 100-year recurrence interval flood volume of 54,000 acre-feet in five feet of rise in the reservoir surface to Elevation 870, with the crest gates closed. The spillway was made wide enough to pass the maximum probable flood of 38,000 cfs, with a rise to Elevation 875. The gross width of the spillway would be 350 feet; and flow over the crest would be controlled by 8 radial gates, each 10 feet high, with a 42-foot-wide opening. The maximum height from the alluvial foundation to the ogee crest would be 35 feet, and the dam height would be 51 feet. Energy of the flow over the crest would be dissipated by a concrete stilling basin about 350 feet wide and 45 feet long, with a floor thickness of 7 feet. Baffle-block and an end sill would be positioned in the stilling basin to increase the slope of the energy gradient within the basin.

Downstream low-flow augmentation and water supply quality and quantity requirements would be met with multiple-depth, gated outlet works in the dam, each consisting of a sluice gate mounted in the upstream face of the concrete spillway section connecting to a conduit through the dam and discharging into the stilling basin. These outlet works would also facilitate drawdown of the reservoir surface below the spillway crest elevation of 865 in anticipation of, and to provide storage for, major flood events. A minimum of two different outlet depths would be provided between the existing channel bottom at Elevation 841 and the spillway crest at Elevation 865. The sluice gates would allow for the discharge of variable flow rates through each outlet and would also facilitate the operation of the outlets either individually or in combinations. A subsequent section describes the need for, and use of, the multiple-depth, gated outlet works.

The embankment portions of the dam would be earthfill having two primary zones. The inside impervious core zone would have a top width of 20 feet at Elevation 878 three feet below the dam crest and extend to the stripped earth foundation at side slopes of one vertical on one and one-half horizontal in the upstream direction and would have a slope of one on one in the downstream direction. The outside pervious zone would have a top width of 30 feet at Elevation 881 and would extend to the stripped earth foundation at side slopes of one vertical on three horizontal upstream and one vertical on two and one-half horizontal downstream. Wave protection would be provided on the upstream slope by a one-foot thickness of sand and gravel bedding, overlain by two feet of rock riprap. The fill portions would be supported at the ends adjacent to the spillway by concrete retaining walls, which would be incorporated into the spillway and stilling basin end walls.

An embankment surmounted by a roadway would be constructed along the low topographic divide, southwest of Green Lake, with the top elevation of the roadway at Elevation 878. A backwater gate in the dike would permit outflow from Green Lake to the reservoir; however, flow through the gate would be terminated during periods of floodwater storage whenever the reservoir level rose above the normal Green Lake elevation of 867. The cost of construction of the dam, spillway, outlet works, and appurtenant facilities at Newburg, as shown in Table 25 and based upon 1969 prices, is estimated at $2,554,800.

Foregone Opportunities and Costs: It is assumed that the basic land value of $550 per acre for existing lands in the Newburg reservoir site is the result of the potential of the land for the production of timber, agricultural crops, livestock, and wildlife; and, therefore, these values are automatically reflected in the economic analyses. The wildlife habitat in the reservoir area consists primarily of swamps, marshes, and upland wooded areas, which constitute about 28 percent of the total reservoir area. Although these areas do cover the entire range of habitat enjoyed by wildlife, they are limited in size and are of minor importance within the watershed as a whole. The full range of existing wildlife areas in the potential reservoir area includes 115 acres each of high- and medium-value wetland and 60 acres of low-value wetland, for a total of 290 acres.

Table 25

SCHEDULE OF ESTIMATED COSTS FOR THE NEWBURG DAM IN THE MILWAUKEE RIVER WATERSHED

ITEM	QUANTITY	UNIT COST	TOTAL COST
FOUNDATION EXCAVATION (COMMON)	15,000 CU. YDS.	$ 2.00	$ 30,000
FOUNDATION STRIPPING	2,000 CU. YDS.	2.00	4,000
CHANNEL IMPROVEMENT EXCAVATION	19,000 CU. YDS.	1.00	19,000
EXCAVATION FROM BORROW	155,000 CU. YDS.	1.00	155,000
PLACE & COMPACT IMPERVIOUS EMBANKMENT	7,500 CU. YDS.	0.30	2,300
PLACE & COMPACT PERVIOUS EMBANKMENT	11,000 CU. YDS.	0.20	2,200
PLACE & COMPACT DIKE EMBANKMENT	133,000 CU. YDS.	0.30	26,600
RIPRAP	3,000 CU. YDS.	9.00	27,000
SAND & GRAVEL BEDDING	1,500 CU. YDS.	4.00	6,000
SAND & GRAVEL TOE DRAIN	800 CU. YDS.	4.00	3,200
FOUNDATION SLURRY TRENCH	44,000 SQ. FT.	5.00	220,000
MASS CONCRETE IN SPILLWAY	10,150 CU. YDS.	50.00	507,500
CONCRETE STILLING BASIN FLOOR	4,320 CU. YDS.	50.00	216,000
CONCRETE WALLS, PIERS & DECK	3,140 CU. YDS.	80.00	251,200
SPILLWAY CREST RADIAL GATES	120,000 LBS.	0.65	78,000
EMBEDDED METAL FOR GATES	24,000 LBS.	1.20	28,800
GATE HOISTS (15 TON)	8	7,500.00	60,000
REINFORCING STEEL	1,180,000 LBS.	0.18	212,000
CARE & DIVERSION	--	--	20,000
MULTIPLE DEPTH GATES	--	--	6,000
		SUBTOTAL	$ 1,874,800
CONTINGENCIES - 25 PERCENT			$ 469,000
ENGINEERING SERVICES			131,000
INTEREST DURING CONSTRUCTION			80,000
		SUBTOTAL	$ 680,000
TOTAL DAM COST			$ 2,554,800

SOURCE- HARZA ENGINEERING COMPANY.

Wildlife habitat in the Newburg reservoir site also includes 100 and 250 acres of high- and medium-value woodland, respectively, for a total of 350 acres; and, therefore, 640 acres of existing wetland and woodland wildlife habitat would be eliminated by the Newburg Reservoir.

Generally, those wildlife species that dwell in both swamp and drier types of woodlands, such as deer, rabbit, and squirrel, will be temporarily lost through reservoir construction and replaced by aquatic habitat species, such as waterfowl and shorebirds. The diversity contributed by the existing swamps, marshes, and riverine shoreline areas would be lost. None of these areas, however, are unique within the watershed nor do they support any known rare or unique species of plant or animal life. Moreover, some initial wetland, woodland, and wildlife losses would be compensated by similar natural development on the shores of the reservoir. The elimination of wildlife habitat areas can be compensated for in part by reservation of lake shoreline areas for protection of wildlife. A portion of the reservoir shoreline would by design remain in a "natural state," the term "natural" referring to that state of the shoreline following the filling of the reservoir. These natural areas would include marshy areas bordering shallow water areas and would normally be located in the upper reaches of an impoundment. If these areas are protected from disturbance, they will, in time, fill in with sediment, be invaded by vegetation, and form desirable wetlands for habitation by waterfowl and other birds and for muskrats. Water levels could be managed to promote desirable stages of aquatic plant succession.

The construction of a Newburg Reservoir would make runway extension at the West Bend Airport very difficult and costly, if not impossible. Some parts of the existing airport would be inundated by the flood pool during both a 10-year and 100-year flood storage.

Reservoir Sedimentation Analysis: As described in Chapter VI, Volume 1, of this report, sediment yield from the Milwaukee River watershed was estimated utilizing, as a basis, actual sediment measurements made in the Milwaukee, Root, and Sheboygan Rivers. The yield values derived from these measurements were compared with published estimates of sediment yields for the nearby Baraboo, Crawfish, and Rock Rivers.[24] These comparisons indicated that the derived yield values were consistent with the published estimates of the other agencies; and it was, therefore, concluded that depletion of storage in reservoirs on the Milwaukee River system due to sediment deposition would be negligible.

The probable sediment loading in the Milwaukee River was estimated to fall within the range of 16 to 61 tons per square mile of drainage area per year. Based upon the calculated unit yields, the probable loss of storage in the proposed Newburg Reservoir over a 50-year period may be expected to range from about 125 to 475 acre-feet, due to the deposition of from 204,000 to 780,000 tons of sediment.[25] This relatively small volume of sediment, deposited over a 50-year period, represents 1 to 3 percent of the volume of the proposed 16,000 acre-foot Newburg Reservoir and would not constitute a significant problem.

Water Quality Effects Attributable to Impoundment: The present status of stream and lake water quality in the watershed is described in Chapter IX, Volume 1, of this report. Future water quality conditions within the watershed will depend, to a large degree, upon land and water management practices and whether both urban and rural development within the watershed is carefully planned and guided in the public interest or allowed to continue in a largely uncontrolled manner. Alternative measures which may be implemented to cope with the present and projected future water quality problems of the watershed are described in Chapter V, Volume 2, of this report.

Water quality affects the public health, the overall quality of the environment, and the economic and aesthetic aspects of present and potential instream and withdrawal water uses. In general, benefits accrue from a level of water quality which permits

[24] *Ibid.*, *Footnote 13.*

[25] *The estimated annual dry weight in tons of sediment accumulation in the Newburg Reservoir was based on the conservative assumption that all suspended sediment entering the impoundment would be ultimately trapped there and was computed as the product of the 255-square mile area tributary to the dam site and the unit sediment contribution ranging from 16 to 61 tons per square mile per year. The resulting calculated annual sediment accumulation in dry weight was converted to the volume it would occupy after settling to the reservoir bottom by dividing by a unit weight of 75 pounds of dry solids per cubic foot of deposited sediment which is equivalent to 1,620 tons per acre-foot.*

the use of water for recreational activities, public and industrial water supply, fish and wildlife propagation and conservation, and aesthetic enjoyment. Costs are incurred and benefits reduced if water quality restricts these uses; makes treatment for beneficial uses more costly; results in the necessity of substituting more remote and, therefore, possibly more expensive water-based recreational activities; or results in corrosion or scaling of domestic, transportation, and industrial equipment and facilities coming in contact with the water. Adverse water quality can also result in loss of aesthetic enjoyment and reduced land values because of excessive aquatic growths.

Multiple-depth, gated outlet works proposed for the dam, in combination with water quality sampling operations in the impoundment, are intended to facilitate management of not only the quantity but also the quality of both the water within, and the water withdrawn from, the Newburg Reservoir. In the absence of such positive control arrangements, water quality problems may develop in, and downstream of, the impoundment due to the temporal and spatial variation in reservoir water quality characteristics.

Spatial water quality differences would not be as striking and, therefore, as significant, from a water quality management perspective, as those that would occur in the Waubeka Reservoir, since the causative phenomenon of summer thermal stratification, characterized by the development of an upper warm zone called the epilimnion and a lower cold zone referred to as the hypolimnion, is unlikely to encompass more than a very small portion of the impoundment because of the relatively shallow condition of the reservoir. The impoundment would have an average depth of 7 feet; 74 percent of the reservoir area would be less than 10 feet deep; 25 percent would be between 10 and 20 feet deep; and about 1 percent would exceed 20 feet of depth, extending to a maximum depth of about 25 feet at the dam. Data for 66 existing lakes with areas in excess of 50 acres in the Fox and Milwaukee River watersheds of southeastern Wisconsin indicate that summer thermal stratification and its attendant water quality stratification generally require a depth greater than 15 to 20 feet; and, therefore, only a small portion of the Newburg Reservoir could be expected to exhibit thermal stratification.

Although spatial variation of water quality would generally be small, such variation may occasionally be significant. For example, a series of hot, calm summer days may produce a temporary thermal stratification characterized by a shallow, warm stratum lying over the reservoir. The lower portion of the impoundment will, even in the absence of a well-defined thermal stratification, tend to contain larger concentrations of nutrients attributable to the decomposition of organic material that was originally at the reservoir site or settled to the bottom. Lower strata will probably be more turbid than the remainder of the impoundment, especially during, and immediately after, rainfall events, when inflowing turbid water, because of its greater density relative to the reservoir water, will tend to move as a discrete current along the reservoir bottom as the sediment and other material slowly settles out.

These small, but potentially significant, variations in water quality with spatial location warrant the installation of a minimum of two gated outlet works positioned at two depths between the reservoir bottom and the crest of the ogee spillway in order to provide the opportunity to manipulate the quality and quantity of water within, and withdrawn from, the reservoir in the event that such control would be necessary. For example, if the lower strata of the impoundment along with the reservoir bottom are occasionally subjected to the influx of turbidity during severe rainfall events in quantities sufficient to interfere with the feeding and reproduction of the anticipated modest fish population, it would be possible to route the sediment-laden current through the reservoir by use of the gated outlets in the dam. Such an operation would, however, have to consider possible detrimental effects on the Milwaukee River downstream of the dam. The incremental cost of the multiple-depth, gated outlet works is less than 1 percent of the total dam cost and is, therefore, small relative to the water quality control potential that would be available.

Historically, streamflows in the Milwaukee River near Newburg have dropped to a weekly average of about 9 cfs, the design low-flow period for maintenance of state water quality standards on the average of once in 10 years. The potential for water quality improvement along the Milwaukee River through flow augmentation is great in that the assimilative capacity of the stream would be significantly increased. Water released from the reservoir would be aerated as it would move along Cedar Creek and the Lower Milwaukee River channel, with conditions approaching saturation at each of the nine existing downstream dams on the Lower Milwaukee River.[26] Although aeration potential at dams exists at present, the oxygen demands on the streams are relatively great compared to total oxygen in solution during periods of low streamflow. Newburg Reservoir releases would increase low flows severalfold and would greatly increase the total dissolved oxygen supply in the Milwaukee River during periods of low streamflow.

Operation of the Newburg Reservoir would serve to reduce the marked variations in river water quality that presently occur downstream of the impoundment site due to short-term storm water runoff and long-term seasonal changes in the proportion of ground water contribution to the total flow. With a more uniform water quality, the Lower Milwaukee River would be better suited for certain uses than at present.

Extensive areas of rooted vegetation, not necessarily detrimental to water quality, may develop in the Newburg Reservoir because much of the impoundment would be relatively shallow. Approximately 26 percent of the reservoir area would be less than three feet deep, and another 22 percent would be only three to six feet deep. The extensive areas with water depths less than three feet would be subject to growth of emergent vegetation, such as cattails and bulrushes. The areas with water depths ranging from three to six feet would be subject to extensive growths of submergent rooted vegetation.

Experience on large, moderately deep natural lakes in the watershed has shown that these bodies of water do not suffer overriding water quality problems even though, unlike the Newburg Reservoir, they are subject to: 1) long (three or more years) residence times of water due to small drainage areas in relation to storage volumes; 2) effects of residential land uses with on-site sewage disposal systems located along high percentages of the lake shoreline; and 3) relatively poor control of domestic sewage flows.

Of the 21 major lakes in the watershed ranging from 50 to 100 acres in surface area, 13 exhibit overabundant aquatic plant growth. This and other water quality problems, however, are generally directly traceable to nutrient contribution from domestic sewage and farm runoff. Implementation of present state standards and orders concerning waste-water treatment and adoption and implementation of the comprehensive watershed plan recommended herein would not only serve to protect and enhance the quality of water in the existing lakes but would be decisive in protecting the quality of water in the Newburg Reservoir.

Land in the drainage area tributary to the Milwaukee River, above and including the main body of the proposed Newburg Reservoir, is primarily in agricultural and open-space use, with the exception of the West Bend area. Cost estimates for the reservoir development include a cost for piping and discharging the effluent from the West Bend sewage treatment plant to the Milwaukee River at a location downstream from the Newburg Dam. The reservoir would receive flow from the entire upper Milwaukee River watershed, including treated sewage effluent from the Campbellsport and Kewaskum sewage treatment plants. These two communities will have, if the stream water quality management recommendations contained in the watershed plan are implemented, high levels of removal of organics and of the nutrient phosphorus. Therefore, no oxygenation or sludge problems should develop in the Newburg Reservoir due to domestic sewage discharges. The average reservoir residence time of two months should partially ameliorate conditions of eutrophication expected in the reservoir.[27]

The Newburg Reservoir would not have the potential for the development of a large, self-sustaining sport fishery because of several factors, all of which are related to its shallow depth. The water would tend to become very warm in the summer season, perhaps as much as 30°C (86°F) at the surface. This high temperature, in combination with the aforementioned expected extensive aquatic vegetation, would create conditions favorable to the maintenance of large populations of carp and other undesirable fish. Fishery management for more desirable species would be both difficult and expensive. Winterkill, a phenomenon common to shallow lakes, would inhibit the development of a self-sustaining fishery. The high probability of

[26] These dams are described in Chapter V of Volume 1 of this report, and the measured effects of existing structures on instream dissolved oxygen are documented in Chapter IX of Volume 1 of this report.

[27] During the annual wet season, inflow to Lake Newburg would equal the volume of the stored water within a period of 30 days or less.

a carp-dominated fishery, the turbidity of the waters resulting from the disturbance of sediments by feeding carp, the high water temperatures created by extensive shallow areas, and the likelihood of extensive weed growths and the regular occurrence of winterkill would detract from the overall quality of the reservoir waters for uses in general and fishery development in particular.

It may be expected that, with carefully regulated land development and with exercise of the water quality management elements proposed in the recommended comprehensive watershed plan, the Newburg Reservoir would be well protected from high levels of nutrient and organic inputs due to the activity of man. However, these measures would not assure that the Newburg Reservoir would be a high-quality lake with a good balance among plant, wildlife, aquatic, and human life and uses. Thus, the Newburg alternative for a multiple-purpose development in the watershed is, for reasons of water quality management and maintenance, as well as for its shallow nature, far less attractive than the proposed Waubeka Reservoir.

Summary of Benefits and Costs: Benefits and costs attendant to the proposed multiple-purpose Newburg Reservoir are summarized in Table 26 for a 50-year project life and a 6 percent interest rate. The benefit-cost ratio for flood control,

Table 26

ESTIMATED COSTS AND BENEFITS FOR THE MULTIPLE PURPOSE NEWBURG RESERVOIR PROJECT IN THE MILWAUKEE RIVER WATERSHED[a]

SCHEDULE OF COSTS

ITEM	CAPITAL COST	PRESENT WORTH OF CAPITAL COST	ANNUAL COST: AMORTIZATION OF CAPITAL COST	ANNUAL COST: OPERATION AND MAINTENANCE	ANNUAL COST: TOTAL	PRESENT WORTH OF COSTS
RESERVOIR--LAND AQUISITION AND STRUCTURE RELOCATION	$12,515,000	$12,515,000	$ 794,000	$ 80,000	$ 874,000	$13,800,000
DAM	2,554,800	2,554,800	162,000	--b	162,000	2,554,800
RECREATION FACILITIES[c]	25,715,000	8,485,000	538,000	500,000[d]	1,038,000	16,400,000
TOTAL	$40,784,800	$23,554,800	$ 1,494,000	$580,000	$ 2,074,000	$32,754,800

SCHEDULE OF BENEFITS

ITEM[e]	ANNUAL BENEFIT	PRESENT WORTH OF BENEFITS
FLOOD CONTROL	$ 59,000	$ 930,000
RECREATION	2,340,000	36,957,000
LAND ENHANCEMENT	33,300	526,000
TOTAL	$ 2,432,300	$38,413,000

PROJECT BENEFIT-COST RATIO--1.17
ANNUAL BENEFIT MINUS ANNUAL COST--$358,300

[a]ECONOMIC ANALYSES ARE BASED ON AN ANNUAL INTEREST RATE OF SIX PERCENT AND ASSUME THAT THE PROJECT WOULD BE INITIATED IN 1970 AND WOULD HAVE A 50 YEAR LIFE.

[b]DAM OPERATION AND MAINTENANCE ARE INCLUDED IN THE ANNUAL RESERVOIR OPERATION AND MAINTENANCE COST.

[c]INCLUDES AN INITIAL RECREATION FACILITY COST OF $4,615,000 (SEE TABLE D-5) AND REPLACEMENT OF AND ADDITION TO THOSE FACILITIES IN 1995 AND 2015 AT COSTS OF $8,500,000 AND $12,600,000, RESPECTIVELY.

[d]AVERAGE VALUE FOR THE PROJECT LIFE BASED ON A UNIT COST OF $0.20 PER VISITATION.

[e]AS DESCRIBED IN APPENDIX D, THE PRESENCE OF RESERVOIR RECREATION OPPORTUNITIES WOULD STIMULATE RETAIL TRADE SUCH THAT NET LOCAL INCOME WOULD INCREASE BY ABOUT $3,000,000 ANNUALLY. THIS SECONDARY BENEFIT IS NOT INCLUDED IN THE TABLE SINCE THE ECONOMIC ANALYSIS DOES NOT INCLUDE THE CAPITAL COSTS THAT WOULD BE REQUIRED TO EXPAND EXISTING BUSINESSES AND TO ESTABLISH NEW ONES IN ORDER TO ACCOMMODATE THE INFLUX OF RECREATIONISTS. LOW FLOW AUGMENTATION COULD YIELD FISHERY, RECREATION, WATER SUPPLY AND AESTHETIC BENEFITS DOWNSTREAM OF THE PROPOSED IMPOUNDMENT SITE. HOWEVER, THE UNPREDICTABLE NATURE OF THE DEMAND FOR THESE BENEFITS AND THEIR INTANGIBLE MONETARY VALUE PRECLUDES ASSIGNMENT OF A DOLLAR VALUE TO THE LOW FLOW AUGMENTATION CAPABILITY OF THE RESERVOIR.

SOURCE- HARZA ENGINEERING COMPANY.

recreation, and low-flow augmentation and municipal water supply, but exclusive of any land enhancement benefit, is 1.16 and, including benefits for land enhancement around the reservoir site, is 1.17.

This plan element would serve to assist in meeting certain watershed land use development objectives, including those relating to recreational uses, as well as the watershed flood control and water quality control objectives. As already noted, flood peaks and associated flood damages would be only partially abated along the main stem of the Milwaukee River. The proposed reservoir may be expected to lower the high water elevation of the 100-year recurrence interval watershed-wide flood event on approximately 0.6 foot at Kletzsch Park Dam, 0.7 foot at Thiensville, 0.8 foot at Grafton, 1.6 feet at Saukville, and 1.2 feet at Waubeka. The reduction of average annual flood damages would be about $59,000, or about 39 percent of the projected damages for conditions occurring under uncontrolled land use development.

Horns Corners-Newburg Reservoirs Combination: A complex of dams and dikes, two permanent reservoirs, a temporary impoundment, control structures, and open channel conveyances, as shown on Map 10, could be constructed so that the impoundment formed by the potential Newburg Dam on the Milwaukee River would be hydraulically connected to the impoundment formed by the potential Horns Corners Dam on Cedar Creek. The two impoundments would be connected by a series of new and improved existing channels leading through the Saukville Depression. Although the Cedarburg Bog could also be integrated into this floodwater storage system, such a connection is considered unwise at this time for ecological reasons.

As was described above, the Newburg Reservoir would provide only 16,000 acre-feet of storage above its conservation pool level and, therefore, could not accommodate the 54,000 acre-feet of runoff from its 163,000-acre tributary area under conditions of a 100-year recurrence interval watershed-wide flood event. The Horns Corners reservoir site lies about five miles south of the Newburg site, and its conservation pool level would be about 20 feet lower than that of the Newburg Reservoir. A natural drainage channel extends northerly from Cedar Creek and the Horns Corners site to a natural depression which lies southeast of the potential Newburg Dam. This depression, referred to herein as the "Saukville Depression," exhibits natural topography which lends itself to construction of simple facilities for the gravity transfer of water from the Milwaukee River to Cedar Creek. Since the Horns Corners Reservoir has a large potential for storage of floodwaters in comparison to the flood potential on Cedar Creek, it would be possible to store floodwaters from the upper Milwaukee River watershed in the Horns Corners Reservoir and also in the Saukville Depression so as to supplement the inadequate storage capacity available at the Newburg Reservoir. The Saukville Depression would provide additional temporary storage during major flood events and would, therefore, not form a permanent impoundment.

System Storage Capability: This interconnected flood control system would provide storage for the entire watershed-wide 100-year recurrence interval flood flows produced by the 163,000-acre drainage area tributary to the potential Newburg Dam site and the 63,000-acre drainage area tributary to the Horns Corners Dam site. During such a major flood event, the Newburg site would receive 54,000 acre-feet of runoff, while the Horns Corners site would receive 21,000 acre-feet, so that a total of 75,000 acre-feet of floodwater would enter the system, consisting of the two reservoirs and the Saukville Depression. The Newburg Reservoir would accommodate 16,000 acre-feet of floodwater between its conservation pool level and a spillway crest elevation of 870 feet above Mean Sea Level Datum. The Horns Corners Reservoir would provide 47,000 acre-feet of storage between its conservation pool level and spillway crest elevation of 850.5. The latter elevation is 2.0 feet higher than the 100-year flood storage elevation proposed herein for the Horns Corners Reservoir as an independent reservoir, thus increasing the costs of this reservoir as a part of an interconnected system over the costs for this reservoir set forth earlier in this chapter. If the outlet of the Saukville Depression were provided with a control structure so as to facilitate temporary floodwater storage at Elevation 870, the resulting available storage volume would be 12,000 acre-feet. The three components of this river control system would together, therefore, provide a total of 75,000 acre-feet of floodwater storage; and, therefore, the potential to interrupt and temporarily retain all the upstream runoff from a 100-year recurrence interval watershed-wide flood event.

Control and Conveyance Works: The interconnected system would require, in addition to the Newburg and Horns Corners impounding structures, as described earlier in this chapter, control and conveyance works to facilitate rapid and positive routing of the 75,000 acre-feet of floodwater.

For purposes of estimating project costs, it was assumed that the channel connecting the three storage areas would have a capacity of 6,600 cfs, equal to the watershed-wide 100-year flood discharge at the Newburg Dam. An earthen canal with a bottom width of 90 feet, a depth of 18 feet, and bank slopes of two on one, constructed at a slope of 0.0002, would provide the necessary capacity. Flood flow diversions from the Newburg Reservoir would be regulated by a radial gate 12 feet high and 52 feet wide and would flow through a concrete transition channel into the earthen canal, the location of which is shown in Figure 9 and on Map 10. The channel would be excavated for a distance of about one mile from the Newburg Dam to the northern end of the Saukville Depression. A dike with gate control would be positioned across the natural drain about two miles south of the Newburg Dam at the south end of the Saukville Depression. This control would be used to impound water in the depression up to a maximum elevation of 870 and to regulate discharge from the depression to the Horns Corners Reservoir. A second earth dike would be required to close a topographic saddle lying between the depression and the Cedarburg Bog at the north end of the depression to prevent the movement of impounded floodwater from the Saukville Depression into the Bog.

Although not included in this alternative, it would be possible to construct approximately one additional mile of new channel and 1.5 miles of channel improvements to permit diversion of floodwaters into the Cedarburg Bog, including Mud and Long Lakes, for temporary storage. Improvement of another four miles of channel downstream of the Bog would facilitate evacuation of the stored floodwaters to Cedar Creek.

As shown in Table 27, estimated diversion facility costs for acquisition of lands and easements; for relocation of roads, bridges, and houses and other structures; for earthwork; and for construction of the diversion channel and control structures would total $3,680,000.

Summary of Benefits and Costs: Benefits which could be expected to accrue from this alternative plan element for flood control would be larger than the sum of such benefits for the individual Newburg and Horns Corners reservoir plan elements and would, in fact, be at least equal to that which would be provided by the Waubeka Reservoir, since the combined reservoir system, like the single Waubeka Reservoir, would abate all Lower Milwaukee River damages for a flood as severe as the 100-year watershed-wide event.

Benefits for flow augmentation and water supply would approximate the sum of similar benefits for the individual projects. However, as was the case for the separate reservoirs, the unpredictable nature of the demand for the benefits and their intangible monetary value precludes assignment of a dollar benefit to the low-flow augmentation that would be possible with the development of the Saukville Depression-Horns Corners Reservoir-Newburg Reservoir river control alternative. Therefore, in the economic analysis of the interconnected reservoir system, the low-flow augmentation benefits were conservatively valued at zero.

The benefits which could be expected to accrue from recreational uses and land enhancement around the reservoirs would be less than the sum

Table 27

ESTIMATED COSTS OF DIVERSION FACILITIES FOR THE SAUKVILLE DEPRESSION--HORNS CORNERS RESERVOIR--NEWBURG RESERVOIR RIVER CONTROL SYSTEM IN THE MILWAUKEE RIVER WATERSHED[a]

ITEM	QUANTITY	UNIT COST	TOTAL COST
LAND ACQUISITION			
CANAL RIGHT-OF-WAY	500 ACRES	$400.00	$ 200,000
FLOODLAND EASEMENT	1,500 ACRES	100.00	150,000
RELOCATION OF ROADS AND BRIDGES	--	--	500,000
ACQUISITION OF HOUSES AND OTHER BUILDINGS[b]	--	--	60,000
EARTHWORK			
CANAL EXCAVATION	925,000 CU. YDS.	1.00	925,000
PLACE AND COMPACT DIKE FILL	80,000 CU. YDS.	0.30	24,000
OVER-HAUL	220,000 CU. YD. MI.	0.20	44,000
CONSTRUCTION			
STRUCTURAL CONCRETE	2,000 CU. YDS.	80.00	160,000
STRUCTURAL EXCAVATION	8,000 CU. YDS.	2.00	16,000
STRUCTURE BACKFILL	4,000 CU. YDS.	1.00	4,000
STRUCTURE COMPACTED BACKFILL	2,000 CU. YDS.	2.00	4,000
REINFORCING STEEL	140,000 LBS.	0.18	25,000
GATES AND HOISTS	--	--	63,000
		SUBTOTAL	$ 2,175,000
CONTINGENCIES - 25 PERCENT			$ 545,000
ENGINEERING SERVICES			160,000
INTEREST DURING CONSTRUCTION			800,000
		SUBTOTAL	$ 1,505,000
TOTAL COST OF DIVERSION FACILITIES			$ 3,680,000[c]

[a] TABULATED COSTS ARE FOR DIVERSION WORKS ONLY AND EXCLUDE CAPITAL COSTS OF THE PROPOSED HORNS CORNERS AND NEWBURG RESERVOIR DEVELOPMENTS. TOTAL COSTS AND BENEFITS ATTENDANT TO THE SAUKVILLE DEPRESSION--HORNS CORNERS RESERVOIR--NEWBURG RESERVOIR MULTI-PURPOSE RIVER CONTROL ALTERNATIVE ARE TABULATED IN TABLE 28.

[b] DEMOLITION OR REMOVAL COSTS ARE ASSUMED TO BE EQUAL TO SALVAGE VALUE.

[c] BASED ON AN ANNUAL INTEREST RATE OF 6 PERCENT AND UTILIZING A 50-YEAR PROJECT LIFE, THE ANNUAL COST FOR AMORTIZATION OF THE INITIAL CAPITAL EXPENDITURE OF $3,680,000 FOR THE DIVERSION FACILITIES IS $234,000. OPERATION AND MAINTENANCE EXPENDITURES FOR THE DIVERSION WORKS ARE ESTIMATED AT $20,000 PER YEAR YIELDING A TOTAL ANNUAL COST FOR AMORTIZATION AND OPERATION AND MAINTENANCE OF $254,000. THE PRESENT WORTH OF THE DIVERSION FACILITY AMORTIZATION AND OPERATION AND MAINTENANCE COSTS IS $4,000,000.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

of such benefits for the Newburg and Horns Corners plan elements and are identifiable only within certain limits. The upper limit of recreation and land enhancement benefits would be equal to the sum of the benefits that would accrue to each of the individual reservoir projects, while the lower limit was established by arbitrarily assuming that the attendant recreation and land enhancement benefits would be equal to one-half of the sum of the recreation and land enhancement benefits previously determined for the Horns Corners and Newburg Reservoirs as separate projects. It is unlikely that the total recreation benefits would be equal to the aforementioned upper limit—that is, the sum of the benefits attendant to each of the two individual reservoir projects—since, as described in Appendix D of Volume 2 of this report, those individual benefits were computed assuming one large recreation facility located far from, and, therefore, not in competition with, other similar facilities. Because the Newburg and Horns Corners reservoir sites are close relative to the wide separation assumed in the original recreation analyses, the total potentially available recreation supply would probably exceed the recreation demand. Actual benefits, therefore, would probably lie between the above limits. Since recreation provides the majority of the benefits for this multi-purpose river control alternative, the project benefit-to-cost ratio will be very sensitive to the assigned recreation benefits.

Costs for recreation facilities were prorated on the same basis as were recreation benefits. The costs for recreation facilities as they were determined in the analyses of the individual reservoir projects are not as dominant a proportion of the total costs for the combined reservoir proposal as are the recreation benefits of total project benefits. For example, in the individual analyses of the Horns Corners Reservoir and the Newburg Reservoir, costs assigned to recreation development are, in each case, approximately one-half the total project costs, while estimated attendant recreation benefits constitute over 95 percent of the total project benefits. When the two reservoirs are combined, this dominance of recreation benefits is retained in the economic analysis. Therefore, the resultant benefit-cost ratio for the Saukville Depression-Horns Corners Reservoir-Newburg Reservoir water control alternative is not as sensitive to assumed recreation facility costs as it is to the recreation benefits.

The present worth of the capital and operation and maintenance costs for the Newburg Dam and Reservoir would be the same as described in the previous discussion of the Newburg alternative plan element. The present worth of the capital and operation and maintenance costs for the Horns Corners Dam and Reservoir would be increased $280,000 due to the need to acquire an additional 700 acres of reservoir lands in order to accommodate the recommended two-foot increase in peak flood storage stage during the 100-year recurrence interval watershed-wide flood event.

The economic analysis of the combined reservoir proposal is summarized in Table 28 and clearly indicates the questionable economic feasibility of the Saukville Depression-Horns Corners Reservoir-Newburg Reservoir flood control system.

One convincing argument against developing this alternative is provided by a review of the incremental flood benefits and costs as revealed by the economic analyses. The incremental annual costs involved in the connection of the two projects are $17,700 for increasing the capacity of the Horns Corners Reservoir and $254,000 for the diversion channels and control works, or a total of $271,700. The incremental annual benefits for flood control are $36,000, being equal to the $149,500 accruing to the combined reservoir project minus $54,500 and $59,000 accruing to the Horns Corners and Newburg Reservoirs, respectively, if both were constructed, but not hydraulically connected, via the Saukville Depression. The incremental benefit-to-cost ratio is, therefore, 0.13, indicating that the *incremental costs* of the combined reservoir system would not yield a net flood control benefit.

The combined reservoir system would be economically desirable only if the development approached the level defined above as the upper limit since, under that condition, the benefits, which would be primarily recreational, would exceed the total project costs. Development corresponding to the aforementioned upper limit is unlikely. With the competition for recreation funds in southeastern Wisconsin, it would be inappropriate to develop two large lakes only five miles apart, as would be the case with the Horns Corners and Newburg Reservoirs. Assuming simultaneous, complete development of the two reservoirs, it is unlikely that the combined recreation visitations would be sufficient to yield the benefits corresponding to the upper limit condition since, as described above and in Appendix D of Volume 2 of this report,

Table 28

ESTIMATED COSTS AND BENEFITS FOR THE MULTIPLE PURPOSE SAUKVILLE DEPRESSION-HORNS CORNERS RESERVOIR-NEWBURG RESERVOIR PROJECT IN THE MILWAUKEE RIVER WATERSHED[a]

SCHEDULE OF COSTS				
	PRESENT WORTH OF CAPITAL AND OPERATION AND MAINTENANCE COSTS		ANNUAL COST OF CAPITAL AMORTIZATION AND OPERATION AND MAINTENANCE	
ITEM	UPPER LIMIT[b]	LOWER LIMIT[b]	UPPER LIMIT[b]	LOWER LIMIT[b]
HORNS CORNERS RESERVOIR DEVELOPMENT[c]				
LAND, RELOCATIONS AND DAM	$18,153,000	$18,153,000	$ 1,152,300	$ 1,152,300
RECREATION FACILITIES	22,200,000	11,100,000	1,405,000	702,500
NEWBURG RESERVOIR DEVELOPMENT[d]				
LAND, RELOCATIONS AND DAM	16,354,800	16,354,800	1,036,000	1,036,000
RECREATION FACILITIES	16,400,000	8,200,000	1,038,000	519,000
DIVERSION FACILITIES[e]	4,000,000	4,000,000	254,000	254,000
TOTAL	$77,107,800	$57,807,800	$ 4,885,300	$ 3,663,800
SCHEDULE OF BENEFITS				
	PRESENT WORTH OF BENEFITS		ANNUAL BENEFITS	
ITEM[f]	UPPER LIMIT[g]	LOWER LIMIT[g]	UPPER LIMIT[g]	LOWER LIMIT[g]
FLOOD CONTROL[h]	$ 2,360,000	$ 2,360,000	$ 149,500	$ 149,500
RECREATION				
HORNS CORNERS RESERVOIR DEVELOPMENT[c]	46,467,000	23,233,500	2,950,000	1,475,000
NEWBURG RESERVOIR DEVELOPMENT[d]	36,957,000	18,478,500	2,340,000	1,170,000
LAND ENHANCEMENT				
HORNS CORNERS RESERVOIR DEVELOPMENT[c]	765,000	382,500	48,500	24,250
NEWBURG RESERVOIR DEVELOPMENT[d]	526,000	263,000	33,300	16,650
TOTAL	$87,075,000	$44,717,500	$ 5,521,300	$ 2,835,400
SUMMARY				
	UPPER LIMIT	LOWER LIMIT		
BENEFIT-COST RATIO	1.13	0.77		
ANNUAL BENEFIT MINUS ANNUAL COSTS	$ 636,000	$ -828,400		

[a]ECONOMIC ANALYSES ARE BASED ON AN ANNUAL INTEREST RATE OF SIX PERCENT AND ASSUME THAT THE PROJECT WOULD HAVE A 50 YEAR LIFE.

[b]THE UPPER COST LIMIT ASSUMES THAT THE HORNS CORNERS RESERVOIR AND NEWBURG RESERVOIR RECREATION FACILITIES WOULD EACH BE COMPLETELY DEVELOPED AS PREVIOUSLY PROPOSED WHEN EACH RESERVOIR WAS CONSIDERED AS AN INDIVIDUAL FLOOD CONTROL ALTERNATIVE. THE LOWER COST LIMIT ASSUMES THAT RECREATION FACILITIES AT THE TWO RESERVOIRS WOULD EACH BE DEVELOPED TO ONE-HALF THE LEVEL OF THAT PREVIOUSLY PROPOSED FOR THE INDIVIDUAL RESERVOIR PROJECTS. ACTUAL COSTS FOR THE SAUKVILLE DEPRESSION-HORNS CORNERS RESERVOIR-NEWBURG RESERVOIR RIVER CONTROL SYSTEM WOULD PROBABLY LIE BETWEEN THESE UPPER AND LOWER LIMITS.

[c]TOTAL BENEFIT AND COST ESTIMATES FOR THE HORNS CORNERS RESERVOIR ARE BASED ON DETAILED SCHEDULES PREVIOUSLY PRESENTED IN TABLES 21, 22, AND 23. THE SAUKVILLE DEPRESSION-HORNS CORNERS RESERVOIR-NEWBURG RESERVOIR RIVER CONTROL ALTERNATIVE REQUIRES THAT THE HORNS CORNERS RESERVOIR 100 YEAR RECURRENCE INTERVAL WATERSHED WIDE FLOOD STORAGE LEVEL BE 2.0 FEET HIGHER THAN ELEVATION 848.5 AS PREVIOUSLY PROPOSED FOR THE HORNS CORNERS RESERVOIR WHEN IT WAS VIEWED AS A SINGLE RESERVOIR ALTERNATIVE. THE PRESENT WORTH OF HORNS CORNERS RESERVOIR COSTS HAS BEEN INCREASED $280,000, AND THEREFORE THE ANNUAL COST INCREASED $17,700, TO ACCOUNT FOR THE ACQUISITION OF 700 ACRES OF ADDITIONAL RESERVOIR LANDS NECESSITATED BY THE HIGHER FLOOD POOL STAGE. INCREMENTAL DAM COSTS ATTENDANT TO THE INCREASED FLOOD STORAGE LEVEL WOULD BE INSIGNIFICANT RELATIVE TO THE TOTAL COST OF THE HORNS CORNERS RESERVOIR COMPONENT OF THE COMBINED RESERVOIR PROJECT.

[d]TOTAL BENEFIT AND COST ESTIMATES FOR THE NEWBURG RESERVOIR ARE BASED ON DETAILED SCHEDULES PREVIOUSLY PRESENTED IN TABLES 24, 25, AND 26.

[e]TOTAL COST ESTIMATES FOR THE DIVERSION FACILITIES ARE BASED ON A DETAILED COST ESTIMATE PREVIOUSLY PRESENTED IN TABLE 27.

[f]LOW FLOW AUGMENTATION COULD YIELD FISHERY, RECREATION, WATER SUPPLY AND AESTHETIC BENEFITS DOWNSTREAM OF THE PROPOSED IMPOUNDMENT SITES. HOWEVER, THE UNPREDICTABLE NATURE OF THE DEMAND FOR THESE BENEFITS AND THEIR INTANGIBLE MONETARY VALUE PRECLUDES ASSIGNMENT OF A DOLLAR VALUE TO THE LOW-FLOW AUGMENTATION CAPABILITY OF THE RESERVOIR COMPLEX.

[g]THE UPPER BENEFIT LIMIT ASSUMES THAT RECREATION AND LAND ENHANCEMENT BENEFITS ACCRUING TO THE COMBINED RESERVOIR PROJECT WOULD BE EQUAL TO THE SUM OF THE HORNS CORNERS RESERVOIR RECREATION AND LAND ENHANCEMENT BENEFITS AND THE NEWBURG RESERVOIR RECREATION AND LAND ENHANCEMENT BENEFITS AS PREVIOUSLY DETERMINED FOR THE TWO RESERVOIRS WHEN ANALYZED AS INDIVIDUAL PROJECTS. THE LOWER BENEFIT LIMIT ASSUMES THAT THE ATTENDANT RECREATION AND LAND ENHANCEMENT BENEFIT FOR THE SAUKVILLE DEPRESSION-HORNS CORNERS RESERVOIR-NEWBURG RESERVOIR SYSTEM WOULD BE EQUAL TO ONE-HALF OF THE SUM OF THE RECREATION AND LAND ENHANCEMENT BENEFITS PREVIOUSLY DETERMINED FOR THE HORNS CORNERS AND NEWBURG RESERVOIRS. ACTUAL BENEFITS WOULD PROBABLY LIE BETWEEN THESE UPPER AND LOWER LIMITS.

[h]FLOOD CONTROL BENEFITS ACCRUING TO THE RIVER CONTROL ALTERNATIVE WOULD BE EQUAL TO THOSE PROVIDED BY THE WAUBEKA RESERVOIR, SINCE THE COMBINED RESERVOIR SYSTEM, LIKE THE SINGLE WAUBEKA RESERVOIR, WOULD ABATE ALL LOWER MILWAUKEE RIVER DAMAGES FOR A FLOOD AS SEVERE AS THE 100 YEAR WATERSHED-WIDE EVENT.

SOURCE- HARZA ENGINEERING COMPANY.

recreation benefits accruing to each reservoir were determined subject to the condition that there would be no other large outdoor recreation attraction in the general vicinity.

Even though it may not be appropriate to develop the entire interconnected system at this time, consideration could be given to the potential for sequential development. The sequence of development would depend upon the primary objectives of the initial and subsequent project elements. One set of priorities for development might be: flood control, recreation, low-flow augmentation, and enhancement of fish and wildlife habitat. In this case the Newburg Dam would be built first, as this element of the system offers the greatest potential for flood control, recreation, and low-flow augmentation. The second element of the system would be construction of the channels and control structures through the Saukville Depression to facilitate diversion of excess floodwaters from the Newburg Reservoir on the Milwaukee River to the Cedar Creek subwatershed. The third construction element would be the Horns Corners Reservoir, and the channels and control structures which would connect the Cedarburg Bog to the system could be constructed last. Changing the order of the priorities assigned to the objectives might change the sequence of development.

Development of the Saukville Depression-Horns Corners Reservoir-Newburg Reservoir river control alternative could be affected by future competition for the limited water and land resources of the watershed. The Jackson Marsh area of the Horns Corners reservoir site is primarily in state ownership at present, and the reserved area is being increased under a planned program. Therefore, it is not likely that the option for development of a Horns Corners Reservoir will be foreclosed by other land uses in the immediate future. However, the Newburg reservoir site is currently in the process of being preempted by urban development in the West Bend area. Therefore, any decision to develop this combined reservoir system, regardless of how that development might be staged, would require an early commitment to the Newburg Reservoir component.

Diversion Channel

As discussed earlier in this chapter in connection with the preliminary screening process with respect to potential reservoir sites, there were identified, in addition to the 19 individual reservoir sites, five technically feasible diversion channels and one potential diversion tunnel (see Map 10). Four of the diversion channels and the diversion tunnel were integral parts of three reservoir sites. All three of these sites were omitted from the detailed analyses because of their lack of potential for multiple-purpose use within the watershed. Since these three reservoirs were not analyzed in detail, the corresponding four diversion channels and one diversion tunnel were similarly rejected for further, more detailed analysis. There remained, therefore, only one diversion channel alternative flood control plan element available for more detailed examination; namely, the diversion channel from the Milwaukee River to Lake Michigan near Saukville, which channel would operate independent of a reservoir.

Saukville Diversion Channel: The U. S. Army Corps of Engineers, in a flood control report[28] dated November 1964, presented a plan for diverting flood flows of the Milwaukee River to Lake Michigan through a diversion channel, with the diversion point being located near Saukville. The diversion proposal, although designed to serve only the single purpose of flood control, was, as part of the Milwaukee River watershed study, subjected to a reexamination, including an update of its attendant costs and benefits, because the facility would abate essentially all flood damages in the Lower Milwaukee River.

Description of the Diversion System: The major features of the plan were described in the Corps report as follows:

> The diversion channel would extend from the Milwaukee River at Saukville about three miles to Lake Michigan at a point about 1-1/2 miles south of Port Washington. Control structures at Saukville would divert flood flows into the diversion channel. A drop structure in the diversion channel would be required at a highway and railroad crossing. The outlet at Lake Michigan would

[28] *U. S. Army Corps of Engineers, Chicago District, Survey Report for Flood Control-Milwaukee River and Tributaries, Wisconsin, November 1964.*

include a chute and stilling basin. Drawings included with this report show details of the plan. (See Figure 10[29] and also the diversion identified by the letter E on Map 10). Additional details are as follows:

a. Control structure. A low dam with two tainter gates would be constructed across the Milwaukee River to divert flood flows into the diversion channel. During flood periods, a minimum flow of 50 cfs would be passed through the dam for pollution control. The elevation of the gate sill would be 741 feet. A concrete weir with a crest elevation at 745 feet across the entrance to the diversion channel would prevent diversion of Milwaukee River flows below that stage. Thus, diversion would not occur until flow in the Milwaukee River exceeded a depth of four feet.

b. Diversion channel. The diversion channel would have a bottom width of 90 feet from the control structure to the drop structure, a distance of 10,400 feet. The slope of the channel would be about 1/3 foot per 1,000 feet. Between the drop structure and the outlet structure, a distance of 5,800 feet, the bottom width of the channel would be 70 feet and the slope would be about 1/4 foot per 1,000 feet. The channel side slopes would be one vertical to three horizontal. Materials excavated from the channel would be deposited on the adjacent banks with a berm width of 40 feet from the top of the bank and a maximum height of 35 feet. Gaps would be provided in the spoil banks to afford overland drainage wherever necessary. At transmission line crossings, spoil would be deposited to provide minimum required clearances. In some reaches, totaling about 6,000 feet, the water surface profile for the design flood would exceed the natural ground elevation. Thus, in such reaches low levees, three to six feet high would be provided. Materials excavated from the channel would be used for the levee embankments. The alinement of the channel would be adjusted, at the time of construction, to minimize relocation of existing buildings and transmission line towers. Velocities through the channel would not exceed seven feet per second. Drainage trapped by the levee embankment would be discharged into the diversion channel through pipe culverts controlled with drainage gates.

c. Drop structure. The drop structure at U. S. 141 and the North Western Railway would be a chute and a 15- by 24-foot pressure conduit under the highway and railroad. New bridges would not be required. The vertical drop in bottom grade would be 47.5 feet. A stilling basin 107 feet wide with baffles would dissipate the energy due to high velocities.

d. Outlet structure. At Lake Michigan, the bluff is about 100 feet above lake level. An outlet structure is required to discharge the diverted flood waters to prevent bluff erosion. The required structure would be a concrete lined channel ranging from 67 to 200 feet wide. A stilling basin would be provided with the floor about 19 feet below lake level as shown on plate 6.

e. New bridges. The construction of the diversion channel would necessitate new highway bridges at crossings of Wisconsin Highway 57 and at three county roads. Detours during construction of the drop structure would be required at U. S. 141 and the North Western Railway.

f. Mitigating measures. In order to preserve the existing fish and wildlife values, the following measures are included in the plan of improvement.

  (1) A 20-car parking area and public access near the site of the control structure.

  (2) The diversion channel to be constructed and sealed in such manner that lateral drainage will not occur, except where levees and interior drainage facilities are required.

[29] *The Corps report includes three figures identified in the report as plates 4 through 6, depicting the diversion channel and the necessary control works. The information on the three original figures is reproduced in this chapter, with the deletion of minor details in Figure 10.*

Figure 10

POTENTIAL FLOODWATER DIVERSION CHANNEL FROM THE MILWAUKEE RIVER AT SAUKVILLE TO LAKE MICHIGAN AS PROPOSED BY THE U.S. ARMY CORPS OF ENGINEERS

PLAN

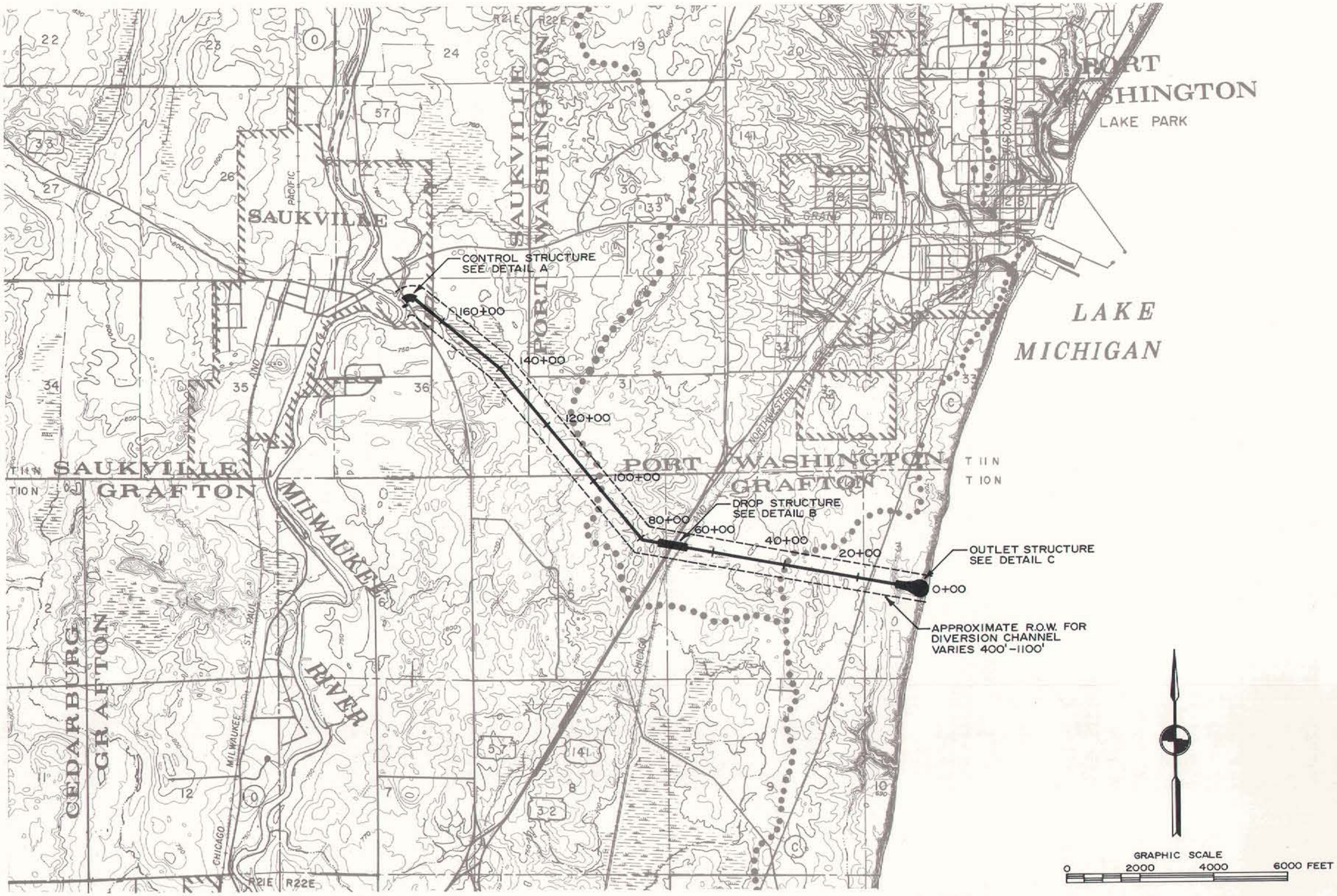


Figure 10 (continued)

PROFILE

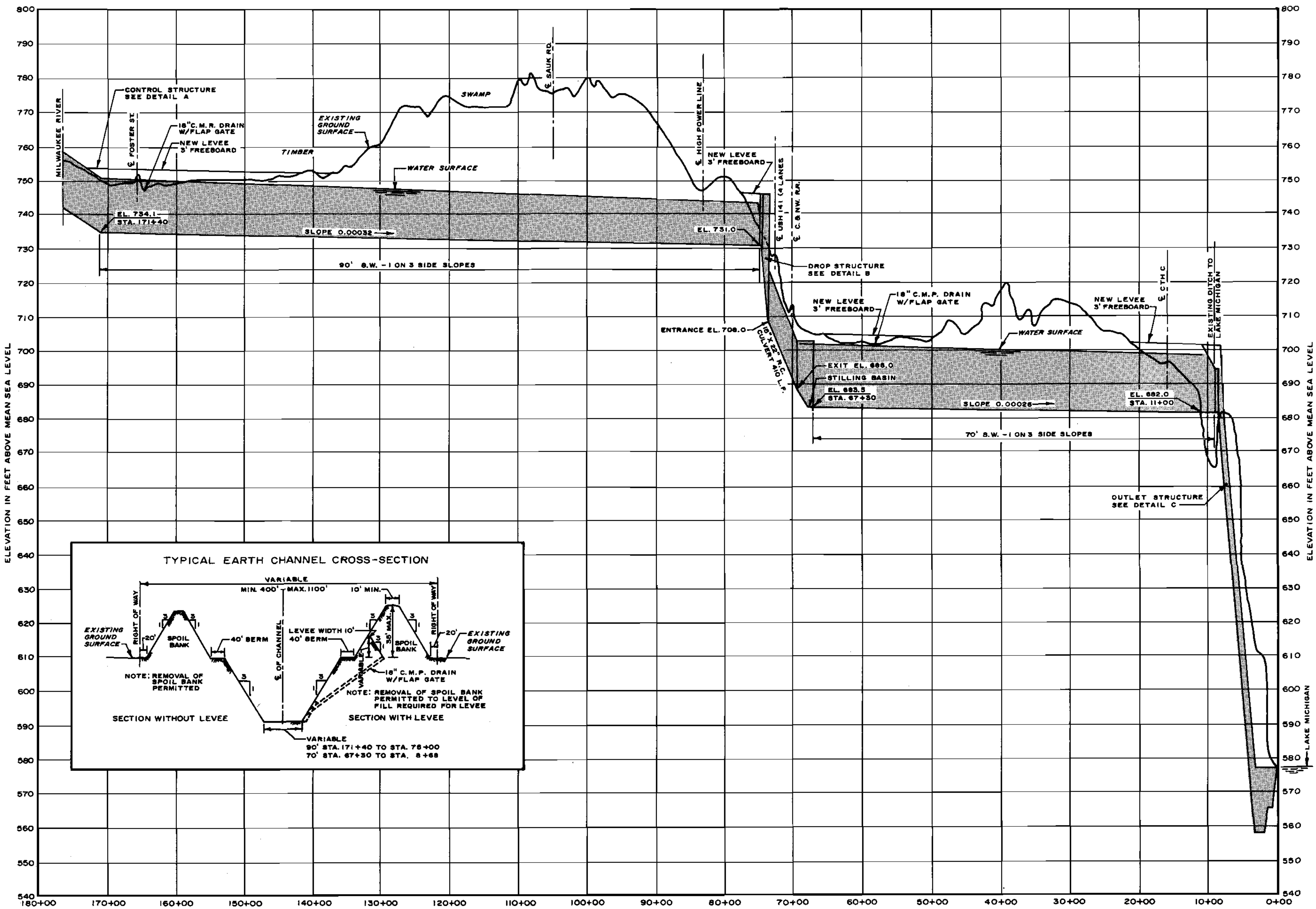
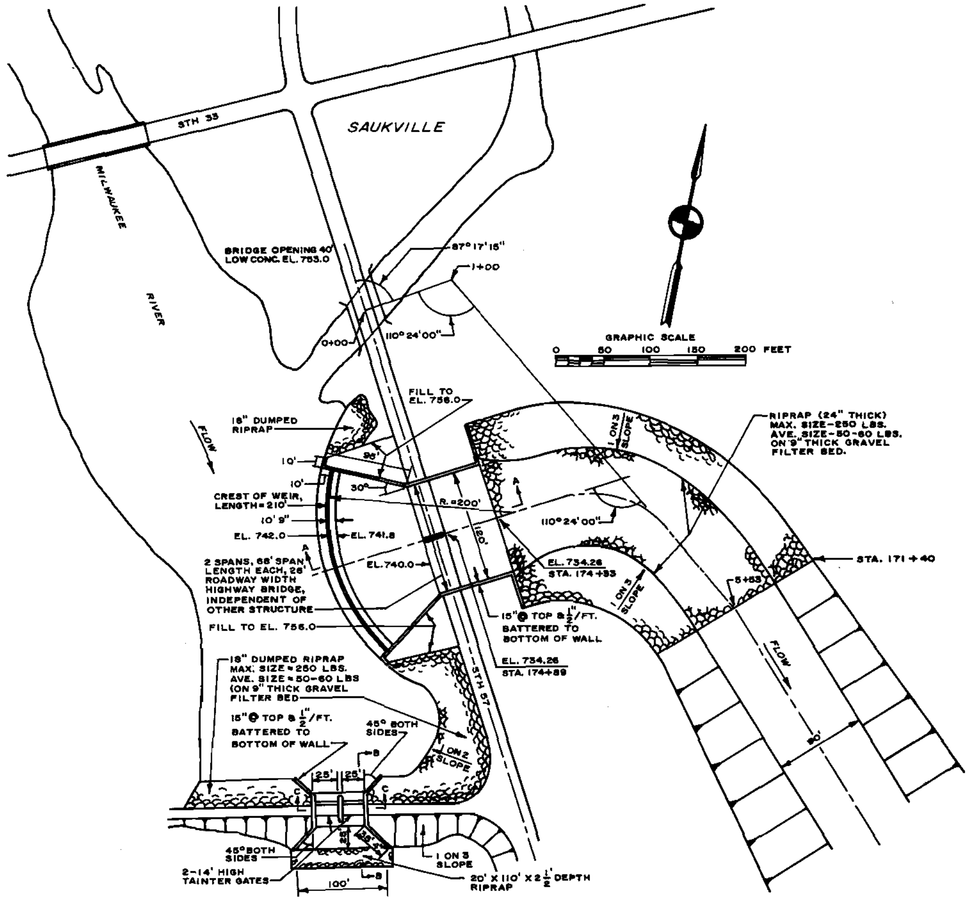
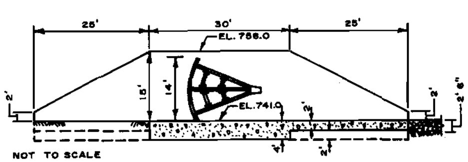


Figure 10 (continued)

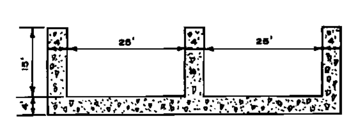
DETAIL A
CONTROL STRUCTURE
PLAN



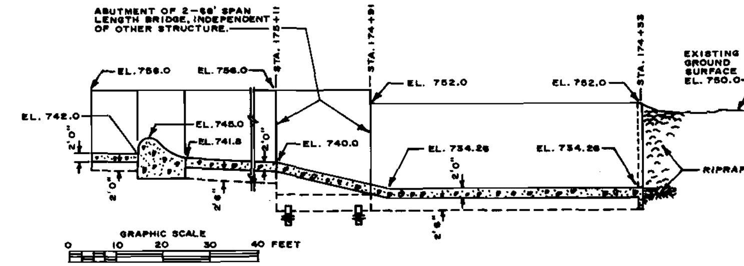
SECTION BB



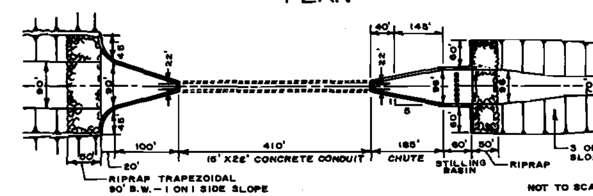
SECTION CC



SECTION AA



DETAIL B
DROP STRUCTURE
PLAN



PROFILE

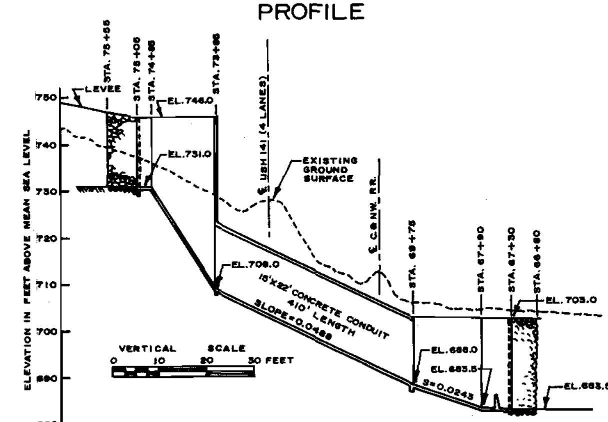
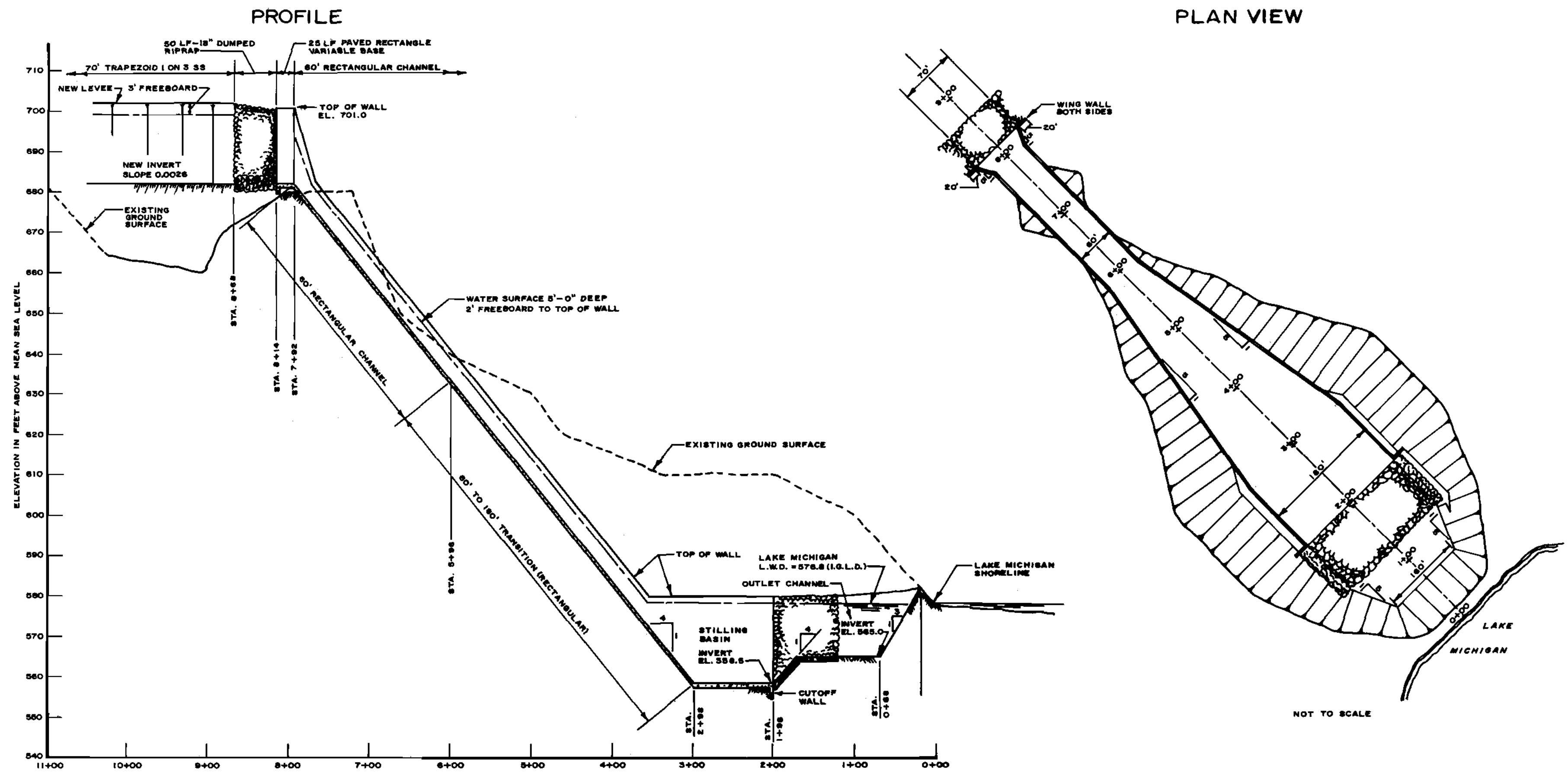


Figure 10 (continued)

DETAIL C
OUTLET STRUCTURE



NOTE: (1) THIS DIVERSION SYSTEM PLAN IS REPRODUCED, WITH THE DELETION OF SOME MINOR DETAILS, FROM PLATES 4, 5, AND 6 AS PUBLISHED IN SURVEY REPORT FOR FLOOD CONTROL—MILWAUKEE RIVER AND ITS TRIBUTARIES, WISCONSIN, U.S. ARMY ENGINEER DISTRICT—CHICAGO, NOVEMBER, 1964.

(2) ALL ELEVATIONS ARE REFERED TO MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT.

Source: U. S. Army Corps of Engineers.

(3) Vegetation of value to wildlife will be reestablished on channel slopes, spoil areas, and levees.

(4) The project area between Wisconsin Highway 141 and County Road C to remain open to public hunting as presently exists.[30]

Reexamination and Update: A careful review of the hydrology, hydraulics, quantities, prices, and cost of the channel, as proposed by the U. S. Army Corps of Engineers in its 1964 report, was made as a part of the Milwaukee River watershed study. All elements of the proposal were found to be sound and reasonable. To make this alternative flood control measure comparable with the other river control alternatives considered in this study, the Construction Cost Index of Engineering News Record was used to update costs from April 1964, the base date of the Corps' economic analysis, to January 1969, the base date of economic analysis in this study. The Construction Cost Index increased from 1,020 to 1,331, or by 30 percent during this period.

The change in the base date resulted in an increase in the capital cost of the diversion channel, from $5,350,000 to $6,975,000. A change in the annual interest rate from 3 1/8 percent, as used in the Corps' analysis, to the 6 percent rate incorporated in the present study, and a similar change in the project life from 100 years to 50 years, combined with the aforementioned change in capital costs, increased the annual costs from $200,000, as reported by the Corps, to $460,800. A summary of the original and adjusted costs is shown in Table 29.

A benefit-to-cost ratio of 1.09 was determined during the 1964 study, with 82 percent, or $178,000 of the $217,000, in annual benefits accruing from reduction of flood damages along the Lower Milwaukee River downstream of the north limits of the Village of Saukville and with the remaining 18 percent, or $39,000, credited to increased land utilization potential. With the channel designed to divert the 100-year flood in its entirety at Saukville, the Corps' estimates showed a residual average annual flood-damage potential of $15,000 of an estimated total potential of $193,000. Thus, the channel would eliminate about 92 percent of the flood damages along the Lower Milwaukee River, from and including Saukville to the City of Milwaukee. The estimated annual flood control benefits include an upward adjustment to account for watershed urbanization, particularly in riverine areas, that could be expected over an approximately 100-year period beginning in 1964.

Table 29

COSTS AND BENEFITS OF A POTENTIAL FLOODWATER DIVERSION CHANNEL FROM THE MILWAUKEE RIVER TO LAKE MICHIGAN AT SAUKVILLE[a]

ITEM	ORIGINAL *PROPOSAL*	UPDATED *VERSION*
FEDERAL INVESTMENT		
CAPITAL COST	$ 4,410,000	$ 5,750,000
INTEREST DURING CONSTRUCTION[b]	138,000	335,000
TOTAL FEDERAL COST	$ 4,584,000	$ 6,085,000
FEDERAL ANNUAL CHARGES		
AMORTIZATION OF TOTAL FEDERAL COST	$ 149,200	$ 366,100
NON-FEDERAL INVESTMENT		
CAPITAL COSTS	$ 940,000	$ 1,225,000
INTEREST DURING CONSTRUCTION[b]	29,000	74,000
NET LOSS OF PRODUCTIVITY ON LAND DURING CONSTRUCTION[c]	12,000	--
TOTAL NON-FEDERAL COST	$ 981,000	$ 1,299,000
NON-FEDERAL ANNUAL CHARGES		
AMORTIZATION OF TOTAL NON-FEDERAL COST	$ 32,200	$ 78,200
NET LOSS LAND PRODUCTIVITY[c]	6,000	--
OPERATION AND MAINTENANCE	11,900	15,600
REPLACEMENT OF OPERATING EQUIPMENT	700	900
SUBTOTAL	$ 50,800	$ 94,700
TOTAL ANNUAL CHARGES	$ 200,000	$ 460,800
TOTAL ANNUAL BENEFITS[d]	$ 217,000	$ 144,500
BENEFIT-TO-COST RATIO	1.09	0.31

[a]THE COSTS AND BENEFITS FOR THE SAUKVILLE DIVERSION CHANNEL WERE ORIGINALLY ESTIMATED BY THE U. S. ARMY CORPS OF ENGINEERS IN 1964 AS A PART OF THE FLOOD CONTROL STUDY FOR THE MILWAUKEE RIVER. THESE COSTS AND BENEFITS WERE UPDATED BY THE SEWRPC AS A PART OF THE MILWAUKEE RIVER WATERSHED STUDY. *THE ORIGINAL COSTS ASSUME A 100-YEAR PROJECT LIFE WHILE THE ADJUST-* ED, OR UPDATED, COSTS ARE BASED UPON A 50-YEAR PROJECT LIFE, WHICH PROJECT LIFE WAS USED IN THE ECONOMIC ANALYSES OF THE OTHER ALTERNATIVE FLOOD CONTROL PLAN ELEMENTS PRESENTED IN THIS CHAPTER. THE UPDATED COSTS UTILIZE A 6 PERCENT ANNUAL INTEREST RATE, IN CONTRAST WITH THE 3.13 PERCENT ANNUAL INTEREST INCORPORATED IN THE U. S. ARMY CORPS OF ENGINEERS' ECONOMIC ANALYSIS. THE UPDATED COSTS ARE BASED ON JANUARY 1969 CONSTRUCTION COSTS RATHER THAN APRIL 1964 COSTS AS USED IN THE CORPS OF ENGINEERS' STUDY. THE 1969 CONSTRUCTION COSTS ARE 30 PERCENT GREATER THAN THE 1964 CONSTRUCTION COSTS BASED UPON THE CONSTRUCTION COST INDEX OF ENGINEERING NEWS RECORD WHICH ROSE FROM 1020 TO 1331 DURING THAT TIME INTERVAL.

[b]BASED ON ONE-HALF OF THE TWO YEAR CONSTRUCTION PERIOD AT AN ANNUAL INTEREST RATE OF 3.13 PERCENT FOR THE ORIGINAL PROPOSAL AND 6 PERCENT FOR THE UPDATED VERSION.

[c]LAND WAS ASSUMED TO HAVE AN ANNUAL PRODUCTIVITY OF 5 PERCENT OF ITS MARKET VALUE. *THE 3.13 PERCENT ANNUAL INTEREST RATE UTILIZED BY THE CORPS OF* ENGINEERS ACCOUNTS FOR ALL BUT 1.87 PERCENT OF THIS. THE NET ANNUAL LOSS OF PRODUCTIVITY ON THE LAND REMOVED FROM PRODUCTION IS THEREFORE, 1.87 PERCENT TIMES THE INITIAL LAND ACQUISITION COST WHICH WAS ESTIMATED TO BE $316,000 IN THE ORIGINAL CORPS OF ENGINEERS ANALYSIS. THE UPDATED VERSION OF THE PROJECT COSTS ASSUMES THAT THE SIX PERCENT ANNUAL INTEREST RATE COMPLETELY ACCOUNTS FOR THE ANNUAL LOSS OF PRODUCTIVITY OF THE LAND REMOVED FROM PRODUCTION.

[d]THE FLOOD FLOW SIMULATION MODEL UTILIZED IN THE MILWAUKEE RIVER WATERSHED STUDY. INDICATES THAT THE SAUKVILLE DIVERSION CHANNEL WOULD REDUCE AVERAGE ANNUAL FLOOD DAMAGES IN THE LOWER MILWAUKEE RIVER FROM $149,500 TO $5,000 FOR A NET ANNUAL FLOOD CONTROL BENEFIT OF $144,500. THIS ADJUSTED ANNUAL FLOOD CONTROL BENEFIT IS LESS THAN THE $217,000 ANNUAL VALUE UTILIZED IN THE CORPS OF ENGINEERS STUDY, BECAUSE THE FORMER, UNLIKE THE LATTER, DOES NOT INCLUDE CREDIT FOR INCREASED FLOODPLAIN LAND UTILIZATION, SUCH LAND USE BEING CONTRARY TO THE ADOPTED WATERSHED DEVELOPMENT OBJECTIVES AND BECAUSE THE ANNUAL FLOOD CONTROL BENEFITS USED IN THE PRESENT STUDY ARE BASED ON MORE CURRENT AND DETAILED DATA CONCERNING ACTUAL AND POTENTIAL FLOOD DAMAGE. THE AVERAGE ANNUAL CORPS OF ENGINEERS FLOOD ABATEMENT BENEFITS, WHICH IS $178,000 OF THE $217,000 TOTAL ANNUAL BENEFIT, WAS NOT ADJUSTED UPWARD SINCE IT ALREADY REFLECTS, FOR THE 100 YEAR PERIOD BEGINNING IN 1964, INCREASED FLOOD DAMAGES THAT WOULD RESULT FROM EXPECTED WATERSHED URBANIZATION PARTICULARLY IN RIVERINE AREAS OF THE LOWER MILWAUKEE RIVER DOWNSTREAM OF AND INCLUDING THE VILLAGE OF SAUKVILLE.

SOURCE- U.S. ARMY CORPS OF ENGINEERS, HARZA ENGINEERING COMPANY, AND SEWRPC.

[30]*Ibid.*, *Footnote 28.*

For the present study, the flow simulation model described in Chapter XII, Volume 1, of this report was used to determine the effect on downstream flooding of the diversion at Saukville of all the runoff from the tributary drainage area upstream of the diversion site during a 100-year recurrence interval watershed-wide flood event. The results of the study differed somewhat from the findings reported by the U. S. Army Corps of Engineers in that no damages were found to occur to houses and commercial establishments downstream from Saukville with the diversion channel in operation. Damages still could be expected to occur in the areas upstream from Saukville, and some minor road closures would occur in the vicinity of the junction of the Milwaukee River and Cedar Creek during a 100-year event. The average annual damages of $149,500 would be reduced to $5,000, yielding an average annual benefit for the Saukville Diversion of $144,500, which, relative to the updated annual cost of $460,800, yields a benefit-cost ratio of 0.31. These benefits are less than those calculated for the 1964 study by the U. S. Army Corps of Engineers, because no credit was included for increased floodland utilization in the watershed study, such utilization being contrary to the development objectives expressed in the adopted regional land use plan; because flood damages in the present study were not projected as far into the future as in the Corps' study; and finally because the Milwaukee River watershed study provided an opportunity to collect more up-to-date information concerning development on the floodlands and, therefore, to make more detailed analyses of flood-damage potential. For example, the analysis of potential damages in the present study was made based upon unit damages due to depth of flooding in three classes of residences, whereas the damages estimated in the Corps' study were based on an average unit value for each structure regardless of cost class of the house and depth of inundation. In summary, then, differences in analytic technique contributed to the resulting significant difference in the annual flood control benefits.

This plan element would not serve all of the watershed land use development objectives but would adequately serve the watershed flood control objectives. As already noted, flood peaks and associated flood damages would be eliminated along the Milwaukee River from the structure to the City of Milwaukee during floods as severe as the 100-year event. It would not eliminate those minor damages which occur upstream from Saukville or prevent some occasional road closures near the junction with Cedar Creek.

Dike-Floodwall Systems with Supplemental Structure Removal and Floodproofing

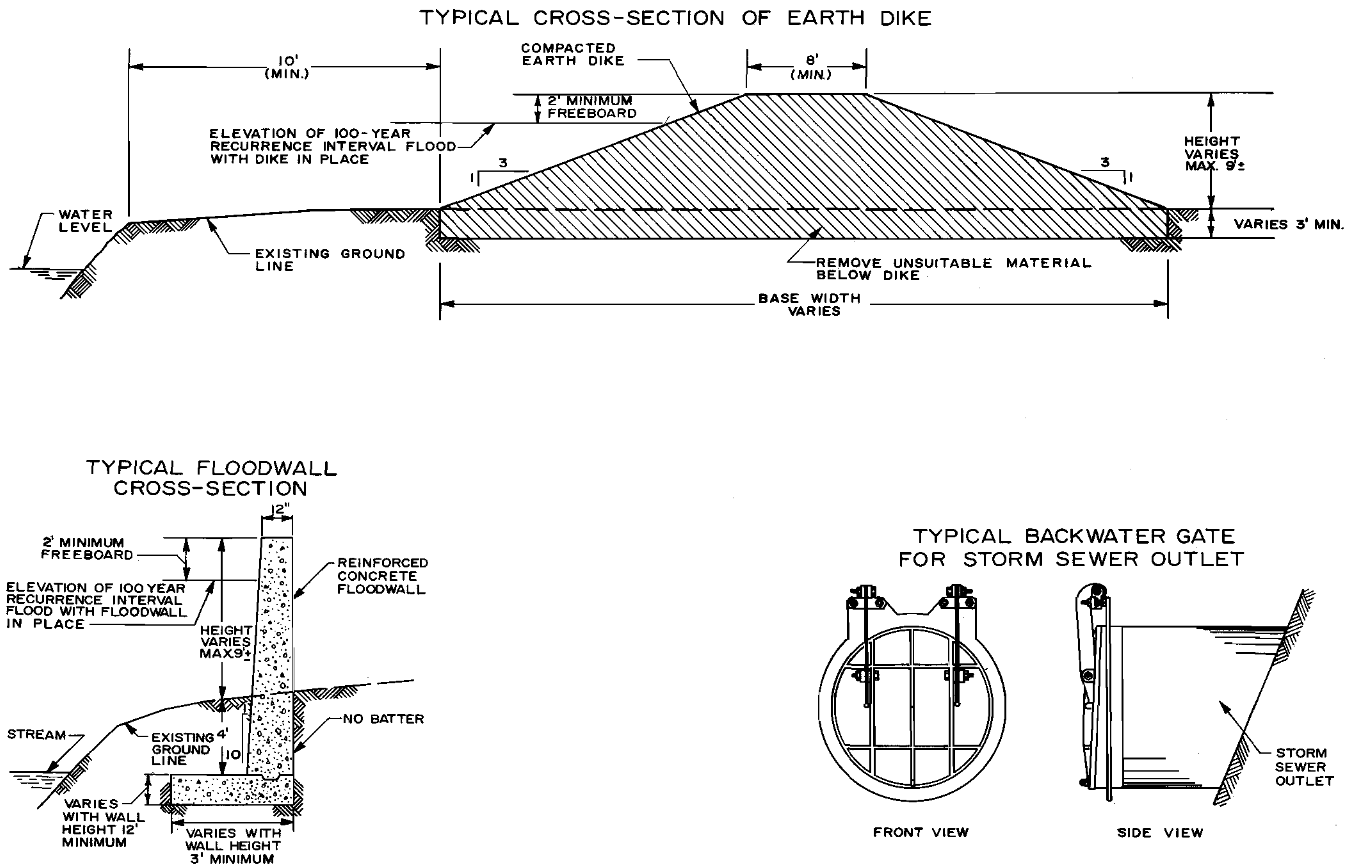
One of the alternative structural flood control plan elements considered in the watershed study was the construction of a system of intermittent earth dikes and concrete floodwalls, supplemented by the removal of existing structures in the floodways and floodproofing of other existing structures in the floodplains of the river system which could not be protected by such dikes and floodwalls. This alternative was developed for the Cities of Glendale in Milwaukee County and Mequon in Ozaukee County and the Villages of Thiensville and Saukville in Ozaukee County, which communities are subject to very high monetary damages from a 100-year recurrence interval flood event under existing land use conditions.

Dike-Floodwall Systems: Earth dikes are a technically feasible means of providing flood protection to a developed area, provided that sufficient space is available between the river and the land uses to be protected to permit such construction. The earth dikes, as shown in Figure 11, would be constructed of compacted earthfill, with a minimum top width of eight feet and three-on-one side slopes. The tops and slopes of the dikes would be vegetated to enhance their appearance and to prevent erosion. In confined areas the earth dikes would have to be replaced by more costly concrete floodwalls or by specially reinforced variations of the earth dike. Concrete floodwall dimensions and design, as indicated in Figure 11, would vary with site conditions and location. Dike and floodwall crests would be positioned so as to provide a freeboard of at least two feet above the 100-year recurrence interval flood stage, that stage being determined by application of the flood-flow simulation model under conditions that assume the existence of the dikes and floodwalls.

In order to be effective in reducing flooding, dikes and floodwalls must normally be supplemented by the installation of backwater gates, as shown in Figure 11, on those storm sewer outfalls and other drainage outlets penetrating the dikes and floodwalls that have street inlets or other entry points in the area to be protected at elevations approximately two feet or less above the 100-year recurrence interval river flood stage. A storm water drainage system, which typically includes the aforementioned street storm water inlets and

Figure 11

TYPICAL EARTH DIKE AND CONCRETE FLOODWALL AND A BACKWATER GATE FOR POSSIBLE FLOOD CONTROL USE IN THE MILWAUKEE RIVER WATERSHED



Earth dikes are a technically feasible means of providing flood protection in a developed area, provided that sufficient space is available between the river and the land uses to be protected. In confined areas more costly concrete floodwalls become necessary. Flood protection systems of intermittent dikes and floodwalls usually incorporate backwater gates so as to prevent the reversed flow of water from the river via the storm drainage system to the developed area behind the levees and floodwalls. Dikes, floodwalls, and backwater control structures are sometimes used in conjunction with minor channel modifications, such as straightening, shaping, and lining and clearing of vegetation, rocks, and miscellaneous debris. Alterations to river channels and their floodplains, including such measures as dike and floodwall construction and minor channel modifications, have the potential to significantly raise flood stages, not only in the river reach seeking flood relief but also in upstream and downstream riverine areas. Therefore, the detailed engineering design of such water control systems must include a complete hydraulic analysis of their effect on flood stages.

Source: U. S. Soil Conservation Service and SEWRPC.

storm sewer outfalls, normally provides for the conveyance of storm water runoff from developed urban areas to the river. During major flood events, however, high river levels can reverse the operation of the storm water drainage system, thus negating its function and resulting in the movement of floodwaters from the river into developed riverine areas, thereby producing unwanted inundation and attendant monetary damages and inconvenience. Backwater gates prevent such flow reversal by functioning as valves that normally pass the storm water to the river but close when the hydraulic head on the river side of the hinged gate exceeds the head on the opposite side of the gate.

While backwater gates, operating as described above, will prevent the movement of floodwaters from the river, they may, depending on topographic conditions, create local flood problems attributable to the accumulation of storm water runoff which does not have access to the river because of the closed storm sewer outfalls. Areas susceptible to this problem can be afforded protection by making provision for temporary or permanent pumping facilities to convey the impounded storm water to the river during major flood events.

At locations where a major artificial drainage ditch or natural watercourse is tributary to the river reach being protected by a dike-floodwall system, a backwater control structure more elaborate and costly than that shown in Figure 11 would be required. Each of these devices would be structurally and hydraulically designed to meet the requirements of the particular location and would perform the same function as the aforementioned backwater gates.

Channel modification, including straightening, shaping, lining, and clearing of vegetation, rocks, and miscellaneous debris which may reduce the hydraulic capacity of the channel, constitute a minor flood control measure commonly used in conjunction with dikes and floodwalls. The objective of such improvements is to reduce the likelihood of ice jams and the accumulation of floating debris and to increase the hydraulic capacity of the channel so as to permit the passage of flood flows at reduced peak stages. Reductions in peak flood stages help to limit the required dike and floodwall heights and the attendant costs and may diminish the unsightly characteristics of extremely high dikes and floodwalls.

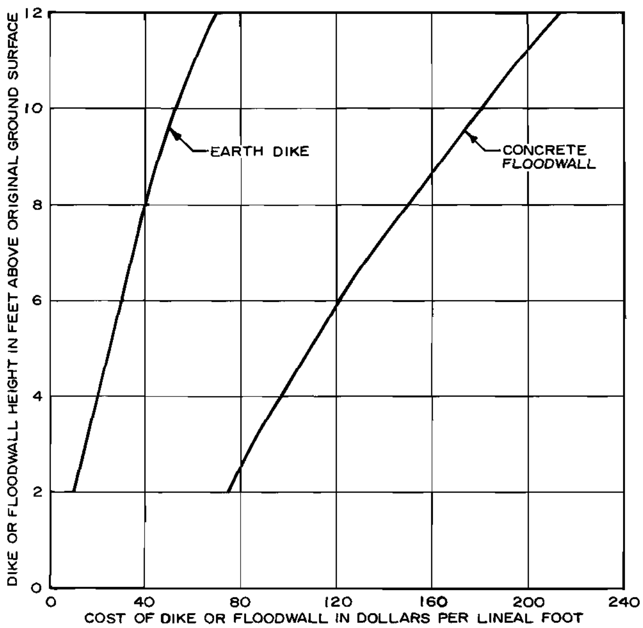
Alterations to the channel and floodplain of a river, including dike and floodwall construction and channel straightening, shaping, lining, and clearing, have the potential to significantly change flood stages and discharges, not only in the reach seeking flood relief, but also in upstream and downstream reaches. The detailed engineering design of any type of river modification intended to abate flood problems must, therefore, include an assessment of the attendant probable hydraulic effects, with particular emphasis on possible increased flood stages within, and upstream and downstream of, the affected reach. The dike and floodwall systems analyzed herein for the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville were accordingly sized to accommodate peak stages corresponding to the 100-year recurrence interval watershed-wide flood event as that flood would occur with the dikes and floodwalls in place, as determined by the flood-flow simulation model for 1990 land use conditions. The potential hydraulic effect of minor channel modifications was not included in the preliminary assessment of the technical and economic feasibility of potential dikes and floodwalls. That preliminary assessment, as described herein, revealed that the costs of dike and floodwall systems would greatly exceed the flood abatement benefits. In light of the extremely uneconomic characteristics indicated by the preliminary analysis, it was determined that the dike and floodwall systems did not merit more detailed hydraulic examination, including analysis of the hydraulic effects of minor channel modifications.

Curves relating the cost of dikes and floodwalls per lineal foot to the design height were prepared to facilitate the estimation of the capital costs that would be incurred by construction of the proposed dike and floodwall systems. Unit costs utilized in the preparation of these curves included embankment placement at $1.25 per cubic yard, stripping at $1.00 per cubic yard, seeding at $0.20 per square yard, concrete at $125.00 per cubic yard, and excavation and backfill at $2.00 per cubic yard. The dike and floodwall cost curves, which are shown in Figure 12, also include engineering administrative costs equal to 15 percent of the construction costs and a 25 percent provision for contingencies. The annual operation and maintenance costs for earth dikes and $1,000, respectively, per mile and included the cost of regular inspection, minor repair, rodent control, mowing, and beautification.

Dike and floodwall land acquisition or easement costs were not incorporated in the aforementioned curves, such costs being a function of riverine land values, which typically exhibit wide variation from community to community within the watershed. The necessary land costs were estimated on the assumption that a 100-foot-wide strip of land parallel and adjacent to the river would be purchased for earth dike construction—equivalent to 2.3 acres per 1,000 lineal feet of dike—and that, similarly, a 30-foot-wide strip—equivalent to 0.7 acre per 1,000 lineal feet—would be purchased for the concrete floodwall construction. The unit market value of riverine land in each community was estimated as being approximately equal to the 1969 equalized assessed valuation of representative river lands. The resulting representative riverine land values, as determined by a review of assessment records, ranged from a high of $25,000 per acre in Thiensville to a low of $3,500

Figure 12

DIKE AND FLOODWALL COST CURVES USED IN THE ECONOMIC ANALYSIS OF ALTERNATIVE FLOOD CONTROL WORKS IN THE MILWAUKEE RIVER WATERSHED



NOTE: COSTS INCLUDE STRIPPING, EXCAVATION, BACKFILL, EMBANKMENT WORK, CONCRETE PLACEMENT, AND SEEDING PLUS 15 PERCENT OF THESE CONSTRUCTION COSTS FOR ENGINEERING-ADMINISTRATION AND 25 PERCENT FOR CONTINGENCIES. LAND AQUISITION, EASEMENT, AND STRUCTURE REMOVAL COSTS ARE NOT INCLUDED.

Source: Harza Engineering Company.

per acre for one of the three reaches in the City of Mequon. Land acquisition costs were omitted for earth dike segments that would be formed by reconstructing and elevating public roadways, since the street or highway rights-of-way are already in public ownership.

The average cost for backwater gates to be installed on existing storm sewer outfalls or other outlets was estimated at $200 per outfall, while the average cost of backwater control structures on drainage ditches and natural watercourses tributary to the main channel would be somewhat higher. It should be noted that the costs of the necessary backwater gates and control structures are, however, typically negligible relative to the aggregate capital cost of land acquisition and dike and floodwall construction. For example, the cost of a backwater gate similar to that shown in Figure 11 is approximately equal to the land acquisition and construction costs of one lineal foot of concrete floodwall. As already noted, minor channel modifications were not incorporated in the preliminary analysis of dike-floodwall systems as presented herein. The costs of such minor channel modifications attendant to dike and floodwall construction would be negligible relative to the capital cost of land acquisition and construction of the dikes and floodwalls.

Structure Removal and Floodproofing: Dikes and floodwalls are generally technically and economically feasible flood control measures only within areas containing relatively intensive concentrations of residences or other major structures.[31] It is generally not economically feasible to utilize dike and floodwall systems for the protection of homes and other structures sited in widely scattered locations along the floodlands. Flood-damage relief for such highly dispersed floodland structures would have to be accomplished by a combination of floodproofing of those homes and other major structures with first-floor elevations above the peak stage of the 100-year recurrence interval flood event and removal of those homes and structures with first-floor elevations below that flood stage. The criteria relating to floodproofing or removal of such floodland structures are largely economic, in that flood damages mount rapidly as first floors are inundated, while floodproofing costs also rise abruptly if first floors are to be protected.

For the purpose of estimating structure floodproofing and structure removal costs, it was assumed that structures located between the 10- and 100-year recurrence interval flood inundation levels would generally not be subjected to first-floor flooding during a 100-year recurrence interval flood event; and, therefore, floodproofing would constitute a technically and economically feasible means of protection against such a flood. All such structures not presently floodproofed would be protected by floodproofing, while existing floodproofing would be extended and upgraded so as to offer full protection against a 100-year recurrence interval flood. Houses and other major structures located within the 10-year recurrence interval floodplain were generally assumed to be subject to first-floor inundation under conditions of a 100-year recurrence interval flood event and, therefore, would have to be removed from the floodlands if flood damages were to be avoided.

[31] *In addition to private residences, the major structure category, as defined for purposes of the analysis described herein, includes barns and other large agricultural related buildings and commercial, industrial, and public buildings. Minor structures, such as garages and sheds, were excluded from the analyses.*

Structure Removal and Costs: In the economic analyses of structure removal, it was assumed that the salvage value of the houses and other major structures at the time of public acquisition would be sufficient to cover demolition costs and subsequent landscaping of the vacated sites. The market value of floodland property, including the structures, was estimated as being approximately equal to the 1969 equalized assessed valuation of representative riverine flood-prone properties. The resulting market values of flood-prone lands and improvements subject to removal varied widely, with some properties having estimated market values of land and improvements in excess of $45,000 and others having estimated values as low as $4,000.

Structure Floodproofing and Costs: It is possible and generally practicable for property owners, as individuals, to make certain structural adjustments to, or impose certain use restrictions on, private properties in order to significantly reduce potential flood damages. These structural measures and use restrictions applied to buildings and their contents are known as "floodproofing." The watershed flood-damage survey revealed that many private individuals have practiced and may be expected to continue to practice various kinds of floodproofing measures, and these measures have undoubtedly contributed substantially to a reduction of historic flood damages. The calculation of future flood damages in this report is based, in part, upon the assumption that private floodproofing measures will continue to be applied to proportionately reduce future damages.

A review of the reports of the flood-damage survey of the Milwaukee River watershed supports the following presentation of floodproofing elements which can be applied by private individuals. It should be noted that selection of the specific floodproofing elements to be applied to a particular structure depends upon the features of the individual structure, such as the kind of structural material, age of the structure, substructure conditions, nature of the exposure to floodwaters, height of the water table, sewerage facilities, and uses demanded of the structure. Extensive floodproofing should be applied only under the guidance of a registered professional engineer who has carefully inspected the building and its contents and has evaluated the flood threat. In order to approximately reflect floodproofing costs in the economic analyses, a representative per structure cost of $1,000 was utilized in the economic analyses, with the realization that the actual floodproofing cost for a particular structure might vary widely from this value because of the above-cited factors and the fact that some structures may be already at least partially floodproofed.

Categorized according to function, floodproofing elements are of four types: 1) general floodproofing, independent of the type of flooding; 2) seepage control; 3) relief from sewer backup; and 4) protection from overland flow.

General Measures

A number of floodproofing measures apply to flood-damage prevention regardless of the manner of flooding. These include the following: 1) keeping valuable items away from areas which could be flooded; 2) using waterproof cement in laying tile or linoleum; 3) having adequate electrical fuse protection in all homes; 4) unplugging, disconnecting, or removing from flood-vulnerable areas all electrical appliances; and 5) anchoring all fuel tanks securely so that the force of buoyancy will not cause floating and spillage. Some flood damages can be avoided by removing electric motors from furnaces and appliances and by removing perishable items from basements during times of flood threat.

Severe flood damages can be caused by fuel oil storage tanks floating loose from their anchorage, rupturing, and spilling oil over the contents and interior of homes. High flood damages can also result from unwise uses of basements or by impractical designs of floodland homes. Use of floodland basements or of the lower levels of "split level" homes as bedrooms, kitchens, or living rooms can result in high flood damages.

Seepage Control

During periods of flooding and accompanying high water tables, basements situated in floodlands on permeable soils are particularly susceptible to seepage through walls. Experience has shown that basements can be severely flooded by seepage within a few hours. Where structures are sound and hydrostatic pressure from ground water is low, basements may be waterproofed against seepage by sealing walls with either asphalt or quick-setting hydraulic compounds. In many instances, however, it is not practical to exclude all seepage water; and it becomes necessary to provide and operate a sump pump. As a safeguard against power failure, homeowners can install an auxiliary gasoline-fueled pump. As a general principle, all homes constructed in floodlands where the water table is high should have basement walls sealed for maximum waterproofing and should be equipped with a sump pit and a sump pump that is actuated automatically as waters rise.

Relief from Sewer Backup

Because of flat topography, high water tables, and surface overflow into manholes, floodland homes often experience flood damage from the backing up of sewage and floodwaters through a basement floor drain connected to the sanitary sewerage system. It is, therefore, advisable for floodland homeowners to guard against sewer backup.

A number of relatively inexpensive standard devices can be installed in sewer lines to prevent reverse flow of water. These include standard backwater valves, horizontal swing-check valves, and a closed-end pipe threaded into a flood drain. It is important to note that, in order for these devices to accomplish flood-damage relief, the floor drain must be of adequate strength to resist the hydrostatic pressure without rupturing and thus introducing floodwaters.

Under certain conditions of rapidly rising floodwaters, more flood-damage prevention may be accomplished by letting a basement flood than by trying to exclude the inflow of floodwater through sewer lines or in other ways. Severe damage can be caused by the differential pressure between floodwaters and empty basements. Basement floors can be uplifted by hydrostatic pressure and ruptured, and basement walls can be collapsed by the differential pressure. Basement floods, walls, and floor drains should not be floodproofed without consideration of the probable forces which the structure must withstand.

Protection from Overland Flow

Generally, it is not practicable to floodproof residences when floodwaters rise above first-floor levels. Exceptions are offered by particularly sturdy structures, such as well-constructed brick buildings, but most frame structures are difficult to floodproof above the first-floor level. Below the first-floor level, overland flow can sometimes be excluded by the installation of seal-tight, wire-reinforced glass on all basement windows. An alternative measure is to seal all exterior openings to basements with glass block, concrete block, or brick and depend entirely on artificial light and air conditioning for light and air in the basement area.

Benefits Accruing from Dikes and Floodwalls with Structure Removal and Floodproofing:

Average annual flood abatement benefits accruing from the potential dike and floodwall construction and supplemental structure removal and floodproofing in the Cities of Glendale and Mequon and in the Villages of Thiensville and Saukville were estimated using the annual flood-damage costs presented in Chapter VIII of Volume 1 of this report. It was assumed that the dikes and floodwalls in conjunction with floodproofing and removal would completely eliminate residential, road-user, commercial, and public-sector damages; and, therefore, the annual flood control benefits accruing from the dike-floodwall system for river reaches within, or coincident with, the aforementioned communities would be equal to the average annual flood damage that would occur without the flood control measure.

The structure removal proposals attendant to this flood control alternative enhance the opportunity to develop the aesthetic and recreation potential of the riverine lands. Structure removal would restore river floodlands to a natural state, thereby enhancing the aesthetic value and in effect recreating environmental corridor lands similar to those recommended for public acquisition, as described in Chapter III of this volume. Such restored environmental corridor lands could be used for outdoor recreation purposes. Such use of riverine lands, compatible with their flood-prone nature, would help to meet rising recreation demands within the watershed.

Dike-Floodwall System for the City of Glendale:

The City of Glendale, which is coincident with Flood Damage Reach 2, as defined and discussed in Chapter VIII of Volume 1 of this report, is characterized by intensive urban development on the natural floodlands of the Milwaukee River, with such floodland occupancy being largely concentrated in the river reach extending from W. Silver Spring Drive upstream about two miles through the Sunny Point Road area just north of Bender Road. Ninety-eight major structures, primarily private residences, may be expected to incur flood damage during a 10-year recurrence interval flood event, while 280 additional major structures, also primarily private residences, could be expected to incur flood damage during a 100-year recurrence interval flood event in this reach.

A system of intermittent earth dikes and concrete floodwalls supplemented by backwater control structures could be designed, constructed, and operated so as to eliminate virtually all damages to the 378 flood-prone structures from flood events up to and including the 100-year recurrence interval flood event.

The dike-floodwall system is shown on Map 11, and Table 30 presents a schedule of the physical requirements and characteristics of the system and the attendant costs and benefits. The hydraulic effect of the dike-floodwall system, as reflected in increased peak stages for a 100-year recurrence interval flood event, is set forth in Table 31, along with the crest elevation of the dikes and floodwalls. The crest elevation includes both the increased stage attributable to the dike-floodwall system and the two-foot minimum freeboard standard, as set forth in Chapter II of this volume. About 9,700 lineal feet of earth dike and 7,000 lineal feet of concrete floodwall would be required, with some segments having a height in excess of 10 feet, as measured from the dike or floodwall base at the existing river bank elevation to the crest of the dike or floodwall. Extensive use of the more costly concrete floodwalls rather than earth dikes would be necessary due to space limitations imposed by the very narrow band of unoccupied land located between the river edge and the existing first tier of structures along much of the flood-prone areas. Flood control in the Sunny Point Road area would be achieved by a 5,700-foot-long continuous structure on the left bank of the river, composed of 3,900 and 1,800 lineal feet of earth dike and concrete floodwall, respectively. The reach bounded by Bender Road on the north and Silver Spring Drive on the south would be protected by 11,000 feet of dikes and floodwalls, consisting of 1,400 and 2,800 lineal feet of earth dike and concrete floodwall, respectively, on the left (east) bank and 4,400 and 2,400 lineal feet of dike and floodwall, respectively, on the right (west) bank. Flood protection afforded by the dikes and floodwalls would be supplemented, with the necessary backwater control structures, including one such structure near the center of Section 29, Town 8 North, Range 22 East, at the confluence of a drainage channel and the Milwaukee River.

Assuming that all of the above flood control measures would be implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost of the dike-floodwall flood control alternative is estimated at $127,000, including amortization of the capital cost of the dikes and floodwalls, as well as the annual dike and floodwall operation and maintenance costs. The average annual flood abatement benefit is estimated at $37,640, yielding a benefit-cost ratio of 0.30. The City of Glendale dike-floodwall system, with supplemental structure floodproofing, as described herein, is, therefore, technically feasible but extremely uneconomical. In addition to this unfavorable economic feature, the great height of the dikes and floodwalls necessitated by high peak flood stages relative to existing riverine area topography and by the safety provision that requires a freeboard of at least two feet above that stage would make the structures extremely unsightly. The residents protected by the dikes and floodwalls, particularly those property owners living near the river, would generally have the view of the river blocked by the structures and would encounter difficulty in gaining access to the river because most of the dikes and floodwalls would have their crests at a height of seven feet or more above the existing ground elevation of the river's edge. While the costs associated with such aesthetically undesirable characteristics are elusive and difficult to assign a monetary value to, they are, nevertheless, very real.

Dike-Floodwall System for the City of Mequon: The City of Mequon, which is coincident with Flood Damage Reaches 5, 7, and 8, as defined in Chapter VIII of Volume 1 of this report, is also characterized by relatively intensive urban development within the natural floodlands of the Milwaukee River. Damage Reach 5, which extends along the river from the south corporate limits of the City of Mequon upstream about three miles to STH 167, contains approximately 19 major structures, all private residences, that may be expected to incur flood damage during a 10-year recurrence interval flood event, and approximately 27 additional major structures, also all private residences, that

Map 11

DIKE-FLOODWALL SYSTEM ON THE MILWAUKEE RIVER CITY OF GLENDALE

LEGEND

CONCRETE FLOODWALL

EARTH DIKE

RM 9.60 RIVER MILE STATION

100-YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE FOR UNCONTROLLED CONDITIONS (NO DIKES OR FLOODWALLS)

10-YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE FOR UNCONTROLLED CONDITIONS (NO DIKES OR FLOODWALLS)

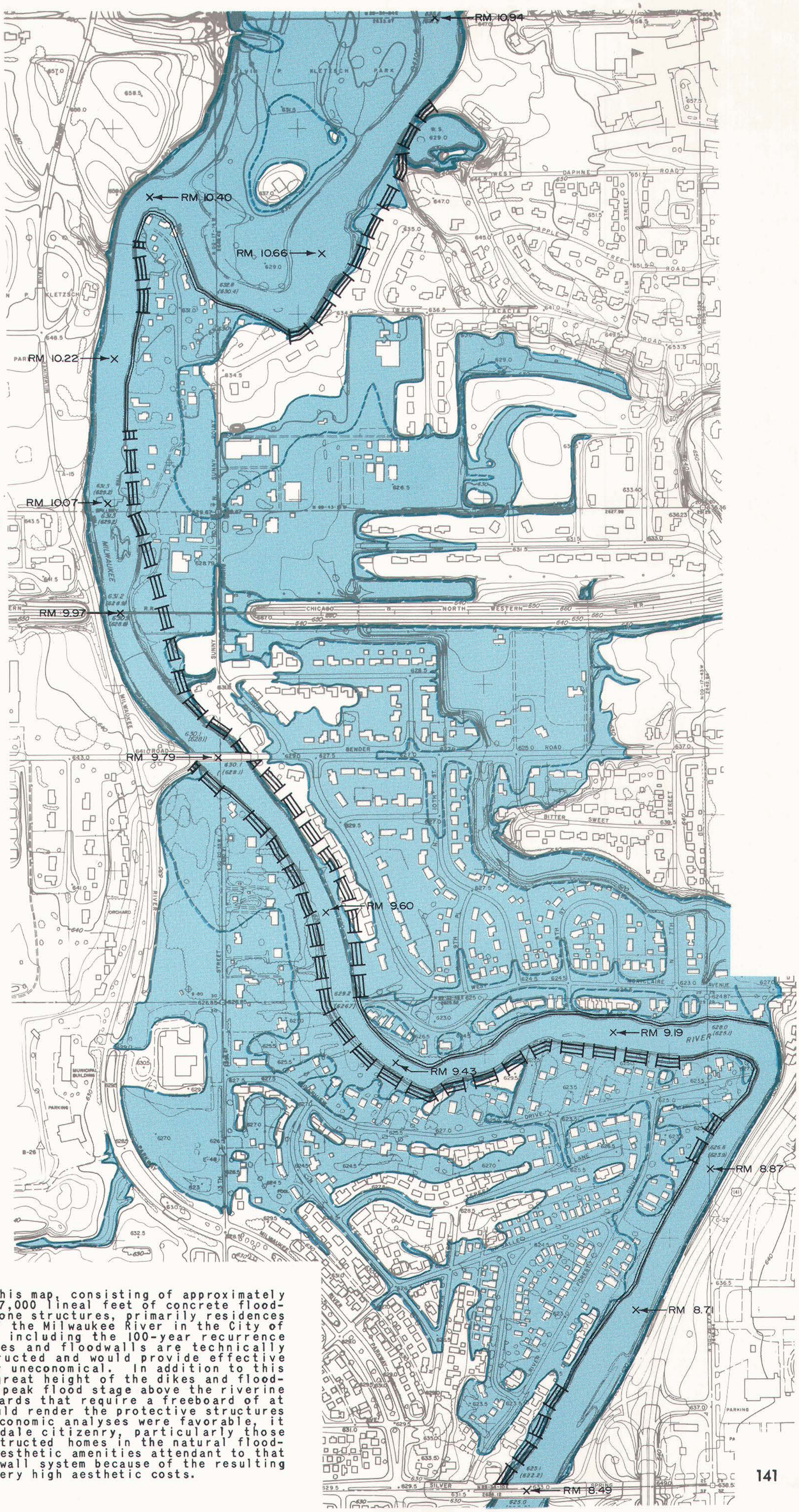
NOTE:

1. THE AREA TO THE LANDWARD SIDE OF THE DIKES AND FLOODWALLS IS TO BE DRAINED AND PROTECTED AS NECESSARY THROUGH APPROPRIATELY LOCATED AND SIZED CULVERTS AND OTHER DRAINAGE FACILITIES EQUIPPED WITH BACKWATER CONTROL DEVICES

2. REFER TO TABLE 31 FOR A LIST OF REQUIRED DIKE AND FLOODWALL CREST ELEVATIONS AND FOR A COMPARISON, AT SELECTED LOCATIONS, BETWEEN 100-YEAR RECURRENCE INTERVAL FLOOD STAGES WITH AND WITHOUT THE DIKE-FLOODWALL SYSTEM, SUCH COMPARISON INDICATING THE HYDRAULIC EFFECT OF THE CONSTRICTION IMPOSED ON THE CHANNEL AND ITS FLOODPLAIN BY THE DIKES AND FLOODWALLS

GRAPHIC SCALE

0 200 400 600 800 FEET



The dike-floodwall system shown on this map, consisting of approximately 9,700 lineal feet of earth dike and 7,000 lineal feet of concrete floodwall, would protect all 378 flood-prone structures, primarily residences located in the natural floodlands of the Milwaukee River in the City of Glendale, against floods up to and including the 100-year recurrence interval event. Although the dikes and floodwalls are technically feasible, that is, could be constructed and would provide effective flood protection, they are extremely uneconomical. In addition to this unacceptable economic feature, the great height of the dikes and floodwalls required by the height of the peak flood stage above the riverine area topography, and by state standards that require a freeboard of at least two feet above that stage, would render the protective structures extremely unsightly. Even if the economic analyses were favorable, it is unlikely that the affected Glendale citizenry, particularly those residents who have purchased or constructed homes in the natural floodlands of the river, because of the aesthetic amenities attendant to that location, would support a dike-floodwall system because of the resulting elusive, but, nevertheless, real, very high aesthetic costs.

Source: SEWRPC.

Table 30

ESTIMATED COSTS AND BENEFITS FOR DIKE-FLOODWALL SYSTEMS WITH SUPPLEMENTAL STRUCTURE REMOVAL AND FLOODPROOFING IN THE CITIES OF GLENDALE AND MEQUON AND VILLAGES OF THIENSVILLE AND SAUKVILLE[a]

LOCATION			DIKE-FLOODWALL SYSTEM											
			EARTH DIKE				CONCRETE FLOODWALL				DIKE-FLOODWALL SYSTEM COST SUMMARY			
COMMUNITY	[b]DAMAGE REACH NO.	RIVER MILES	LENGTH IN FEET	CONSTRUCTION, ENGINEERING, ADMINISTRATIVE COST PLUS CONTINGENCIES	LAND ACQUISITION COSTS	TOTAL CAPITAL COST OF DIKES	LENGTH IN FEET	CONSTRUCTION, ENGINEERING, ADMINISTRATIVE COST PLUS CONTINGENCIES	LAND ACQUISITION COSTS[c]	TOTAL CAPITAL COST OF FLOODWALL	CAPITAL COST	AMORTIZATION OF CAPITAL COSTS	ANNUAL COSTS OPERATION AND MAINTENANCE[d]	TOTAL
CITY OF GLENDALE	2	8.1-12.0	9,700	$ 392,500	$335,000	$ 727,500	7,000	$1,121,000	$ 73,500	$1,194,500	$1,922,000	$122,000	$ 5,000	$127,000
VILLAGE OF THIENSVILLE	6	18.8-20.6	1,600	61,000	92,000	153,000	1,600	350,000	27,500	377,500	530,500	33,600	900	34,500
CITY OF MEQUON	5	16.0-18.8	8,100	235,000	52,500	287,500	2,700	432,000	6,700	438,700	726,200	46,000	3,600	49,600
	7	18.8-22.0	--	--	--	--	--	--	--	--	--	--	--	--
	8	22.0-26.3	3,000	118,000	27,000	145,000	5,300	1,086,000	25,900	1,111,900	1,256,900	79,500	2,100	81,600
MEQUON SUBTOTAL			11,100	353,000	79,500	432,500	8,000	1,518,000	32,600	1,550,600	1,983,100	125,500	5,700	131,200
VILLAGE OF SAUKVILLE	12	35.0-37.5	10,100	290,000	134,000	424,000	2,700	386,000	15,200	401,200	825,200	52,300	4,300	56,600
TOTAL	--	--	32,500	$1,096,500	$640,500	$1,737,000	19,300	$3,375,000	$148,800	$3,523,800	$5,260,800	$333,400	$15,900	$349,300

LOCATION			SUPPLEMENTAL STRUCTURE REMOVAL AND FLOODPROOFING																BENEFIT-COST SUMMARY		
			EXISTING MAJOR STRUCTURES SUBJECT TO FLOODING WITH NO FLOOD ABATEMENT MEASURES						EXISTING MAJOR STRUCTURES THAT WOULD NOT BE PROTECTED BY DIKE-FLOODWALL SYSTEM						STRUCTURE REMOVAL-FLOODPROOFING COST SUMMARY						
			10- TO 100-YEAR INUNDATION LEVEL[e]			BELOW 10-YEAR INUNDATION LEVEL[e]			10- TO 100-YEAR INUNDATION LEVEL (FLOODPROOF)[f]			BELOW 10-YEAR INUNDATION LEVEL (REMOVE)[g]									
COMMUNITY	[b]DAMAGE REACH NO.	RIVER MILES	HOMES	OTHER	TOTAL	HOMES	OTHER	TOTAL	HOMES	OTHER	TOTAL	HOMES	OTHER	TOTAL	CAPITAL COST OF FLOOD-PROOFING	CAPITAL COST OF LAND AND IMPROVEMENTS[i]	TOTAL CAPITAL COST	ANNUAL COST	ANNUAL COST OF DIKE-FLOODWALL SYSTEM WITH SUPPLEMENTAL STRUCTURE FLOODPROOFING AND REMOVAL	ANNUAL BENEFIT[j]	BENEFIT/COST RATIO
CITY OF GLENDALE	2	8.1-12.0	268	12	280	74	24	98	0	0	0	0	0	0	$ --	$ --	$ --	$ --	$127,000	$ 37,640	0.30
VILLAGE OF THIENSVILLE	6	18.8-20.6	16	33	49	0	0	0	0	1	1	0	0	0	1,000	--	1,000	60	34,560	6,710	0.19
CITY OF MEQUON	5	16.0-18.8	27	0	27	19	0	19	7	0	7	1	0	1	7,000	17,500	24,500	1,550	51,150	17,980	0.35
	7[k]	18.8-22.0	16	0	16	32	0	32	16	0	16	32	0	32	16,000	449,000	465,000	29,500	29,500	37,430	1.27
	8	22.0-26.3	26	0	26	79	0	79	25	0	25	20	0	20	25,000	300,000	325,000	20,600	102,200	16,880	0.17
MEQUON SUBTOTALS			69	0	69	130	0	130	48	0	48	53	0	53	48,000	766,500	814,500	51,650	182,850	72,290	0.40
VILLAGE OF SAUKVILLE	12	35.0-37.5	86	27	113	4	3	7	10[l]	0	10	2	0	2	10,000	31,000	41,000	2,600	59,200	7,690	0.13
TOTAL	--	--	439	72	511	208	27	235	58	1	59	55	0	55	$59,000	$797,500	$856,500	$54,310	$403,610	$124,330	0.31

[a]DIKE AND FLOODWALL SYSTEMS WERE DEVELOPED ONLY FOR THESE FOUR COMMUNITIES IN THE WATERSHED SINCE, BECAUSE OF EXISTING INTENSIVE URBANIZATION OF FLOODLANDS, THEY WOULD EXPERIENCE HEAVY DAMAGE AND SIGNIFICANT DISRUPTION OF NORMAL ACTIVITIES DURING A 100-YEAR RECURRENCE INTERVAL FLOOD EVENT UNDER EXISTING LAND USE CONDITIONS. ECONOMIC ANALYSES ARE BASED ON AN ANNUAL INTEREST RATE OF SIX PERCENT AND A 50-YEAR AMORTIZATION PERIOD AND PROJECT LIFE.

[b]MAJOR FLOOD DAMAGE REACHES ARE DEFINED AND DISCUSSED IN CHAPTER VIII OF VOLUME 1 OF THIS REPORT.

[c]DIKE AND FLOODWALL LAND ACQUISITION COSTS ARE BASED ON THE EQUALIZED ASSESSED VALUE PER ACRE OF REPRESENTATIVE RIVERINE LANDS IN EACH COMMUNITY. EARTH DIKES WOULD REQUIRE ACQUISITION OF A 100 FOOT WIDE STRIP OF LAND ALONG THE RIVER'S EDGE WHICH IS EQUIVALENT TO 2.3 ACRES PER 1,000 LINEAL FEET, WHILE CONCRETE FLOODWALLS WOULD REQUIRE ACQUISITION OF A 30 FOOT WIDE STRIP EQUIVALENT TO 0.7 ACRES PER 1,000 LINEAL FEET.

[d]ANNUAL OPERATION AND MAINTENANCE COSTS FOR EARTH DIKES AND CONCRETE FLOODWALLS WERE ESTIMATED AT $2,000 AND $1,000, RESPECTIVELY, PER MILE.

[e]STRUCTURE IDENTIFICATION AND COUNTS WERE OBTAINED FROM LARGE SCALE FLOOD HAZARD MAPS (1" = 200', 2' - 4' CONTOUR INTERVAL) AND FROM LAND USE DATA COMPILED ON LOW-FLIGHT AERIAL PHOTOGRAPHS (1" = 400'). MAJOR FLOOD PRONE STRUCTURES WERE CLASSIFIED AS BEING EITHER HOMES OR SOME OTHER TYPE OF MAJOR STRUCTURE. GARAGES AND OTHER MINOR STRUCTURES WERE EXCLUDED. IN ADDITION TO HOMES, THE MAJOR STRUCTURE CATEGORY INCLUDES BARNS AND OTHER LARGE AGRICULTURAL RELATED BUILDINGS AS WELL AS COMMERCIAL, INDUSTRIAL, AND PUBLIC BUILDINGS. EXTREMELY LARGE BUILDINGS OR BUILDING COMPLEXES WERE COUNTED AS SEVERAL STRUCTURES IN ORDER TO BETTER REFLECT THEIR SIZE.

[f]HOUSES AND MAJOR STRUCTURES NOT PROTECTED BY DIKES OR FLOODWALLS AND HAVING FIRST FLOOR ELEVATIONS ABOVE THE 10-YEAR RECURRENCE INTERVAL FLOOD STAGE WOULD BE FLOODPROOFED UNDER THIS FLOOD CONTROL ALTERNATIVE. THE NUMBER OF STRUCTURES INCLUDED IN THIS CATEGORY AND THEREFORE SUBJECT TO FLOODPROOFING WAS ASSUMED TO BE EQUAL TO THE NUMBER OF STRUCTURES BETWEEN THE 10- AND 100-YEAR RECURRENCE INTERVAL FLOOD HAZARD LINES.

[g]HOUSES AND MAJOR STRUCTURES NOT PROTECTED BY DIKES OR FLOODWALLS AND HAVING FIRST FLOOR ELEVATIONS BELOW THE 10-YEAR RECURRENCE INTERVAL FLOOD STAGE WOULD BE REMOVED UNDER THIS FLOOD CONTROL ALTERNATIVE. THE NUMBER OF STRUCTURES INCLUDED IN THIS CATEGORY AND THEREFORE SUBJECT TO REMOVAL WAS ASSUMED TO BE EQUAL TO THE NUMBER OF STRUCTURES BETWEEN THE CHANNEL AND THE 10-YEAR RECURRENCE INTERVAL FLOOD HAZARD LINE.

[h]THE AVERAGE CAPITAL COST OF FLOODPROOFING WAS ESTIMATED TO BE $1,000 PER STRUCTURE.

[i]THE ACQUISITION COST OF LAND, STRUCTURES, AND OTHER IMPROVEMENTS IS BASED ON THE EQUALIZED ASSESSED VALUE OF REPRESENTATIVE RIVERINE PROPERTIES AND IMPROVEMENTS IN EACH COMMUNITY.

[j]THE ANNUAL BENEFIT ASSUMES THAT THIS FLOOD CONTROL ALTERNATIVE WOULD, FOR ALL REACHES EXCEPT REACH 7, ELIMINATE VIRTUALLY ALL FLOOD DAMAGES. SUCH DAMAGES CONSIST OF RESIDENTIAL DAMAGES, ROAD USER DETOUR COSTS, COMMERCIAL DAMAGES, AND PUBLIC SECTOR LOSSES.

[k]ALTHOUGH DIKES OR FLOODWALLS ARE NOT PROPOSED FOR REACH 7, ONE OF THE THREE REACHES COMPRISING THE CITY OF MEQUON, THAT REACH IS INCLUDED WITH COSTS AND BENEFITS ACCRUING TO STRUCTURE FLOODPROOFING AND REMOVAL SO AS TO FACILITATE AN ANALYSIS FOR THIS ENTIRE CIVIL DIVISION UNDER THE FLOOD CONTROL CATEGORY OF DIKE-FLOODWALL SYSTEMS WITH SUPPLEMENTAL STRUCTURE REMOVAL AND FLOODPROOFING. THE 32 MAJOR STRUCTURES IN THE 10-YEAR FLOODPLAIN OF REACH 7 IN THE CITY OF MEQUON INCLUDES 13 PRIVATE RESIDENCES ALONG VILLA GROVE ROAD IN SECTION 24, TOWN 9 NORTH, RANGE 21 EAST, RECENTLY PURCHASED BY THE CITY OF MEQUON FOR ULTIMATE REMOVAL FROM THE FLOODLANDS. SIX OF THESE HAVE NOT AS YET (1971) BEEN REMOVED BUT WILL BE EVACUATED FROM THE FLOODLANDS BY 1980. COSTS AND BENEFITS ATTENDANT TO THE ACQUISITION AND REMOVAL OF THESE 13 STRUCTURES HAVE BEEN INCLUDED IN THE ECONOMIC ANALYSES.

[l]INCLUDES 5 STRUCTURES ON THE EAST BANK IMMEDIATELY UPSTREAM OF RIVER MILE STATION 37.31 WHICH WOULD NOT BE SUBJECT TO INUNDATION UNDER NATURAL CONDITIONS BUT WOULD, WITH THE DIKES AND FLOODWALLS IN PLACE, INCUR MINOR FLOOD DAMAGE DURING A 100-YEAR RECURRENCE INTERVAL FLOOD AND THEREFORE REQUIRE FLOODPROOFING.

SOURCE- SEWRPC.

Table 31

HYDRAULIC EFFECT OF THE DIKE-FLOODWALL SYSTEM IN THE CITY OF GLENDALE--100-YEAR RECURRENCE INTERVAL FLOOD EVENT

LOCATION[a]			NO DIKES OR FLOODWALLS		WITH DIKE-FLOODWALL SYSTEM					
					LOCATION OF DIKES OR FLOODWALLS					
STATION (RIVER MILE)	STRUCTURE NAME OR OTHER IDENTIFICATION	STRUCTURE NUMBER	DISCHARGE (CFS)	STAGE (FEET MEAN SEA LEVEL)	EAST BANK	WEST BANK	DISCHARGE (CFS)	STAGE (FEET MEAN SEA LEVEL)[b]	STAGE INCREASE ATTRIBUTABLE TO DIKE-FLOODWALL SYSTEM (FEET)[b]	ELEVATION OF DIKE OR FLOOD-WALL CREST (FEET MEAN SEA LEVEL)[c]
8.49	SILVER SPRING DRIVE BRIDGE	207	16,136	--	--	--	16,136	--	--	--
8.50	--	--	16,136	625.1	--	X	16,136	625.1	0.0	627.1
8.71	--	--	16,136	626.0	--	X	16,136	626.0	0.0	628.0
8.87	--	--	16,136	626.8	--	X	16,136	627.0	0.2	629.0
9.19	--	--	16,136	628.6	X	X	16,136	629.0	0.4	631.0
9.43	--	--	16,136	629.0	X	X	16,136	630.3	1.3	632.3
9.60	--	--	16,136	629.4	X	X	16,136	632.4	3.0	634.4
9.78	--	--	16,136	630.1	X	X	16,136	634.4	4.3	636.4
9.79	BENDER ROAD BRIDGE	206	16,136	--	--	--	16,136	--	--	--
9.80	--	--	16,136	630.1	X	--	16,136	634.4	4.3	636.4
9.96	--	--	16,136	630.9	X	--	16,136	634.9	4.0	636.9
9.97	C&NW RR BRIDGE	205	16,136	--	--	--	16,136	--	--	--
9.98	--	--	16,136	631.2	X	--	16,136	634.9	3.7	636.9
10.06	--	--	16,136	631.3	X	--	16,136	635.0	3.7	637.0
10.07	KLETZSCH PARK DAM	204	16,136	--	X	--	16,136	--	--	637.0
10.08	--	--	16,136	631.3	X	--	16,136	635.0	3.7	637.0
10.22	--	--	16,136	631.8	X	--	16,136	635.1	3.3	637.1
10.40	--	--	16,136	--	X	--	16,136	635.4	--	--
10.66	NORTH LIMIT--CITY OF GLENDALE ON EAST BANK OF RIVER	--	16,136	633.2	X	--	16,136	636.7	3.5	638.7
10.94	--	--	16,136	633.5	--	--	16,136	636.7	3.2[d]	--
11.28	--	--	16,136	633.8	--	--	16,136	636.6	2.8[d]	--
11.29	GREEN TREE ROAD BRIDGE	203	16,136	--	--	--	16,136	--	--	--
11.30	--	--	16,136	636.0	--	--	16,136	636.9	0.9[d]	--
11.32	--	--	16,136	636.8	--	--	16,136	637.5	0.7[d]	--
11.54	--	--	16,136	638.3	--	--	16,136	638.7	0.4[d]	--
11.66	--	--	16,136	639.3	--	--	16,136	639.6	0.3[d]	--
11.67	GOOD HOPE ROAD BRIDGE	201 201A 202 202A	16,136	--	--	--	16,136	--	--	--
11.68	--	--	16,136	639.4	--	--	16,136	639.7	0.3[d]	--
11.86	--	--	16,136	640.6	--	--	16,136	640.8	0.2[d]	--
12.21	--	--	16,136	642.1	--	--	16,136	642.3	0.2[d]	--
12.49	NORTH LIMIT--CITY OF GLENDALE ON WEST BANK	--	16,136	--	--	--	16,136	--	--	--
12.62	--	--	16,136	644.6	--	--	16,136	644.6	0.0	--
12.83	--	--	16,136	645.4	--	--	16,136	645.4	0.0	--
12.84	PEDESTRIAN BRIDGE	200	16,136	--	--	--	16,136	--	--	--
12.85	--	--	15,830	645.5	--	--	15,830	645.5	0.0	--

[a] THE TABULATED STATIONS ARE SELECTED FROM THOSE USED IN THE FLOOD FLOW SIMULATION MODEL. LOCATIONS CORRESPONDING TO RIVER MILE STATIONS 8.49 THROUGH 10.94 ARE SHOWN ON MAP 11.

[b] STAGES CORRESPONDING TO THE DIKE-FLOODWALL SYSTEM ARE EQUAL TO OR GREATER THAN THE COMPARABLE STAGES FOR THE UNCONTROLLED SITUATION, THAT IS, THE CONDITION OF NO DIKES OR FLOODWALLS. THE STAGE INCREASE REPRESENTS THE HYDRAULIC EFFECT OF LATERALLY CONSTRICTING, WITH DIKES AND FLOODWALLS, THE NATURAL CROSS-SECTION OF THE RIVER AT FLOOD FLOW, WHICH CROSS-SECTION NORMALLY INCLUDES BOTH THE CHANNEL AND ADJACENT FLOODPLAIN, WITH THE RESULT THAT THE CONSTRICTED RIVER FLOWS AT A HIGHER STAGE TO COMPENSATE FOR THE LOSS OF FLOODPLAIN CARRYING CAPACITY OR CONVEYANCE.

[c] THIS IS THE MINIMUM ACCEPTABLE DIKE OR FLOODWALL CREST ELEVATION AND IS EQUAL TO THE 100-YEAR RECURRENCE INTERVAL FLOOD STAGE, UNDER CONDITIONS OF THE DIKES AND FLOODWALLS, PLUS A FREEBOARD PROVISION OF TWO FEET IN CONFORMANCE WITH THE WATER CONTROL FACILITY STANDARDS FOR THE MILWAUKEE RIVER WATERSHED AS SET FORTH IN CHAPTER II OF VOLUME 2 OF THIS REPORT.

[d] FLOOD STAGE INCREASES FOR THE RIVERINE AREA UPSTREAM OF THE GLENDALE DIKE-FLOODWALL SYSTEM ARE ACCEPTABLE IN THAT THEY WOULD NOT RESULT IN A SIGNIFICANT INCREASE IN 100-YEAR FLOOD DAMAGE RELATIVE TO THAT WHICH WOULD OCCUR WITHOUT THE DIKES AND FLOODWALLS.

SOURCE- SEWRPC.

could be expected to incur flood damage during a 100-year recurrence interval flood event. These flood-prone structures in Damage Reach 5 are concentrated primarily along, and immediately adjacent to, the left bank of the Milwaukee River in the vicinity of the Lac du Cours area in Section 36, Town 9 North, Range 21 East.

A system of intermittent earth dikes and concrete floodwalls supplemented with backwater control structures and structure removal and floodproofing could be designed, constructed, and operated so as to eliminate virtually all damages to the 46 flood-prone structures located in Damage Reach 5 from flood events up to and including the 100-year recurrence interval flood event.

The dike-floodwall system is shown on Map 12, and Table 30 presents a schedule of the physical requirements and characteristics of the system and the attendant costs and benefits. The hydraulic effect of the dike-floodwall system, as reflected in increased peak stages for a 100-year recurrence interval flood event, is set forth in Table 32, along with the crest elevation of the dikes and floodwalls. The crest elevation includes both the increased stage attributable to the dike-floodwall system and the two-foot minimum freeboard standard, as set forth in Chapter II of this volume. About 8,100 lineal feet of earth dike and 2,700 lineal feet of concrete floodwall, incorporated into a 6,400-foot-long continuous dike and floodwall structure on the left (east) bank of the river, and a 4,400-foot-long continuous dike structure on the right (west) bank, would be required, with some segments having a height in excess of 10 feet, as measured from the dike or floodwall base at the existing river bank elevation to the crest of the dike or floodwall. A 1,600-foot portion of the earth dike on the left (east) bank would be formed by reconstructing a segment of River Road so as to elevate it about seven feet above its present grade. Extensive use of the more costly concrete floodwall rather than earth dikes would be necessary due to space limitations imposed by the very narrow band of unoccupied land located between the river edge and the existing first tier of structures along much of the flood-prone areas. Flood protection afforded by the dikes and floodwalls would be supplemented with the floodproofing of about 7 private residences located primarily on the right (west) bank of the river by the removal of one structure on that bank and by the necessary backwater control structures, including one such structure near the confluence of the Milwaukee River and the drainage channel from the Lac du Cours area.

Assuming that all of the above flood control measures would be implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost of the dike-floodwall flood control alternative is estimated at $51,150, including amortization of the capital cost of the dikes and floodwalls and of the structure removal and floodproofing measures, as well as annual dike and floodwall operation and maintenance costs. The average annual flood abatement benefit is estimated at $17,980, yielding a benefit-cost ratio for Damage Reach 5 of 0.35.

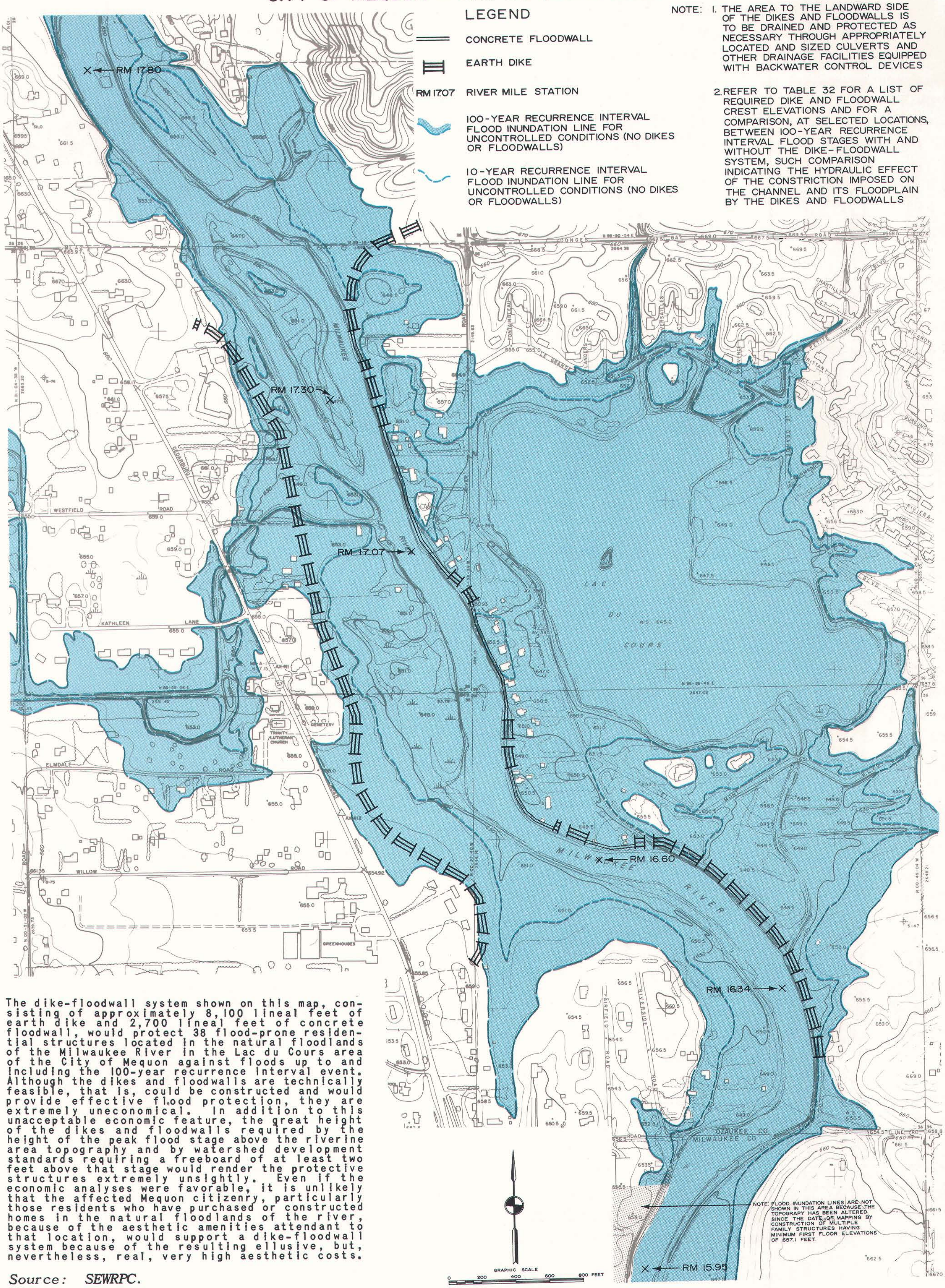
Damage Reach 7 within the City of Mequon is bound on the south by STH 167 and, excluding the Village of Thiensville on a portion of the right (west) bank, extends upstream about three miles to the southwest corner of Section 18, Town 9 North, Range 22 East. Approximately 32 major structures located within this reach, all private residences, may be expected to incur flood damage during a 10-year recurrence interval flood event, and about 16 additional major structures, also all private residences, may be expected to incur flood damage during a 100-year recurrence interval flood event. The flood-prone structures are located on both sides of the river and are widely scattered throughout the length of Damage Reach 5. Because of this dispersion, dikes and floodwalls are not a feasible solution in this damage reach.

The 32 major structures located in the 10-year floodplain of Reach 7 in the City of Mequon include 13 private residences along Villa Grove Road in Section 24, Town 9 North, Range 21 East, recently purchased by the City of Mequon for ultimate removal from the floodlands. Six of these have not yet (1971) been removed but are proposed to be by 1980. Costs and benefits attendant to the acquisition and removal of these 13 structures have been included in the economic analyses.

Assuming that structure floodproofing and removal measures, as set forth in Table 30, would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost of these measures is estimated at $29,500, including amortization of the capital cost of floodproofing 16 structures and purchasing and removing another 32 structures. The average annual benefit

Map 12

DIKE-FLOODWALL SYSTEM ON THE MILWAUKEE RIVER CITY OF MEQUON — LAC DU COURS AREA



The dike-floodwall system shown on this map, consisting of approximately 8,100 lineal feet of earth dike and 2,700 lineal feet of concrete floodwall, would protect 38 flood-prone residential structures located in the natural floodlands of the Milwaukee River in the Lac du Cours area of the City of Mequon against floods up to and including the 100-year recurrence interval event. Although the dikes and floodwalls are technically feasible, that is, could be constructed and would provide effective flood protection, they are extremely uneconomical. In addition to this unacceptable economic feature, the great height of the dikes and floodwalls required by the height of the peak flood stage above the riverine area topography and by watershed development standards requiring a freeboard of at least two feet above that stage would render the protective structures extremely unsightly. Even if the economic analyses were favorable, it is unlikely that the affected Mequon citizenry, particularly those residents who have purchased or constructed homes in the natural floodlands of the river, because of the aesthetic amenities attendant to that location, would support a dike-floodwall system because of the resulting ellusive, but, nevertheless, real, very high aesthetic costs.

Source: SEWRPC.

Table 32

HYDRAULIC EFFECT OF THE DIKE-FLOODWALL SYSTEM IN THE CITY OF MEQUON--100-YEAR RECURRENCE INTERVAL FLOOD EVENT

LAC DU COURS AREA

Location[a]			No Dikes or Floodwalls		With Dike-Floodwall System					
Station (River Mile)	Structure Name or Other Identification	Structure Number	Discharge (cfs)	Stage (feet Mean Sea Level)	Location of Dikes or Floodwalls: East Bank	Location of Dikes or Floodwalls: West Bank	Discharge (cfs)	Stage (feet Mean Sea Level)[b]	Stage Increase Attributable to Dike-Floodwall System (feet)[b]	Elevation of Dike or Floodwall Crest (feet Mean Sea Level)[c]
15.95	--	--	15,830	652.2	--	--	15,830	652.2	--	--
16.34	--	--	15,830	653.6	X	--	15,830	653.6	0.0	655.6
16.60	--	--	15,830	654.2	X	X	15,830	654.2	0.0	656.2
17.07	--	--	15,670	654.4	X	X	15,670	655.2	0.8	657.2
17.30	--	--	15,670	654.5	X	X	15,670	655.9	0.4	657.9
17.80	--	--	15,670	655.4	--	--	15,670	656.7	1.3[d]	--
18.23	--	--	15,670	656.5	--	--	15,670	657.4	0.9[d]	--
18.45	--	--	15,670	657.0	--	--	15,670	657.8	0.8[d]	--
18.77	--	--	15,670	658.0	--	--	15,670	658.6	0.6[d]	--
18.82	--	--	15,670	658.1	--	--	15,670	658.6	0.5[d]	--
18.83	STH 167 Bridge	196	15,670	--	--	--	15,670	--	--	--
18.84	--	--	15,670	658.1	--	--	15,670	658.6	0.5[d]	--
18.87	--	--	15,670	658.3	--	--	15,670	658.8	0.5[d]	--
19.10	South Limit--Village of Thiensville	--	15,670	--	--	--	15,670	--	--	--
19.14[e]	--	--	15,670	658.9	--	--	15,670	659.3	0.4[d]	--

CTH M (HIGHLAND ROAD) AREA

Location[a]			No Dikes or Floodwalls		With Dike-Floodwall System					
Station (River Mile)	Structure Name or Other Identification	Structure Number	Discharge (cfs)	Stage (feet Mean Sea Level)	Location of Dikes or Floodwalls: East Bank	Location of Dikes or Floodwalls: West Bank	Discharge (cfs)	Stage (feet Mean Sea Level)[b]	Stage Increase Attributable to Dike-Floodwall System (feet)[b]	Elevation of Dike or Floodwall Crest (feet Mean Sea Level)[c]
22.15	--	--	15,670	664.0	--	--	15,670	664.5	0.5	--
22.48	--	--	15,670	664.0	X	--	15,670	664.6	0.6	666.6
22.76	--	--	15,670	--	X	X	15,670	664.7	--	666.7
22.88	--	--	15,670	664.1	X	X	15,670	664.8	0.7	666.8
23.05	--	--	15,670	664.2	X	X	15,670	665.0	0.8	667.0
23.14	--	--	15,670	664.3	X	X	15,670	665.3	1.0	667.3
23.15	CTH M (Highland Road) Bridge	194	15,670	--	--	--	15,670	--	--	--
23.16	--	--	15,670	664.6	--	--	15,670	665.5	0.9[d]	--
23.94	--	--	15,670	665.1	--	--	15,670	665.9	0.8[d]	--
24.74	--	--	15,670	665.6	--	--	15,670	666.3	0.7[d]	--
25.33	--	--	15,670	666.3	--	--	15,670	666.8	0.5[d]	--
25.74	--	--	15,670	668.4	--	--	15,670	668.6	0.2[d]	--
26.12	--	--	15,670	670.2	--	--	15,670	670.3	0.1[d]	--
26.24	--	--	15,670	670.3	--	--	15,670	670.4	0.1[d]	--
26.25	CTH C (Pioneer Road) Bridge & North Limit--City of Mequon	193	15,670	--	--	--	15,670	--	--	--
26.26	--	--	15,670	670.3	--	--	15,670	670.4	0.1[d]	--
26.35	--	--	15,760	670.4	--	--	15,760	670.4	0.0	--

[a] THE TABULATED STATIONS ARE SELECTED FROM THOSE USED IN THE FLOOD FLOW SIMULATION MODEL. LOCATIONS CORRESPONDING TO RIVER MILE STATIONS 15.95 THROUGH 17.80 ARE SHOWN ON MAP 12 AND LOCATIONS CORRESPONDING TO RIVER MILE STATIONS 22.15 THROUGH 23.15 ARE SHOWN ON MAP 13.

[b] STAGES CORRESPONDING TO THE DIKE-FLOODWALL SYSTEM ARE EQUAL TO OR GREATER THAN THE COMPARABLE STAGES FOR THE UNCONTROLLED SITUATION, THAT IS, THE CONDITION OF NO DIKES OR FLOODWALLS. THE STAGE INCREASE REPRESENTS THE HYDRAULIC EFFECT OF LATERALLY CONSTRICTING, WITH DIKES AND FLOODWALLS, THE NATURAL CROSS-SECTION OF THE RIVER AT FLOOD FLOW, WHICH CROSS-SECTION NORMALLY INCLUDES BOTH THE CHANNEL AND ADJACENT *FLOODPLAIN, WITH THE RESULT THAT* THE CONSTRICTED RIVER FLOWS AT A HIGHER STAGE TO COMPENSATE FOR THE LOSS OF FLOODPLAIN CARRYING CAPACITY OR CONVEYANCE. THE INDICATED STAGE INCREASES FOR THE CTH M AREA DIKES AND FLOODWALLS *ALSO REFLECT THE HYDRAULIC* EFFECT OF THE VILLAGE OF THIENSVILLE DIKE-FLOODWALL SYSTEM LOCATED DOWNSTREAM OF CTH M AREA.

[c] THIS IS THE MINIMUM ACCEPTABLE DIKE OR FLOODWALL CREST ELEVATION AND IS EQUAL TO THE 100-YEAR RECURRENCE INTERVAL FLOOD STAGE, UNDER CONDITIONS OF THE DIKES AND FLOODWALLS, PLUS A FREEBOARD PROVISION OF TWO FEET IN CONFORMANCE WITH THE WATER CONTROL FACILITY STANDARDS FOR THE MILWAUKEE RIVER WATERSHED AS SET FORTH IN CHAPTER II OF VOLUME 2 OF THIS REPORT.

[d] THESE FLOOD STAGE INCREASES FOR THE RIVERINE AREAS UPSTREAM OF THE DIKE-FLOODWALL SYSTEMS ARE ACCEPTABLE IN THAT THEY WOULD NOT RESULT IN A SIGNIFICANT INCREASE IN 100-YEAR FLOOD DAMAGE RELATIVE TO THAT WHICH WOULD OCCUR WITHOUT THE DIKES AND FLOODWALLS.

[e] FLOOD STAGE DATA FOR THE LAC DU COURS AREA DIKES AND FLOODWALLS IS TERMINATED AT RM 19.14 SINCE THE VILLAGE OF THIENSVILLE DIKE-FLOODWALL SYSTEM BEGINS IMMEDIATELY UPSTREAM OF THAT POINT.

SOURCE- SEWRPC.

is estimated at $37,430, yielding a benefit-cost ratio for Damage Reach 7 of 1.27.

Damage Reach 8, the last of the three damage reaches within the City of Mequon, extends from the southwest corner of Section 18, Town 9 North, Range 22 East, upstream approximately four miles to the northern corporate limits of Mequon. Approximately 79 major structures located within this reach, all private residences, may be expected to incur flood damage during a 10-year recurrence interval flood event; and about 26 additional major structures, also all private residences, may be expected to incur flood damage during a 100-year recurrence interval flood event. These flood-prone structures are concentrated primarily along, and immediately adjacent to, both banks of the Milwaukee River immediately south of CTH M.

A system of intermittent earth dikes and concrete floodwalls supplemented with backwater control structures and structure removal and floodproofing could be designed, constructed, and operated so as to eliminate virtually all damages to the approximately 105 flood-prone structures located in Damage Reach 8 resulting from up to and including the 100-year recurrence interval flood event.

The dike-floodwall control system is shown on Map 13, and Table 30 presents a schedule of the physical requirements of the system and the attendant costs and benefits. The hydraulic effect of the dike-floodwall system, as reflected in increased peak stages for a 100-year recurrence interval flood event, is set forth in Table 32, along with the crest elevation of the dikes and floodwalls. The crest elevation includes both the increased stage attributable to the dike-floodwall system and the two-foot minimum freeboard standard, as set forth in Chapter II of this volume. About 3,000 lineal feet of earth dike and 5,300 lineal feet of concrete floodwall would be required, with some segments having a height in excess of 13 feet, as measured from the dike or floodwall base at the existing river bank elevation to the crest of the dike or floodwall. Flood protection for structures located on the left (east) bank of the river would be achieved with a 4,500-foot-long continuous structure, composed of 900 lineal feet of earth dike formed by elevating the east approach of the CTH M bridge and 3,600 feet of concrete floodwall. Flood relief would be provided to right (west) bank structures by a 3,800-foot-long continuous structure consisting of 2,100 lineal feet of earth dike, 400 feet of which would be formed by elevating the west approach to the CTH M bridge, and 1,700 lineal feet of concrete floodwall. Extensive use of the more costly concrete floodwall rather than earth dikes would be necessary due to spatial limitations imposed by the very narrow band of unoccupied land located between the river edge and the existing first tier of structures along most of the flood-prone areas. Backwater control structures would be necessary, including such structures on the short channel segments which hydraulically connect the Milwaukee River to a large pond in the floodplain along the left (east) bank of the river just downstream of the CTH M bridge.

Flood protection afforded by the dikes and floodwalls would be supplemented by the floodproofing of 25 structures and the removal of 20 structures, all of which are located outside the concentrated riverine residential areas immediately south of CTH M.

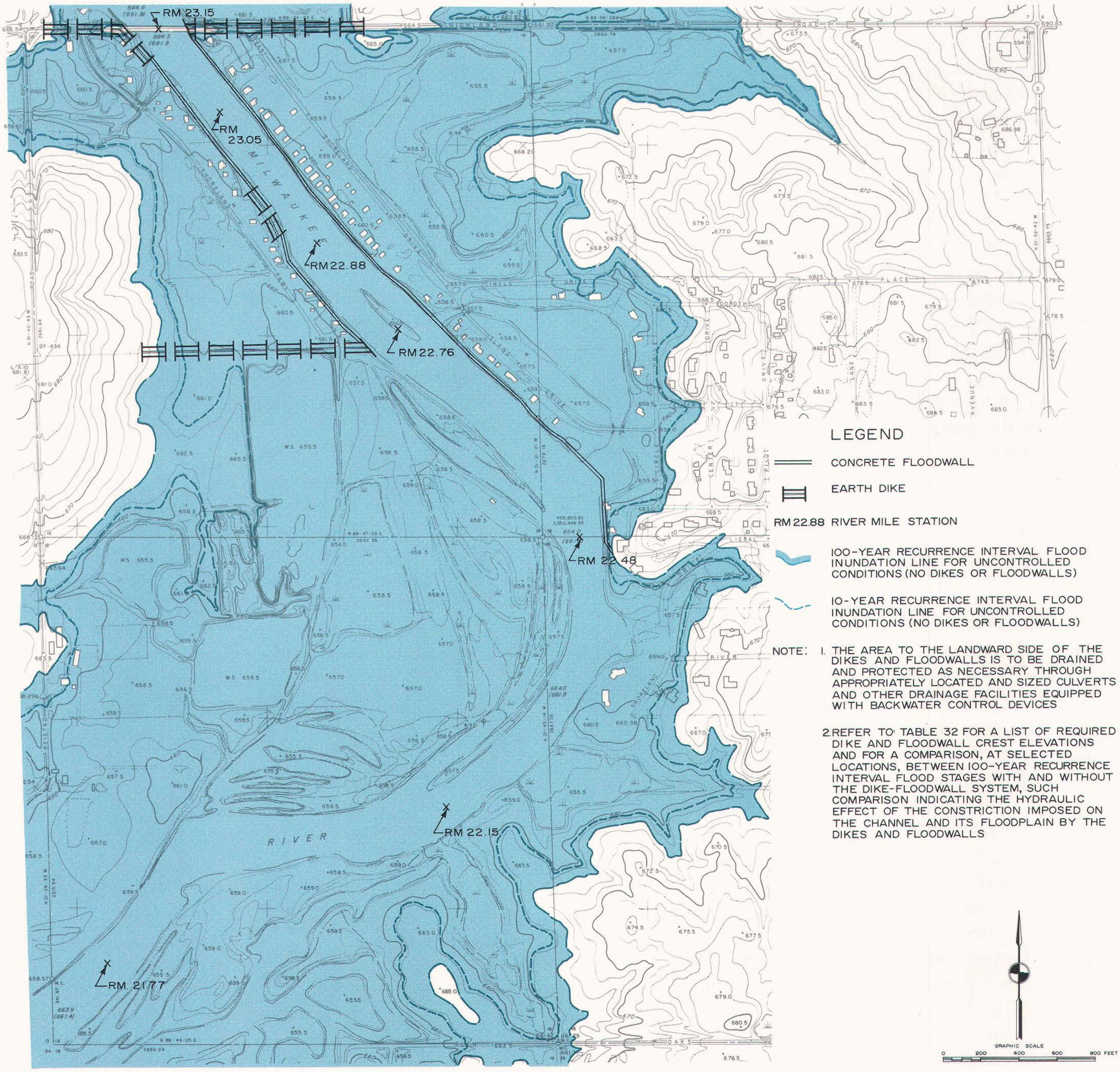
Assuming that all of the above flood control measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost of the dike-floodwall system with structure floodproofing and removal is estimated at $102,200, including amortization of the capital cost of the dikes and floodwalls and of the structure removal and floodproofing, as well as annual dike and floodwall operation and maintenance costs. The average annual flood abatement benefit is estimated at $16,880, yielding a benefit-cost ratio for Damage Reach 8 of 0.17.

Considering all of the floodlands within the entire City of Mequon, the total annual cost for complete abatement of flood damages attendant to floods up to and including the 100-year recurrence interval watershed-wide flood, as that abatement would be provided by 11,100 feet of earth dikes and 8,000 feet of concrete floodwalls with the necessary appurtenant backwater control facilities and by the floodproofing of 48 private residences and the removal of an additional 53 private residences, is estimated at $182,850. The average annual flood abatement benefits accruing to such a combination of flood control measures in the City of Mequon are estimated at $72,290, yielding an aggregate benefit-cost ratio of 0.40.

The dike-floodwall systems in the Lac du Cours and CTH M areas supplemented by structure floodproofing and removal throughout the remain-

Map 13

DIKE-FLOODWALL SYSTEM ON THE MILWAUKEE RIVER
CITY OF MEQUON-CTH M AREA



The dike-floodwall system shown on this map, consisting of approximately 3,000 lineal feet of earth dike and 5,300 lineal feet of concrete floodwall, would protect 60 flood-prone residential structures located in the natural floodlands of the Milwaukee River in the Highland Road area of the City of Mequon against floods up to and including the 100-year recurrence interval event. Although the dikes and floodwalls are technically feasible, that is, could be constructed and would provide effective flood protection, they are extremely uneconomical. In addition to this unacceptable economic feature, the great height of the dikes and floodwalls required by the height of the peak flood stage above the riverine area topography and by watershed development standards requiring a freeboard of at least two feet above that stage would render the protective structures extremely unsightly. Even if the economic analyses were favorable, it is unlikely that the affected Mequon citizenry, particularly those residents who have purchased or constructed homes in the natural floodlands of the river, because of the aesthetic amenities attendant to that location, would support a dike-floodwall system because of the resulting ellusive, but, nevertheless, real, very high aesthetic costs.

Source: SEWRPC.

der of Mequon's 10 lineal miles of floodland, as described herein, are technically feasible but extremely uneconomical. In addition to this unfavorable economic feature, the great height of the dikes and floodwalls, necessitated by high peak flood stages relative to existing riverine area topography and by the safety provision that requires a freeboard of at least two feet above that stage, would make the structures extremely unsightly. The residents protected by the dikes and floodwalls, particularly those property owners living near the river, would generally have the view of the river blocked by the structures and would encounter difficulty in gaining access to the river because most of the dikes and floodwalls would have their crests at a height of seven feet or more above the existing elevation of the river's edge. While the costs associated with such aesthetically undesirable characteristics are elusive and difficult to assign a monetary value to, they are, nevertheless, real.

Dike-Floodwall System for the Village of Thiensville: The Village of Thiensville, which is coincident with Flood Damage Reach 6, as defined and discussed in Chapter VIII of Volume 1 of this report, is characterized by primarily commercial development within the natural floodlands of the Milwaukee River, such floodland occupancy being entirely located on the right (west) bank of the river in a reach extending approximately from the south corporate limits of Thiensville upstream about three-fourths of a mile to the Village park located just east of the Thiensville Dam. Although there are 49 major flood-prone structures located in this short reach, the estimated annual structural damages are rather low because all of the flood-prone buildings are located relatively high above the river, being positioned between the 10- and 100-year inundation levels. A flood event having a recurrence interval of greater than 10 years, however, may be expected to cause considerable disruption of business and community activities because of the extensive area that would be inundated.

A system of intermittent earth dikes and concrete floodwalls supplemented with backwater control structures and floodproofing could be designed, constructed, and operated so as to eliminate virtually all damages to the approximately 49 flood-prone structures for floods up to and including the 100-year recurrence interval watershed-wide flood event.

The dike-floodwall system is shown on Map 14, and Table 30 presents a schedule of the physical requirements and characteristics of the system and the attendant costs and benefits. The hydraulic effect of the dike-floodwall system, as reflected in increased peak stages for a 100-year recurrence interval flood event, is set forth in Table 33, along with the crest elevation of the dikes and floodwalls. The crest elevation includes both the increased stage attributable to the dike-floodwall system and the two-foot minimum freeboard standard, as set forth in Chapter II of this volume. About 1,600 lineal feet of earth dike and 1,600 lineal feet of concrete floodwall incorporated into a 3,200-foot-long continuous structure would be required, with some segments having a height in excess of 12 feet, as measured from the dike or floodwall base at the existing river bank elevation to the crest of the dike or floodwall. A 1,000 lineal foot portion of the earth dike would pass through the Village park and could provide spectator seating for existing ball fields and tennis courts. Flood protection afforded by the dikes and floodwalls would be supplemented with the floodproofing of one structure and by the necessary backwater control structures, including one such structure at the confluence of Pigeon Creek and the Milwaukee River and another at the point where the Thiensville Dam millrace rejoins the river.

Assuming that all of the above flood control measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost of this dike-floodwall flood control alternative is estimated at $34,560, including amortization of the capital costs of the dikes and floodwalls and of the structure floodproofing, as well as annual dike and floodwall operation and maintenance costs. The average annual flood abatement benefit is estimated at $6,710, yielding a benefit-cost ratio for the Village of Thiensville of 0.19.

The Village of Thiensville dike-floodwall system, with supplemental structure floodproofing, as described herein, is technically feasible but extremely uneconomical. In addition to this unfavorable economic feature, the great height of the dikes and floodwalls necessitated by high peak flood stages relative to existing riverine area topography and by the safety provision that requires a freeboard of at least two feet above that stage, would make the structures extremely

Map 14

DIKE-FLOODWALL SYSTEM ON THE MILWAUKEE RIVER VILLAGE OF THIENSVILLE

The dike-floodwall system shown on the map, consisting of approximately 1,600 lineal feet of earth dike and 1,600 lineal feet of concrete floodwall, would protect 48 flood-prone residential and commercial structures located in the natural floodlands of the Milwaukee River in the Village of Thiensville against floods up to and including the 100-year recurrence interval event. Although the dikes and floodwalls are technically feasible, that is, could be constructed and would provide effective flood protection, they are extremely uneconomical. In addition to this unacceptable economic feature, the great height of the dikes and floodwalls necessitated by the height of the peak flood stage relative to existing riverine area topography and by watershed development standards requiring a freeboard of at least two feet above that stage would render the protective structures extremely unsightly. The undesirable aesthetic impact of the structures, however, probably would be less than that which would be experienced as a result of similar dikes and floodwalls in the Cities of Glendale and Mequon and in the Village of Saukville, due to the primarily commercial character of the existing Thiensville development.

Source: SEWRPC.

Table 33

HYDRAULIC EFFECT OF THE DIKE-FLOODWALL SYSTEM IN THE VILLAGE OF THIENSVILLE--100-YEAR RECURRENCE INTERVAL FLOOD EVENT

LOCATION[a]			NO DIKES OR FLOODWALLS		WITH DIKE-FLOODWALL SYSTEM					
					LOCATION OF DIKES OR FLOODWALLS					
STATION (RIVER MILE)	STRUCTURE NAME OR OTHER IDENTIFICATION	STRUCTURE NUMBER	DISCHARGE (CFS)	STAGE (FEET MEAN SEA LEVEL)	EAST BANK	WEST BANK	DISCHARGE (CFS)	STAGE (FEET MEAN SEA LEVEL)[b]	STAGE INCREASE ATTRIBUTABLE TO DIKE-FLOODWALL SYSTEM (FEET)[b]	ELEVATION OF DIKE OR FLOODWALL CREST (FEET MEAN SEA LEVEL)[c]
19.10	SOUTH LIMIT--VILLAGE OF THIENSVILLE	--	15,670	--	--	--	15,670	--	--	--
19.14	--	--	15,670	658.9	--	--	15,670	659.3	0.4	--
19.38	--	--	15,670	--	--	X	15,670	660.0	--	662.0
19.60	--	--	15,670	660.1	--	X	15,670	660.7	0.6	662.7
19.61	THIENSVILLE DAM	195	15,670	--	--	X	15,670	--	--	--
19.62	--	--	15,670	662.0	--	X	15,670	662.9	0.9	664.9
19.65	--	--	15,670	662.2	--	X	15,670	663.0	0.8	665.0
19.97	--	--	15,670	662.4	--	--	15,670	663.3	0.9[d]	--
20.20	--	--	15,670	662.7	--	--	15,670	663.5	0.8[d]	--
20.36	EAST LIMIT--VILLAGE OF THIENSVILLE	--	15,670	--	--	--	15,670	--	--	--
20.90	--	--	15,670	663.4	--	--	15,670	664.0	0.6[d]	--
21.20	--	--	15,670	663.6	--	--	15,670	664.2	0.6[d]	--
21.77	--	--	15,670	663.9	--	--	15,670	664.4	0.5[d]	--
22.15[e]	--	--	15,670	664.0	--	--	15,670	664.5	0.5[d]	--

[a]THE TABULATED STATIONS ARE SELECTED FROM THOSE USED IN THE FLOOD FLOW SIMULATION MODEL. LOCATIONS CORRESPONDING TO RIVER MILE STATIONS 19.10 THROUGH 20.36 ARE SHOWN ON MAP 14.

[b]STAGES CORRESPONDING TO THE DIKE-FLOODWALL SYSTEM ARE EQUAL TO OR GREATER THAN THE COMPARABLE STAGES FOR THE UNCONTROLLED SITUATION, THAT IS, THE CONDITION OF NO DIKES OR FLOODWALLS. THE STAGE INCREASE REPRESENTS THE HYDRAULIC EFFECT OF LATERALLY CONSTRICTING, WITH DIKES AND FLOODWALLS, THE NATURAL CROSS-SECTION OF THE RIVER AT FLOOD FLOW, WHICH CROSS-SECTION NORMALLY INCLUDES BOTH THE CHANNEL AND ADJACENT FLOODPLAIN, WITH THE RESULT THAT THE CONSTRICTED RIVER FLOWS AT A HIGHER STAGE TO COMPENSATE FOR THE LOSS OF FLOODPLAIN CARRYING CAPACITY OR CONVEYANCE. THE INDICATED STAGE INCREASES ALSO REFLECT THE HYDRAULIC EFFECT OF THE CITY OF MEQUON-LAC DU COURS AREA DIKE-FLOODWALL SYSTEM LOCATED DOWNSTREAM OF THE VILLAGE OF THIENSVILLE.

[c]THIS IS THE MINIMUM ACCEPTABLE DIKE OR FLOODWALL CREST ELEVATION AND IS EQUAL TO THE 100-YEAR RECURRENCE INTERVAL FLOOD STAGE, UNDER CONDITIONS OF THE DIKES AND FLOODWALLS, PLUS A FREEBOARD PROVISION OF TWO FEET IN CONFORMANCE WITH THE WATER CONTROL FACILITY STANDARDS FOR THE MILWAUKEE RIVER WATERSHED AS SET FORTH IN CHAPTER II OF VOLUME 2 OF THIS REPORT.

[d]FLOOD STAGE INCREASES FOR THE RIVERINE AREA UPSTREAM OF THE THIENSVILLE DIKE-FLOODWALL SYSTEM ARE ACCEPTABLE IN THAT THEY WOULD NOT RESULT IN A SIGNIFICANT INCREASE IN 100-YEAR FLOOD DAMAGE RELATIVE TO THAT WHICH WOULD OCCUR WITHOUT THE DIKES AND FLOODWALLS.

[e]FLOOD STAGE DATA IS TERMINATED AT RM 22.15 SINCE THE CITY OF MEQUON--CTH M AREA DIKE-FLOODWALL SYSTEM BEGINS IMMEDIATELY UPSTREAM OF THAT POINT.

SOURCE- SEWRPC.

unsightly. The undesirable aesthetic impact of the structures probably would be less than that which would be experienced in the previously discussed Cities of Glendale and Mequon, due to the primarily commercial character of the existing development in the Village of Thiensville.

Dike-Floodwall System for the Village of Saukville: The Village of Saukville, which is coincident with Flood Damage Reach 12, as defined and discussed in Chapter VIII of Volume 1 of this report, is also characterized by intensive urban development of the natural floodlands of the Milwaukee River, such floodland occupancy being distributed along both sides of the river throughout the approximately two-mile-long riverine area of the Village. Although there are 120 major flood-prone structures located in this reach, the estimated annual structural damages are relatively low because 113 of the structures are located between the 10- and 100-year inundation levels; and only seven structures may be expected to incur flood damage during a 10-year recurrence interval flood event. A flood event having a recurrence interval of greater than 10 years may be expected to cause considerable disruption of business and community activities because of the extensive area that would be inundated.

A system of intermittent earth dikes and concrete floodwalls supplemented with backwater control structures and structure floodproofing and removal could be designed, constructed, and operated so as to eliminate virtually all damages to the 120 flood-prone structures from floods up to and including the 100-year recurrence interval flood event.

The dike-floodwall system is shown on Map 15, and Table 30 presents a schedule of the physical requirements and characteristics of the system and the attendant costs and benefits. The

Map 15

DIKE-FLOODWALL SYSTEM ON THE MILWAUKEE RIVER VILLAGE OF SAUKVILLE

LEGEND

CONCRETE FLOODWALL

EARTH DIKE

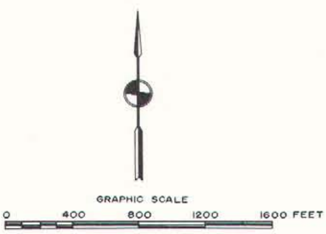
RM36.25 RIVER MILE STATION

100-YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE FOR UNCONTROLLED CONDITIONS (NO DIKES OR FLOODWALLS)

10-YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE FOR UNCONTROLLED CONDITIONS (NO DIKES OR FLOODWALLS)

NOTE: 1. THE AREA TO THE LANDWARD SIDE OF THE DIKES AND FLOODWALLS IS TO BE DRAINED AND PROTECTED AS NECESSARY THROUGH APPROPRIATELY LOCATED AND SIZED CULVERTS AND OTHER DRAINAGE FACILITIES EQUIPPED WITH BACKWATER CONTROL DEVICES.

2. REFER TO TABLE 34 FOR A LIST OF REGUIRED DIKE AND FLOODWALL CREST ELEVATIONS AND FOR A COMPARISON, AT SELECTED LOCATIONS, BETWEEN 100-YEAR RECURRENCE INTERVAL FLOOD STAGES WITH AND WITHOUT THE DIKE-FLOODWALL SYSTEM, SUCH COMPARISON INDICATING THE HYDRAULIC EFFECT OF THE CONSTRICTION IMPOSED ON THE CHANNEL AND ITS FLOODPLAIN BY THE DIKES AND FLOODWALL.



The dike-floodwall system shown on the map, consisting of approximately 10,100 lineal feet of earth dike and 2,700 lineal feet of concrete floodwall, would protect 113 flood-prone residential and commercial structures located in the natural floodlands of the Milwaukee River in the Village of Saukville against floods up to and including the 100-year recurrence interval event. Although the dikes and floodwalls are technically feasible, that is, could be constructed and would provide effective flood protection, they are extremely uneconomical. In addition to this unacceptable economic feature, the great height of the dikes and floodwalls necessitated by the height of the peak flood stage relative to existing riverine area topography and by watershed development standards requiring a freeboard of at least two feet above that stage would render the protective structures extremely unsightly. Even if the economic analyses were favorable, it is unlikely that the affected Saukville citizenry, particularly those residents who have purchased or constructed homes in the natural floodlands of the river, because of the aesthetic amenities attendant to that location, would support a dike-floodwall system because of the resulting ellusive, but, nevertheless, real, very high aesthetic costs.

Source: SEWRPC.

hydraulic effect of the dike-floodwall system, as reflected in increased peak stages for a 100-year recurrence interval flood event, is set forth in Table 34, along with the crest elevation of the dikes and floodwalls. The crest elevation includes both the increased stage attributable to the dike-floodwall system and the two-foot minimum freeboard standard, as set forth in Chapter II of this volume. About 10,100 lineal feet of earth dike and 2,700 lineal feet of concrete floodwall would be required, with some segments having a height in excess of 10 feet, as measured from the dike or floodwall base at the existing river bank elevation to the crest of the dike or floodwall. Flood protection for structures located on the left (east) bank of the river would be achieved with a 5,900-foot-long continuous structure composed of 5,600 lineal feet of earth dike and 300 feet of concrete floodwall. A 300-foot segment of that earth dike would be formed by reconstructing and elevating a 300-foot portion of STH 33, and another 2,500-foot portion would be formed by elevating STH 57. Flood relief would be provided to right (west) bank structures by a 6,900-foot-long continuous struc-

Table 34

HYDRAULIC EFFECT OF THE DIKE-FLOODWALL SYSTEM IN THE VILLAGE OF SAUKVILLE--100-YEAR RECURRENCE INTERVAL FLOOD EVENT

Location[a]			No Dikes or Floodwalls		With Dike-Floodwall System					
					Location of Dikes or Floodwalls					
Station (River Mile)	Structure Name or Other Identification	Structure Number	Discharge (cfs)	Stage (feet Mean Sea Level)	East Bank	West Bank	Discharge (cfs)	Stage (feet Mean Sea Level)[b]	Stage Increase Attributable to Dike-Floodwall System (feet)[b]	Elevation of Dike or Floodwall Crest (feet Mean Sea Level)[c]
35.99	--	--	12,285	754.0	--	--	12,285	754.0	--	--
36.09	--	--	12,285	754.1	--	x	12,285	754.1	0.0	756.1
36.25	--	--	12,285	754.9	--	x	12,285	754.9	0.0	756.9
36.67	--	--	12,285	756.8	x	x	12,285	756.9	0.1	758.9
36.78	--	--	12,285	757.0	x	x	12,285	757.0	0.0	759.0
36.79	STH 33 Bridge	144	12,285	--	--	--	12,285	--	--	--
36.82	--	--	12,285	757.1	x	x	12,285	757.1	0.0	759.1
36.88	--	--	12,285	757.2	x	x	12,285	757.9	0.7	759.9
37.15	--	--	12,285	757.4	--	x	12,285	758.2	0.8	760.2
37.31	--	--	12,285	757.9	--	x	12,285	758.6	0.7	760.6
37.57	North Limit of Village of Saukville	--	12,285	--	--	x	12,285	--	--	--
37.65	--	--	12,285	759.6	--	x	12,285	759.6	0.0	761.6
37.92	--	--	12,285	759.8	--	--	12,285	759.8	0.0	--
38.39	--	--	12,285	760.5	--	--	12,285	760.5	0.0	--
39.00	--	--	12,285	761.6	--	--	12,285	761.6	0.0	--
39.45	--	--	12,285	762.7	--	--	12,285	762.7	0.0	--
39.89	--	--	12,285	764.0	--	--	12,285	764.0	0.0	--
39.93	CM & St P RR Bridge	143	12,285	--	--	--	12,285	--	--	--
39.97	--	--	12,285	764.1	--	--	12,285	764.1	0.0	--
40.31	--	--	12,285	764.8	--	--	12,285	764.8	0.0	--
41.18	--	--	12,285	766.7	--	--	12,285	766.7	0.0	--

[a] The tabulated stations are selected from those used in the flood flow simulation model. Locations corresponding to river mile stations 35.99 through 37.92 are shown on Map 15.

[b] Stages corresponding to the dike-floodwall system are equal to or greater than the comparable stages for the uncontrolled situation, that is, the condition of no dikes or floodwalls. The stage increase represents the hydraulic effect of laterally constricting, with dikes and floodwalls, the natural cross-section of the river at flood flow, which cross-section normally includes both the channel and adjacent floodplain, with the result that the constricted river flows at a higher stage to compensate for the loss of floodplain carrying capacity or conveyance.

[c] This is the minimum acceptable dike or floodwall crest elevation and is equal to the 100-year recurrence interval flood stage, under conditions of the dikes and floodwalls, plus a freeboard provision of two feet in conformance with the water control facility standards for the Milwaukee River watershed as set forth in Chapter II of Volume 2 of this report.

Source- SEWRPC.

ture consisting of 4,500 lineal feet of earth dike and 2,400 feet of concrete floodwall. Flood protection afforded by the dikes and floodwalls would be supplemented by the floodproofing of 10 structures and the removal of two structures, these structures being located on the left (east) bank of the Milwaukee River north of STH 33.

Assuming that all of the above flood control measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost of this dike-floodwall flood control alternative is estimated at $59,200, including amortization of the capital costs of the dikes and floodwalls and of the structure floodproofing and removal, as well as annual dike and floodwall operation and maintenance costs. The average annual flood abatement benefit is estimated at $7,690, yielding a benefit-cost ratio for the Village of Saukville of 0.13.

The Village of Saukville dike-floodwall system, with supplemental structure removal and floodproofing, as described herein, is technically feasible but extremely uneconomical. In addition to this unfavorable economic feature, the great height of the dikes and floodwalls necessitated by high peak flood stages relative to existing riverine area topography and by the safety provision that requires a freeboard of at least two feet above that stage, would make the structures extremely unsightly. The residents protected by the dikes and floodwalls, particularly those property owners near the river, would generally have the view of the river blocked by the structures and would encounter difficulty in gaining access to the river because most of the dikes and floodwalls would have their crests at a height of six feet or more above the existing elevation of the river's edge. While the costs associated with such aesthetically undesirable characteristics are elusive and difficult to assign a monetary value to, they are, nevertheless, real.

Summary of Dike-Floodwall Systems: The flood control alternative for the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville, consisting of a total of 32,500 lineal feet of earth dikes and 19,300 feet of concrete floodwalls supplemented by the floodproofing of 59 major structures and the removal of 55 major structures, as described herein, is technically feasible and would eliminate virtually all residential and commercial flood damages to the 746 flood-prone major structures located in these reaches, as well as all road-user and public-sector losses from floods up to and including the 100-year recurrence interval watershed-wide flood event.

This flood control measure is, however, extremely uneconomical for each of the four communities, yielding overall benefit-cost ratios of 0.30 for the City of Glendale, 0.40 for the City of Mequon, 0.19 for the Village of Thiensville, and 0.13 for the Village of Saukville. The total annual cost that would accrue to the application of dike-floodwall systems in the four aforementioned communities, supplemented with structure floodproofing and removal, is estimated at $403,600. The approximate total annual flood control benefits resulting from these efforts is estimated at $124,330, yielding an aggregate benefit-cost ratio of 0.31 for the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville.

In addition to these unfavorable economic aspects, highly undesirable aesthetic conditions would be created due to the great height of the dikes and floodwalls, such heights being necessitated by high peak flood stages relative to existing riverine area topography and by the safety provision that requires a freeboard of at least two feet above that stage. Riverine residents protected by the dikes and floodwalls, particularly those property owners living near the river, would generally have their view of the river blocked and would encounter difficulty in gaining access to it because most of the dikes and floodwalls would have their tops at a height of six feet or more above the existing ground elevation at the river's edge. The costs attendant to such unsightly conditions are elusive, in that it is difficult to assign a monetary value to them, but are, nevertheless, real. The proposals could be expected to be objectionable to the residents and property owners of riverine property in the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville, particularly because many of these residents have undoubtedly purchased or constructed homes in the natural floodlands of the river because of the aesthetic amenities attendant to such a location. It is, therefore, unlikely that dike and floodwall construction along the Milwaukee River, as described herein, would enjoy the support of the citizenry now living on the floodplain, even if the economic analyses were more favorable. Floodplain residents may well prefer to live with the cost of flood damage in preference to a reduction of the aesthetic value of their property.

ALTERNATIVE NONSTRUCTURAL FLOOD CONTROL PLAN ELEMENT

A nonstructural flood control plan element, consisting entirely of structure floodproofing and removal and intended to abate 100-year recurrence interval flood damages, was also evaluated under the watershed study. The six previously discussed structural flood control alternatives would provide flood protection to only the lower portion of the watershed because the four reservoirs and the one diversion channel considered were so located within the river system as to be able to control flood flows in only portions of the Lower Milwaukee River and, in some instances, a portion of lower Cedar Creek, while the sixth alternative of dike and floodwall construction, supplemented with structure floodproofing and removal, was also considered feasible only for those lower Milwaukee River communities exhibiting concentrated urban floodland development. Unlike the structural alternatives, the nonstructural floodproofing and removal concept would have watershed-wide application.

This alternative would abate flood damage to homes and other major structures by a combination of floodproofing of those private residences and other major structures located in the floodlands but having first-floor elevations above the peak stage of the 100-year recurrence interval flood event and by removal of those residences and other major structures located in the floodlands and having first-floor elevations below that flood stage. As already noted, the criteria relating to removal or floodproofing of floodland structures are largely economic, in that flood damages mount rapidly as first floors are inundated, while floodproofing costs also rise abruptly if first floors are to be protected. For the purpose of estimating structure floodproofing and structure removal costs, it was assumed that structures located between the 10- and 100-year recurrence interval flood inundation levels would not be subjected to first-floor flooding during a 100-year recurrence interval flood event; and, therefore, floodproofing would constitute a technically and economically feasible means of protection against such a flood. All such structures not presently floodproofed would be protected by floodproofing, while existing floodproofing would be extended and upgraded so as to offer full protection against a 100-year recurrence interval flood. Houses and other major structures located within the 10-year recurrence interval floodplain were generally assumed to be subject to first-floor inundation under conditions of a 100-year recurrence interval flood event and, therefore, would have to be removed from the floodlands if flood damages were to be avoided.

A secondary consideration that might influence the actual number of structures to be floodproofed or removed and which was not considered in the analysis described herein is the nature of the resulting boundary line or transition zone between the floodland area to be cleared of structures and the adjacent floodland area which would remain in urban land use. Homes and other major structures remaining after implementation of floodproofing and removal measures would have to be served with streets and utilities. It would, moreover, be desirable to create an aesthetically pleasing transition between the occupied and unoccupied riverine lands. In order to meet these practical and aesthetic needs, the dividing line between the structure floodproofing area and the structure removal area should be relatively smooth and possibly coincident with existing roadways or topographic and natural features. The precise identification of structures to be floodproofed and removed would, therefore, have to be reconsidered during a detailed design of this structure floodproofing and removal flood control alternative, should it be adopted and implemented.

In the economic analyses of structure removal, it was assumed that the salvage value of the homes and other major structures at the time of public acquisition would be sufficient to cover demolition costs and subsequent landscaping of the vacated sites. The market value of floodland property, including the structures, was estimated as being approximately equal to the 1969 equalized assessed valuation of representative riverine flood-prone properties.

It is possible and generally practicable for property owners, as individuals, to make certain structural adjustments or to impose certain use restrictions on private properties in order to reduce flood damage. These structural measures and use restrictions applied to buildings and contents are known as "floodproofing" and were discussed earlier in this chapter. It should, however, again be noted that selection of the specific floodproofing elements to be applied to a particular structure depends upon the features of the individual structure, such as the kind of structural material, age of the structure, substructure conditions, nature of the exposure to floodwaters, height of the water table, sewerage facilities, and uses demanded of the structure. Extensive floodproofing should be applied only under the guidance of a registered professional engineer who has carefully inspected the building and its contents and has evaluated the flood threat. In order to approximately reflect floodproofing costs in the economic analyses, a representative per structure cost of $1,000 was utilized in the economic analyses, with the realization that the actual floodproofing cost for a particular structure might vary widely from this value because of the above factors and the fact that some structures are already, as revealed by the flood-damage survey, at least partially floodproofed.

Average annual flood abatement benefits accruing to structure floodproofing and removal along the Lower Milwaukee River were estimated using annual flood-damage costs presented in Chapter VIII of Volume 1 of this report. It was assumed that structure floodproofing and removal would completely eliminate residential and commercial damages but would not reduce road-user and public-sector losses. Therefore, annual flood control benefits accruing to structure removal and floodproofing would be equal to the average annual residential and commercial flood damage that would occur without the flood control measure.

Land value enhancement will generally accrue to residential properties, as well as to vacant land expected to ultimately undergo residential development, that are contiguous with certain presently urbanized portions of the floodland from which all structures would be removed under this flood control alternative. The increase in the market value of such lands reflects the desirability of a location adjacent to an open space, greenway, or park, as opposed to one completely encircled by urban residential development. Such land value enhancement would accrue only to residential or potential residential properties presently adjacent to areas with extensive urban development within the floodlands, which development would be eliminated by structure removal, with the vacated sites subsequently landscaped and otherwise converted to a generally natural state or to park land.

Most of the structure floodproofing and removal envisioned under this flood control alternative would not produce significant land value enhancement since, generally speaking, the homes and other major structures slated for removal are scattered along the riverine area and not arranged in large concentrated clusters. Their removal, therefore, would not provide the large open spaces necessary to the attainment of significant land value enhancement. There are two exceptions within the watershed to this general observation, however, in that significant land value enhancement could be expected to accompany floodland structure removal within much of the intensely urbanized riverine area of Glendale; and such land value enhancement could also be expected to accompany floodland clearance immediately south of CTH M in the City of Mequon. The estimated monetary value of the land value enhancement for these two areas is presented in this chapter and assumes a $10 per front foot increased market value for existing residential property or potential residential property adjacent to extensive floodland urban development that would be removed under this flood control alternative. The assumed land value enhancement is equivalent to $1,000 for a lot with a 100-foot frontage. If the $1,000 increased value for a 100-foot frontage lot is distributed at a 6 percent annual interest rate over the 50 years project life utilized in the watershed study, the annual land value enhancement for the hypothetical lot would be $63.00.

Annual land value enhancement benefits accruing to floodland structure removal, computed as described herein for the City of Glendale and for the area immediately south of CTH M in the City of Mequon, are small relative to the flood control benefits, the flood control benefits for these two areas being more than six times the corresponding land value enhancement benefits.

The structure removal proposals of this flood control alternative enhance the opportunity to develop the aesthetic and recreation potential of the riverine lands. Structure removal would restore river floodlands to a natural state, thereby enhancing the aesthetic value and in effect recreating environmental corridors similar to those recommended for public acquisition, as described in Chapter III of this volume. Such restored environmental corridor lands could be used for outdoor recreation purposes. Such use of riverine lands, compatible with their flood-prone nature, would help to meet rising recreation demands within the watershed. Some of the riverine lands that would be available as a result of floodland structure removal might be converted to recreation use; and significant monetary benefits may accrue to such use in locations where structure removal provides large, attractive park sites. The incremental costs of such recreation developments, which costs would consist of expenditures beyond those required to landscape the evacuated homesites, and the monetary benefits that would accrue are not included in the economic analyses.

Structure Floodproofing and
Removal in the City of Glendale

The City of Glendale, which is coincident with Flood Damage Reach 2, as defined and discussed in Chapter VIII of Volume 1 of this report, is characterized by intensive urban development of the natural floodlands of the Milwaukee River, such floodland occupancy being largely concentrated in the river reach extending from W. Silver Spring Drive upstream about two miles through the Sunny Point Road area just north of Bender Road. Ninety-eight major structures, primarily private residences, may be expected to incur flood damage during a 10-year recurrence interval flood event, while 280 additional major structures, also primarily private residences, may be expected to incur flood damage during a 100-year recurrence interval flood event in this reach. Future flood damage to private residences and other major structures would be virtually eliminated by floodproofing 280 structures and by removal of 98 structures. Table 35 sets forth a schedule of the approximate number and types of structures to be floodproofed and removed and also summarizes the attendant costs and benefits.

Assuming that the aforementioned structure floodproofing and removal measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost is estimated at $151,000, consisting entirely of amortization of the capital cost of the floodproofing and removal. The average annual flood abatement benefit is estimated at $36,110 and the average annual land value enhancement occurring to properties adjoining the large riverine area that would be vacated is estimated at $2,000. The total average annual benefits for flood abatement and land value enhancement are, therefore, $38,110, yielding a benefit-cost ratio of 0.25. The City of Glendale structure floodproofing and removal flood control plan element, as described herein, is, therefore, extremely uneconomical.

This unfavorable economic result might be moderated somewhat by the fact that floodland structure removal within the City of Glendale would offer the potential for park development, with recreation and aesthetic benefits probably in excess of the attendant costs for recreation facilities, since the necessary land would be placed in public ownership as a result of this flood control alternative. Approximately 125 acres of riverine area adjacent to about two miles of the Milwaukee River and extending from Silver Spring Drive upstream through the Sunny Point Road area just north of Bender Road would be available for public use under this structure floodproofing and removal alternative. The evacuated land might be incorporated into the Milwaukee County Park System as a riverine connection between Lincoln Park on the south and Kletzsch Park on the north. Incremental costs and recreation and aesthetic benefits that would accrue to this potential use of the evacuated riverine land are not included in the benefit-cost analysis.

Structure Floodproofing and
Removal in the City of Mequon

The City of Mequon, which is coincident with Flood Damage Reaches 5, 7, and 8, as defined and discussed in Chapter VIII of Volume 1 of this report, is also characterized by intensive urban development within the natural floodlands of the Milwaukee River. Damage Reach 5, which extends along the river from the south corporate limits of the City of Mequon upstream about three miles to STH 167, contains 19 private residences that may be expected to incur flood damage during a 10-year recurrence interval flood event and 27 additional homes that may be expected to incur flood damage during a 100-year recurrence interval flood event. These flood-prone structures in Damage Reach 5 are concentrated primarily along, and immediately adjacent to, the left (east) bank of the Milwaukee River in the vicinity of the Lac du Cours area in Section 36, Town 9 North, Range 21 East. Future flood damage to private residences would be virtually eliminated by floodproofing 27 structures and by removal of 19 structures. Table 35 sets forth a schedule of the approximate number and types of structures to be floodproofed and removed and also summarizes the attendant costs and benefits.

Assuming that the aforementioned structure floodproofing and removal measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost is estimated at $22,800, consisting entirely of amortization of the capital cost of the floodproofing and removal. The

Table 35

ESTIMATED COSTS AND BENEFITS FOR STRUCTURE FLOODPROOFING AND REMOVAL IN THE MILWAUKEE RIVER WATERSHED[a]

Location: Subwatershed	Location: Community	Location: Damage Reach Number[d]	Location: River Miles	Structure Floodproofing[b]: Major Structures Between 10 and 100-Year[e] Flood Hazard Lines (Floodproof): Homes	Other	Total	Structure Floodproofing[b]: Capital Cost of Floodproofing[f]	Structure Removal[c]: Major Structures Between Channel and 10-Year Flood Hazard Line (Remove): Homes	Other	Total	Structure Removal[c]: Capital Cost of Land and Improvements[g]	Benefit-Cost Summary: Capital Cost of Floodproofing and Removal	Annual Cost (Amortization of Capital Cost)	Annual Benefit[h]	Benefit-Cost Ratio
Lower Milwaukee River	City of Glendale	2	8.1-12.0	268	12	280	$280,000	74	24	98	$2,107,000	$2,387,000	$151,000	$ 38,110	0.25
	Village of Thiensville	6	18.8-20.6	16	33	49	49,000	0	0	0	--	49,000	3,100	5,180	1.67
	City of Mequon	5	16.0-18.8	27	0	27	27,000	19	0	19	332,000	359,000	22,800	15,740	0.69
		7[i]	18.8-22.0	16	0	16	16,000	32	0	32	449,000	465,000	29,500	35,900	1.22
		8	22.0-26.3	26	0	26	26,000	79	0	79	950,000	976,000	61,800	17,620	0.29
	Mequon Sub-Totals			69	0	69	69,000	130	0	130	1,731,000	1,800,000	114,100	69,260	0.61
	Village of Saukville	12	35.0-37.5	86	27	113	113,000	4	3	7	108,000	221,000	14,000	3,755	0.27
	Remainder of Lower Milwaukee River	--	--	36	12	48	48,000	9	2	11	185,000	233,000	14,800	13,240	0.90
Lower Milwaukee River Subtotals	--	--	--	475	84	559	$559,000	217	29	246	$4,131,000	$[illegible],690,000	$297,000	$129,545	0.44
Middle Milwaukee River	--	--	47.90-74.27	24	22	46	--[j]	28	15	43	--[j]	--[j]	--[j]	--[j]	--[j]
Upper Milwaukee River	--	--	74.27-96.88	5	6	11	--	37	8	45	--	--	--	--	--
West Branch	--	--	79.49-100.36	2	0	2	--	0	0	0	--	--	--	--	--
East Branch	--	--	74.27-92.24	16	8	24	--	10	10	20	--	--	--	--	--
Crooked Lake Creek	--	--	84.93-90.06	0	0	0	--	0	0	0	--	--	--	--	--
Silver Creek (West Bend Township)	--	--	67.31-71.93	1	2	3	--	6	1	7	--	--	--	--	--
North Branch	--	--	47.90-70.56	3	0	3	--	14	17	31	--	--	--	--	--
Silver Creek (Sherman Township)	--	--	57.34-66.94	1	0	1	--	17	4	21	--	--	--	--	--
Cedar Creek	--	--	27.57-60.29	46	26	72	--	50	8	58	--	--	--	--	--
Lincoln Creek	--	--	7.86-13.61	0	0	0	--	0	0	0	--	--	--	--	--
Subtotal for the Milwaukee River Watershed Excluding the Lower Milwaukee River Subwatershed	--	--	--	98	64	162	--	162	63	225	--	--	--	--	--
Total	--	--	--	573	148	721	--	379	92	471	--	--	--	--	--

[a] ECONOMIC ANALYSES ARE BASED ON AN ANNUAL INTEREST RATE OF SIX PERCENT AND A 50-YEAR AMORTIZATION PERIOD AND PROJECT LIFE.

[b] HOUSES AND MAJOR STRUCTURES HAVING FIRST FLOOR ELEVATIONS ABOVE THE 10-YEAR RECURRENCE INTERVAL FLOOD STAGE WOULD BE FLOODPROOFED UNDER THIS FLOOD CONTROL ALTERNATIVE. THE NUMBER OF STRUCTURES INCLUDED IN THIS CATEGORY AND THEREFORE SUBJECT TO FLOODPROOFING WAS ASSUMED TO BE EQUAL TO THE NUMBER OF STRUCTURES BETWEEN THE 10- AND 100-YEAR RECURRENCE INTERVAL FLOOD HAZARD LINES.

[c] HOUSES AND MAJOR STRUCTURES HAVING FIRST FLOOR ELEVATIONS BELOW THE 10-YEAR RECURRENCE INTERVAL FLOOD STAGE WOULD BE REMOVED UNDER THIS FLOOD CONTROL ALTERNATIVE. THE NUMBER OF STRUCTURES INCLUDED IN THIS CATEGORY AND THEREFORE SUBJECT TO REMOVAL WAS ASSUMED TO BE EQUAL TO THE NUMBER OF STRUCTURES BETWEEN THE CHANNEL AND THE 10-YEAR RECURRENCE INTERVAL FLOOD HAZARD LINE.

[d] MAJOR FLOOD DAMAGE REACHES ARE DEFINED AND DISCUSSED IN CHAPTER VIII OF VOLUME 1 OF THIS REPORT.

[e] STRUCTURE IDENTIFICATION AND COUNTS WERE OBTAINED FROM LAND USE DATA COMPILED ON LOW FLIGHT AERIAL PHOTOGRAPHS IN COMBINATION WITH LARGE SCALE FLOOD HAZARD MAPS (1" = 200' SCALE, 2' - 4' CONTOUR INTERVAL) AVAILABLE FOR MOST OF THE LOWER MILWAUKEE RIVER, FOR CEDAR CREEK FROM THE MILWAUKEE RIVER UPSTREAM THROUGH THE CITY OF CEDARBURG AND FOR THE CITY OF WEST BEND, WITH SMALL SCALE FLOOD HAZARD MAPS (1" = 2000' AND 1" = 5200' SCALES, 10' AND 20' CONTOUR INTERVAL) BEING USED IN THE REMAINDER OF THE WATERSHED. MAJOR FLOOD PRONE STRUCTURES WERE CLASSIFIED AS BEING EITHER HOMES OR SOME OTHER TYPE OF MAJOR STRUCTURE. GARAGES AND OTHER MINOR STRUCTURES WERE EXCLUDED. IN ADDITION TO HOMES, THE MAJOR STRUCTURE CATEGORY INCLUDES BARNS AND OTHER LARGE AGRICULTURAL RELATED BUILDINGS AS WELL AS COMMERCIAL, INDUSTRIAL, AND PUBLIC BUILDINGS. EXTREMELY LARGE BUILDINGS OR BUILDING COMPLEXES WERE COUNTED AS SEVERAL STRUCTURES IN ORDER TO BETTER REFLECT THEIR SIZE.

[f] THE AVERAGE CAPITAL COST OF FLOODPROOFING WAS ESTIMATED TO BE $1,000 PER STRUCTURE.

[g] THE ACQUISITION COST OF LAND, STRUCTURES, AND OTHER IMPROVEMENTS IS BASED ON THE EQUALIZED ASSESSED VALUE OF REPRESENTATIVE RIVERINE PROPERTIES AND IMPROVEMENTS IN EACH COMMUNITY.

[h] THE ANNUAL BENEFIT ASSUMES THAT THIS FLOOD CONTROL ALTERNATIVE WOULD ELIMINATE ALL RESIDENTIAL AND COMMERCIAL DAMAGES BUT WOULD NOT REDUCE ROAD USER DETOUR OR PUBLIC SECTOR LOSSES. IN DAMAGE REACHES 2 AND 8, THE ESTIMATED ANNUAL FLOOD DAMAGE ABATEMENT BENEFITS OF $36,110 AND $15,120, RESPECTIVELY, WERE SUPPLEMENTED WITH ESTIMATED ANNUAL LAND ENHANCEMENT BENEFITS OF $2,000 AND $2,500 RESPECTIVELY, TO REFLECT THE INCREASED PROPERTY VALUE THAT WOULD ACCRUE TO RESIDENTIAL LANDS CONTIGUOUS WITH FLOODLAND AREAS THAT WOULD, UNDER THIS FLOOD CONTROL PLAN ELEMENT, BE CONVERTED FROM THE EXISTING RESIDENTIAL USE TO OPEN SPACE USE.

[i] THE 32 MAJOR STRUCTURES IN THE 10-YEAR FLOODPLAIN OF REACH 7 IN THE CITY OF MEQUON INCLUDES 13 PRIVATE RESIDENCES ALONG VILLA GROVE ROAD IN SECTION 24, TOWN 9 NORTH, RANGE 21 EAST, RECENTLY PURCHASED BY THE CITY OF MEQUON FOR ULTIMATE REMOVAL FROM THE FLOODLANDS. SIX OF THESE HAVE NOT AS YET (1971) BEEN REMOVED BUT WILL BE EVACUATED FROM THE FLOODLANDS BY 1980. COSTS AND BENEFITS ATTENDANT TO THE ACQUISITION AND REMOVAL OF THESE 13 STRUCTURES HAVE BEEN INCLUDED IN THE ECONOMIC ANALYSES.

[j] THE ABSENCE OF DETAILED TOPOGRAPHIC DATA FOR THAT PORTION OF THE WATERSHED LYING OUTSIDE OF THE LOWER MILWAUKEE RIVER SUBWATERSHED PRECLUDED AN ANALYSIS OF THE COSTS AND BENEFITS ATTENDANT TO STRUCTURE FLOODPROOFING AND REMOVAL IN THOSE AREAS. BASED ON THE RESULTS FOR THE LOWER MILWAUKEE RIVER, AS SET FORTH IN THIS TABLE, IT IS REASONABLE TO CONCLUDE THAT STRUCTURE FLOODPROOFING AND REMOVAL MEASURES WOULD GENERALLY BE ECONOMICALLY UNSOUND FOR THE REMAINDER OF THE WATERSHED.

SOURCE- SEWRPC.

average annual flood abatement benefit is estimated at $15,740, yielding a benefit-cost ratio for Damage Reach 5 of 0.69. The structure floodproofing and removal flood control plan element for Reach 5 in the City of Mequon, as described herein, is, therefore, uneconomical.

Damage Reach 7 within the City of Mequon is bound on the south by STH 167 and, excluding the Village of Thiensville on a portion of the right (west) bank, extends upstream about three miles to the southwest corner of Section 18, Town 9 North, Range 22 East. Thirty-two private residences may be expected to incur flood damage during a 10-year recurrence interval flood event, and 16 additional homes may be expected to incur flood damage during a 100-year recurrence interval flood event. The flood-prone structures are located on both sides of the river and are widely scattered throughout the length of Damage Reach 7.

The 32 major structures in the 10-year floodplain of Reach 7 in the City of Mequon include 13 private residences along Villa Grove Road in Section 24, Town 9 North, Range 21 East, recently purchased by the City of Mequon for ultimate removal from the floodlands. Six of these have not yet (1971) been removed but will be evacuated from the floodlands by 1980. Costs and benefits attendant to the acquisition and removal of these 13 structures have been included in the economic analyses.

Future flood damage to private residences would be virtually eliminated by floodproofing 16 structures and removal of 32 structures. Table 35 sets forth a schedule of the approximate number and types of structures to be floodproofed and removed and also summarizes the attendant costs and benefits.

Assuming that the aforementioned structure floodproofing and removal measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost of these measures is estimated at $29,500, consisting entirely of amortization of the capital cost of the floodproofing and removal. The average annual flood abatement benefit is estimated at $35,900, yielding a benefit-cost ratio for Damage Reach 7 of 1.22.

The flood control plan for Reach 7 within the City of Mequon, consisting entirely of structure floodproofing, as described herein, constitutes both a technically and an economically feasible solution to that community's flood problems, the implementation of which would enhance the aesthetic setting of the remaining riverine residences in this reach.

Damage Reach 8, the last of the three damage reaches within the City of Mequon, extends from the southwest corner of Section 18, Town 9 North, Range 22 East, upstream approximately four miles to the northern corporate limits of Mequon. Seventy-nine private residences may be expected to incur flood damage during a 10-year recurrence interval flood event, and 26 additional homes may be expected to incur flood damage during a 100-year recurrence interval flood event. These flood-prone structures are concentrated primarily along, and immediately adjacent to, both banks of the Milwaukee River immediately south of CTH M. Future flood damage to private residences would be virtually eliminated by floodproofing 26 structures and by removal of 79 structures. Table 35 sets forth a schedule of the approximate number and types of structures to be floodproofed and removed and also summarizes the attendant costs and benefits.

Assuming that the aforementioned structure floodproofing and removal measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost is estimated at $61,800, consisting entirely of amortization of the capital cost of the floodproofing and removal. The average annual flood abatement benefit is estimated at $15,120, and the average annual land value enhancement accruing to properties adjoining the large riverine area immediately south of CTH M that would be vacated is estimated at $2,500. The total average annual benefits for flood abatement and land value enhancement are, therefore, estimated at $17,620, yielding a benefit-cost ratio of 0.29. The structure floodproofing and removal flood control plan element for Reach 8 in the City of Mequon, as described herein, is, therefore, extremely uneconomical.

This unfavorable economic result might be moderated somewhat by the fact that floodland structure removal immediately south of CTH M within the City of Mequon would offer the potential for park development, with recreation and aesthetic benefits probably in excess of the attendant costs for recreation facilities, since the necessary land would be in public ownership as a result of this flood control alternative. A total of approximately 100 acres of riverine area, lying on both banks of the Milwaukee River at the CTH M location, would be available for park development under this structure floodproofing and removal alternative.

Considering the entire City of Mequon, the total annual cost for complete abatement of damage from a 100-year recurrence interval watershed-wide flood as that abatement would be provided by the floodproofing and removal of 69 and 130 homes, respectively, is estimated at $114,100. The average annual flood abatement benefits accruing to such a combination of flood control measures in the City of Mequon are estimated at $66,760, and the average annual land enhancement benefits are approximately $2,500, yielding an aggregate benefit-cost ratio of 0.61. In summary, the City of Mequon structure floodproofing and removal alternative applied throughout the 10 lineal miles of floodlands within the City of Mequon, as described herein, would be uneconomical.

Structure Floodproofing in the Village of Thiensville

The Village of Thiensville, which is coincident with Flood Damage Reach 6, as defined and discussed in Chapter VIII of Volume 1 of this report, is characterized by primarily commercial development within the natural floodlands of the Milwaukee River, such floodland occupancy being entirely located on the right (west) bank of the river in a reach extending approximately from the south corporate limits of Thiensville upstream about three-fourths of a mile to the Village park located just east of the Thiensville Dam. Although there are 49 major flood-prone structures located in this short reach, the estimated annual structural damages are relatively low because all of the flood-prone buildings are located relatively high above the river, being positioned between the 10- and 100-year inundation levels. A flood event having a recurrence interval of greater than 10 years, however, may be expected to cause considerable disruption of business and community activities because of the extensive area that would be inundated.

Future flood damage to business and commercial structures and to private residences would be virtually eliminated by floodproofing 49 structures. Structure removal would not be necessary. Table 35 sets forth a schedule of the approximate number and types of structures to be floodproofed and also summarizes the attendant costs and benefits.

Assuming that the aforementioned structure floodproofing measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost is estimated at $3,100, consisting entirely of amortization of the capital cost of the floodproofing. The average annual flood abatement benefit is estimated at $5,180, yielding a benefit-cost ratio for the Village of Thiensville of 1.67.

The nonstructural flood control plan element, consisting entirely of structure floodproofing within the Village of Thiensville, as described herein, constitutes a technically and economically feasible solution to that community's flood problems, the implementation of which would not necessarily produce any objectionable aesthetic features.

Structure Floodproofing and Removal in the Village of Saukville

The Village of Saukville, which is coincident with Flood Damage Reach 12, as defined and discussed in Chapter VIII of Volume 1 of this report, is also characterized by intensive urban development of the natural floodlands of the Milwaukee River, such floodland occupancy being distributed along both sides of the river throughout the approximately two-mile-long riverine area of the Village. Although there are 120 major flood-prone structures in this reach, the estimated annual structural damages are rather low because 113 of the buildings are located between the 10- and 100-year inundation levels; and only seven structures may be expected to incur flood damage during a 10-year recurrence interval flood event. A flood event having a recurrence interval of greater than 10 years may be expected to cause considerable disruption of business and community activities because of the extensive area that would be inundated.

Future flood damage to private residences and other major structures would be virtually eliminated by floodproofing 113 structures and removing 7 structures. Table 35 sets forth a schedule of the approximate number and types of structures to be floodproofed and removed and also summarizes the attendant costs and benefits.

Assuming that the aforementioned structure floodproofing and removal measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the annual cost is estimated at $14,000, consisting entirely of amortization of the capital cost of the floodproofing and removal. The average annual flood abatement benefit is estimated at $3,755, yielding a benefit-cost ratio for the Village of Saukville of 0.27. The Village of Saukville structure floodproofing and removal flood control plan element, as described herein, is, therefore, extremely uneconomical.

Structure Floodproofing and Removal in the Remainder of the Watershed

The riverine areas of the lower Milwaukee River watershed, extending along 48 miles of the Milwaukee River from Lake Michigan upstream to the confluence of the main stem with the North Branch, contain relatively few flood-prone structures outside the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville. The structure floodproofing and structure removal flood-damage control alternative described herein for these two cities and two villages would require the floodproofing of 511 structures and the eventual removal of 235 structures so as to eliminate monetary damages resulting from floods up to and including the 100-year recurrence interval watershed-wide flood event. In contrast, future flood damage to homes and other major structures in the remainder of the lower Milwaukee River watershed would be virtually eliminated by the floodproofing of only 48 structures and removal of only 11 structures. Table 35 sets forth a schedule of the approximate number and types of structures that would have to be floodproofed and removed and also summarizes the attendant costs and benefits.

Full implementation of the aforementioned floodproofing and removal measures in the Lower Milwaukee River outside the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville would, at an annual interest rate of 6 percent and a project amortization period of 50 years, have an annual cost estimated at $14,800, consisting entirely of amortization of the capital cost of the floodproofing and removal measures. The average annual flood abatement benefit is estimated at $13,240, yielding a benefit-cost ratio of 0.90 for the structural floodproofing and removal measures. Such measures, although uneconomical, would be less so than similar measures applied within the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville, where large numbers of flood-prone structures are concentrated.

As discussed in Chapter VIII, Volume 1, of this report, the watershed-wide flood-damage survey conducted under the watershed study included a mail survey in which letters of inquiry were sent to officials of all federal, state, and local units and agencies of government within the watershed. The results of this mail survey indicated that significant flood damages occurred only in the floodlands of the Lower Milwaukee River. This fact was subsequently substantiated by the detailed field survey and home interview portion of the flood-damage survey and still later by application of the flood-flow simulation model developed under the watershed study, which model provided an accurate delineation on large-scale topographic maps of the 10- and 100-year recurrence interval flood hazard lines of the lower watershed. These topographic maps, prepared under the study specifically for this purpose, also provided an independent basis for the identification and enumeration of flood-prone structures.

In order to refine the flood-damage analysis reported in Chapter VIII of Volume 1 of this report, the results of the flood-flow simulation model were used to delineate the 10- and 100-year recurrence interval flood hazard lines for the entire watershed on available small-scale U. S. Geological Survey quadrangle maps. These small-scale flood hazard maps, in combination with land use data compiled on 1" = 400' scale 1967 and 1970 aerial photographs, indicated the existence of an additional 387 flood-prone structures scattered along the 168 lineal miles of major stream channel lying outside the lower Milwaukee River watershed. The approximate number of such flood-prone structures and their distribution by subwatershed are set forth in Table 35.

It should be emphasized that the number of major flood-prone structures located outside the lower Milwaukee River subwatershed, and particularly their position with respect to the floodplains—that is, the area between the 10- and 100-year recurrence interval flood hazard lines—cannot, because of map scale limitations, be established as accurately as within the lower Milwaukee River watershed. The number and location of flood-prone structures outside the lower Milwaukee River watershed, as determined from the available small-scale maps, indicates that the 387 flood-prone structures may be expected to incur average annual residential and commercial flood damages of about $100,000.

The absence of reported flood problems outside the lower Milwaukee River watershed, even though the flood-flow simulation model application indicated that such damages may be expected, is probably explained by the widely scattered distribution of flood-prone structures in the riverine areas of the upper watershed, as opposed to the highly concentrated location of such structures in the lower watershed. This widely scattered distribution of flood-prone structures is indicated in Table 35, which shows that the flood-prone structures in the upper watershed are located in 9 of 10 subwatersheds and that a 100-year recurrence interval flood event would damage an average of about 17 major structures per mile of the Lower Milwaukee River, while the same event would damage an average of only about two structures per mile in the remainder of the watershed. Therefore, while the total number of flood-prone structures lying outside the lower Milwaukee River watershed is equal to about 32 percent of the total number of such structures in the entire watershed, the highly dispersed location of the former is such that they do not constitute a significant problem for, or within, any given city, village, or county or for any federal, state, or local agency and, thus, were not reported by those municipalities and agencies contacted during the watershed-wide SEWRPC flood-damage survey.

Because of the highly dispersed location of these flood-prone structures, the only feasible means of providing flood-damage relief is the nonstructural measure of floodproofing and removal. The absence of detailed topographic data for the upper Milwaukee River watershed, however, precluded an analysis of the costs and benefits attendant to structure floodproofing and removal in those areas. Based on the results of the previously described detailed technical and economic analysis of structure floodproofing and removal measures for the Lower Milwaukee River, it is reasonable to conclude that such measures would generally be uneconomical for the remainder of the watershed.

Summary of Structure Floodproofing and Removal Flood-Damage Control Alternative

The watershed-wide flood-damage control alternative, consisting of the floodproofing of approximately 721 major flood-prone structures, 559 of which are located along the Lower Milwaukee River, and the eventual removal of about 471 major flood-prone structures, 246 of which lie in Lower Milwaukee River floodlands, would eliminate virtually all residential and commercial flood damages resulting from floods up to and including the 100-year recurrence interval watershed-wide flood event. Although this flood control measure would be effective, it is, with a few exceptions, extremely uneconomical. For example, application of this alternative to flood-prone structures along the Lower Milwaukee River would require an estimated total annual expenditure of $297,000; and the attendant total annual flood control and land enhancement benefit would total $129,545, yielding a benefit-cost ratio of 0.44.

River reaches through the Village of Thiensville and through a portion of the City of Mequon are exceptions to the generally unfavorable economic results attendant to structure floodproofing and removal. Full protection could be provided to existing flood-damage-prone structures in the Village of Thiensville by floodproofing alone without any removal, and such efforts would yield a benefit-cost ratio of 1.67. Structure removal and floodproofing would also be economical in that portion of Mequon consisting of the riverine area extending from STH 167 upstream to the southwest corner of Section 18, Town 9 North, Range 22 East, the estimated benefit-cost ratio for application of such measure to this reach being 1.22.

These isolated floodland areas in which structure floodproofing and removal would be economical include only 97 major structures, or about 8 percent of the total of such structures located in the watershed. Therefore, if structure floodproofing and removal measures were implemented in these areas, only a very small portion of the total watershed flood problem would be alleviated. Floodproofing, in contrast to structure removal, would achieve most of the flood-damage abatement in the aforementioned two isolated floodland areas exhibiting positive benefit-cost ratios.

The structure removal portion of the floodproofing-removal measure, as described herein, would vacate and convert to public use two riverine areas on the Lower Milwaukee River that would be large enough and otherwise suited for park development. Approximately 125 acres of riverine areas in the City of Glendale adjacent to about two miles of the Milwaukee River, extending from Silver Spring Drive upstream through the Sunny Point Road area just north of Bender Road, would be available for public use under this structure floodproofing and removal alternative. This land might be incorporated into the Milwaukee County Park System as a riverine connection between Lincoln Park on the south and Kletzsch Park on the north.

A total of about 100 acres of riverine area lying on both banks of the Milwaukee River immediately south of CTH M in the City of Mequon would also be available for park development under the structure floodproofing and removal alternative. Park developments in these two riverine areas would offer recreation and aesthetic benefits probably in excess of the attendant incremental costs for recreation facilities, since the necessary land would be in public ownership as a result of this flood control alternative. The incremental cost of such recreation developments, which cost would consist of expenditures beyond those required to landscape the evacuated homesites, and the monetary benefits that would accrue are not included in the economic analyses.

ACCESSORY FLOOD CONTROL PLAN ELEMENTS

Adequate Hydraulic Capacity of Bridges

The watershed development objectives and supporting principles and standards set forth in Chapter II of this volume require that bridge and culvert waterway openings, together with the approach and crossing roadways, be considered as an integral part of the water control facilities of any comprehensive watershed plan in order to achieve an integrated and effective river drainage system within the watershed. Application of the hydrologic and hydraulic information set forth in Appendices F and G of this volume, together with an analysis of the hydraulic performance of existing and proposed bridges, provides a sound basis for recommending bridge and culvert modification or replacement in order to provide adequate hydraulic capacity. The flood-flow data provided by the watershed study also provide a sound basis for the hydraulic design of bridges proposed in new locations over the major streams of the watershed.

Certain existing major stream crossings, as set forth in Table 36, may be expected to have substandard hydraulic characteristics under 1990 land use conditions; and, when modified or replaced by the local or state highway agencies concerned as a part of a highway improvement program, these crossings should be designed to provide adequate hydraulic capacity in accordance with the recommended standards. Benefit cost analyses were not considered as a valid factor in evaluating bridge or culvert modification or replacement because the affected structures have, with few exceptions, served their useful life and will, in any case, require modification or replacement for transportation system improvement or maintenance purposes.

The location, as well as the design, of all new bridges and culverts—that is, of structures proposed to be located over major streams at points within the watershed where presently no crossing exists—as well as the design of existing bridge and culvert replacements or modifications, should be based upon the applicable objectives and standards set forth in Chapter II of this volume. Of particular importance is the standard which requires that all new and replacement bridges and culverts over perennial waterways be designed so as to accommodate the 100-year recurrence interval flood event without raising the peak stage, either upstream or downstream, more than 0.5 foot above the peak stage for the 100-year recurrence interval flood, as established in the adopted comprehensive watershed plan.

Floodland Use Regulations

The natural hydraulic function of the floodlands of a watershed is to provide for the conveyance and storage of floodwaters. Major reductions in the conveyance and storage potential of the floodlands, caused by the filling of, or by the construction of, substantial structures in the floodlands, may result in increased peak flood discharges and, more importantly, corresponding increased peak flood stages, both upstream and downstream of an altered reach. If such filling and development is allowed to continue to preempt the natural floodplains of the stream system of the watershed, flood hazards and concomitant damage to property and danger to health and life may be expected to increase sharply. This will, in turn, lead to increasing demands for the construction of structural flood control measures, such as reservoirs, channel improvements, dikes and floodwalls, and diversion channels. As urban development proceeds on an areawide basis over the watershed, such an approach can only become self-defeating, since the number of persons and value of property in the path of floodwaters will increase at a more rapid rate than that at which protection through public works construction can be afforded. Moreover, the actions of upstream communities to prevent damage to land uses located in the natural floodplains may commit the downstream communities to the construction of extensive and expensive flood control works. The intelligent exercise of floodland use regulations is, therefore, required in all floodland areas, either alone or in conjunction with the development of flood control measures, as described in this chapter. Floodland use regulations generally emphasize the prohibition or regulation of flood-vulnerable land uses in the floodlands. Such prohibition and regulation are normally exercised under local police powers. Generally, the use of the floodplain should be restricted to compatible open uses; and any filling of the floodplains should be avoided.

Table 36

RIVER CROSSINGS IN THE MILWAUKEE RIVER WATERSHED HAVING SUBSTANDARD HYDRAULIC CAPACITIES[a]

RIVER OR CREEK	CROSSING NAME	STRUCTURE NUMBER[b]	COUNTY	CONSTRUCTION DATE	RECOMMENDED DESIGN FREQUENCY IN YEARS	HYDRAULIC INADEQUACY: APPROACH ROAD OVERTOPPED	HYDRAULIC INADEQUACY: BRIDGE OR CULVERT ROADWAY OVERTOPPED
MILWAUKEE RIVER	BENDER ROAD	206	MILWAUKEE	1929	50	X	--
	CTH M	194	OZAUKEE	1949	50	X	--
	STH 33	144	OZAUKEE	1928	50	X	--
	CTH A	89	WASHINGTON	1952	50	X	--
	CTH MY	87	WASHINGTON	1929	50	X	--
	CTH H	53	WASHINGTON	1950	50	X	X
WEST BRANCH	CTH V	27	FOND DU LAC	1964	50	X	X
	RUSTIC DRIVE	25	FOND DU LAC	1908	10	X	--
	ELMORE ROAD	23	FOND DU LAC	1923	50	X	X
EAST BRANCH	COUNTY LINE ROAD	50	FOND DU LAC-WASHINGTON	1923	10	X	--
CROOKED LAKE CREEK	PARK ROAD	44	FOND DU LAC	--	10	X	X
NORTH BRANCH	RIVERSIDE DRIVE	140	OZAUKEE-WASHINGTON	1890	10	X	--
	CTH M	139	WASHINGTON	1927	10	X	--
	TRADING POST TRAIL	138	WASHINGTON	1966	50	X	X
	CTH H	137	WASHINGTON	--	50	X	--
	CTH X	136	WASHINGTON	1927	50	X	X
	JAY DRIVE	135	WASHINGTON	1909	10	X	X
	STH 144	119	SHEBOYGAN	--	50	X	X
	CTH W	112	SHEBOYGAN	--	50	X	X
	TOWN ROAD	110	SHEBOYGAN	1961	10	X	--
	CTH NN	98	SHEBOYGAN	1932	50	X	--
SILVER CREEK (SHEBOYGAN COUNTY)	TOWN ROAD	132	SHEBOYGAN	1919	10	X	X
	STH 144	129	SHEBOYGAN	1920	50	X	X
	CTH K	122	SHEBOYGAN-OZAUKEE	--	50	X	X
SILVER CREEK (WASHINGTON COUNTY)	USH 45	76	WASHINGTON	--	50	X	X
	CITY PARK DRIVE	74	WASHINGTON	--	10	X	--
	SILVERBROOK DRIVE	68A	WASHINGTON	--	10	X	X
	STH 33	67	WASHINGTON	--	50	X	X
CEDAR CREEK	GREEN BAY ROAD	192	OZAUKEE	1927	50	X	--
	CEDAR CREEK ROAD	178	OZAUKEE	1915	10	X	--
	HORNS CORNERS ROAD	173	OZAUKEE	1888	10	X	--
	CTH M	170	WASHINGTON	1930	50	X	X
	CTH G	169	WASHINGTON	1956	50	X	--

[a] THIS TABLE IDENTIFIES PUBLIC BRIDGES AND CULVERTS WHICH, WHEN CONSIDERED IN CONJUNCTION WITH THEIR APPROACH ROADWAYS, HAVE SUBSTANDARD HYDRAULIC CAPACITIES ACCORDING TO THE WATER CONTROL FACILITY STANDARDS SET FORTH IN CHAPTER II OF THIS VOLUME. APPENDIX G OF THIS VOLUME SETS FORTH DETAILED HYDRAULIC INFORMATION PERTAINING TO THE RIVER CROSSINGS LISTED IN THIS TABLE.

[b] BRIDGES AND CULVERTS ARE IDENTIFIED BY STRUCTURE NUMBER AND ARE LOCATED ON MAP 36 OF VOLUME 1 OF THIS REPORT.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

As indicated in Chapter XV of Volume 1 of this report, an accurate delineation of the floodlands of a watershed is essential to the sound, effective, and legal administration of floodland use regulations. These floodlands, defined as those parts of the riverine areas which are periodically subject to inundation, are, for regulatory purposes, categorized and divided into the channel, the 100-year floodplain, and the 100-year floodway areas. The hydraulic and hydrologic analyses completed under the watershed study identify and delineate the channel; the 100-year recurrence interval flood inundation lines as the floodplain; and, as an approximation of the floodway, the 10-year recurrence interval flood inundation lines for 216 miles of major perennial stream channels within the watershed.

Floodland regulations based on a two-district floodway-floodplain approach are recommended for watershed-wide application, because the two-district approach recognizes the quite different hydraulic function of, as well as the quite different flood hazard existing in, the floodway and the floodplain. The rational nature of the two-district approach as a basis of floodland regulation enhances the likelihood of public acceptance of such regulations; and, furthermore, legal precedence indicates that such regulations are more apt to receive the support of the courts.

The floodway is defined as that portion of the floodlands of a river, including the channel, necessary to convey and discharge the 100-year recurrence interval flood. The floodway encompasses those floodland areas that may be expected to exhibit floodwater depths and velocities of such magnitude as to constitute a threat to the safety and well-being of floodplain inhabitants and a danger to floodplain structures. The floodway should, therefore, be maintained in primarily open-space uses that are compatible with its function to safely convey flood flows.

The floodplain is defined as that portion of the floodlands, excluding the floodway, subject to inundation by the 100-year recurrence interval flood. With respect to floodland regulations, the primary reason for including the floodplain is to identify flood-prone areas and restrict and regulate uses in those areas so as to minimize flood damage. In general, filling and intensive urban development should be prohibited in floodplains, with extensive open-space-type uses encouraged. Permitted uses should be subject to building height requirements, floodproofing provisions, and other similar restrictions intended to minimize flood damages. An additional and, from an areawide viewpoint, most important reason for delineating the floodplain and regulating land use therein, particularly in essentially open floodplain areas, is to preserve the natural valley storage, the removal of which, by extensive filling and by the process of urbanization, could significantly raise flood discharges and stages within the watershed.

The floodplains, which together with the floodways, constitute only 7 percent of the total watershed area, are, because of their susceptibility to recurrent inundation and their critical function as natural floodwater storage areas, generally unsuited for intensive urban development, particularly when considered relative to the large expanse of watershed lands lying above and outside the floodplains. Urbanization within the Milwaukee River watershed should, therefore, be directed to those areas outside the floodways and floodplains suitable for urban development. Population growth and attendant urbanization generate a need for readily accessible park and open-space areas, in order to provide recreational opportunities and to maintain and enhance the overall quality of the environment within the watershed and the Region of which the watershed is a part. Unoccupied riverine lands, including the floodways and floodplains, provide an excellent natural resource base to meet these recreational, aesthetic, and ecological needs. The flood-prone characteristics of such lands are completely consistent with recreational use and aesthetic enjoyment. The presence of the river enhances the overall experience; and, the linear continuous nature of riverine lands provides, as exemplified by the Milwaukee County parkway system, open-space areas close to, and readily accessible to, urban residents.

In undeveloped floodplain and floodway areas, therefore, floodland regulations should seek to retain most, if not all, of the floodlands in open-space use so as to not only absolutely assure the prevention of future flood problems but so as to better adjust land use development to the underlying and sustaining natural resource base of the watershed. If development and fill are to be prohibited in the floodplain, the floodway in essentially unoccupied floodland areas may be approximated as that area subject to inundation by the 10-year recurrence interval flood. Thus, the watershed study, by delineating the 10- and

100-year recurrence interval flood hazard line along the major streams and watercourses provides a sound basis for the local enactment of fully coordinated floodland use regulations throughout most of the riverine areas of the watershed.

Certain portions of the Milwaukee River watershed, however, contain extensive riverine areas in which urban development has been unwisely allowed to encroach onto the natural floodlands. In such areas it may be desirable to designate a true floodway by the conduct of special hydraulic engineering studies. The designation of such a floodway must reflect not only areawide hydrologic and hydraulic conditions but also existing and committed land use development. Such designated floodways can be effectively utilized in communities with extensive existing floodplain development as a zoning tool in the alternative to the 10-year recurrence interval floodplain.

A designated floodway district, together with the corresponding floodplain district, was determined under the Milwaukee River watershed study for the City of Glendale in order to illustrate the techniques used and the factors to be considered in urban floodway delineation (see Map 16). For comparison purposes, the 10- and 100-year recurrence interval floodplains for the City of Glendale are shown on Map 17. It is important to note that the designated floodway shown on Map 16 represents only one of many potential floodways that could be delineated through the City of Glendale. The backwater submodel portion of the flood-flow simulation model developed under the Milwaukee River watershed study comprises the basic analytic tool used to perform necessary hydraulic computations. Constricted valley cross sections reflecting the floodway location were used to compute the 100-year recurrence interval flood stages and stage increases attendant to the floodway designation, which stages and stage increases are set forth in Table 37.

Numerous factors must be considered in establishing the boundary of a designated floodway. It should, as exemplified by the one possible Glendale floodway shown on Map 16, be generally smooth and continuous so as to reflect the desired, if not the expected, behavior of the river during a major flood event. Where possible, the number and value of structures within the designated floodway should be minimized, since the subsequent floodland use regulations should designate such floodway structures as nonconforming floodland uses, with the intent that they be eventually removed from the floodway. The floodway determination procedure must consider the implications of increasing the stage of the 100-year recurrence interval flood both upstream and downstream of, as well as within, the study area.[32] Floodland regulations must incorporate the 100-year recurrence interval flood stages associated with a designated floodway, since completion of intensive urbanization of the associated floodplains would mean that essentially all conveyance potential would be removed from the floodplain which, in effect, forces the river, during the 100-year recurrence interval flood event, to pass within the floodway limits at increased stage. Stage increases in upstream communities should generally be 0.5 foot or less; and, if that stage increase is exceeded, as in the case of the potential Glendale floodway, which, as shown in Table 37, increases the 100-year flood stage 0.9 foot at the south corporate limit of the Village of River Hills, the concurrence of the upstream community may be required prior to adoption of floodland regulations by the downstream community. It is important to note also that flood stage increases within the community for which the floodway is being determined have the effect of enlarging the area to which floodplain regulations must apply. This is so because constricting the width of the floodway so as to eliminate from the floodway structures on its fringe has the effect of increasing the 100-year recurrence interval flood stage, thereby laterally extending the corresponding floodplains and subjecting additional land and structures to floodland regulations. This incremental 100-year floodplain regulatory area corresponding to the potential designated Glendale floodway is also shown on Map 16.

The floodway delineation should incorporate existing and planned community land use in the floodplain fringe areas. Thus, if it is hydraulically acceptable and otherwise consistent with the floodway concept, the designated floodway should include riverine areas in open-space land uses that are compatible with regular flood inundation,

---

[32] *Chapter NR 116 of the Wisconsin Administrative Code specifies, as a general rule, a maximum allowable 100-year flood stage increase in urban areas of 0.5 foot attributable to a floodway delineation but also indicates that smaller or larger stage increments may be prescribed or authorized, depending on local land use conditions and plans.*

Table 37

HYDRAULIC EFFECT OF A DESIGNATED FLOODWAY FOR THE CITY OF GLENDALE--100-YEAR RECURRENCE INTERVAL FLOOD EVENT

Location[a]			Natural Conditions No Floodway		With Designated Floodway		
Station (River Mile)	Structure Name or Other Identification	Structure Number	Discharge (CFS)	Stage (Feet Mean Sea Level)	Discharge (CFS)	Stage (Feet Mean Sea Level)[b]	Stage Increase Attributable to Designated Floodway (Feet)[b]
7.98	--	--	16,136	621.8	16,136	621.8	0.0
8.11	--	--	16,136	621.8	16,136	621.8	0.0
8.12	C & NW RR BRIDGE	208	16,136	--	16,136	--	--
8.13	--	--	16,136	622.0	16,136	622.0	0.0
8.32	--	--	16,136	624.0	16,136	624.0	0.0
8.48	--	--	16,136	625.0	16,136	625.1	0.1
8.49	SILVER SPRING DRIVE BRIDGE	207	16,136	--	16,136	--	--
8.50	--	--	16,136	625.1	16,136	625.2	0.1
8.71	--	--	16,136	626.0	16,136	626.0	0.0
8.87	--	--	16,136	626.8	16,136	626.9	0.1
9.19	--	--	16,136	628.6	16,136	628.8	0.2
9.43	--	--	16,136	629.0	16,136	629.8	0.8
9.60	--	--	16,136	629.4	16,136	630.8	1.4
9.78	--	--	16,136	630.1	16,136	631.7	1.6
9.79	BENDER ROAD BRIDGE	206	16,136	--	16,136	--	--
9.80	--	--	16,136	630.1	16,136	631.7	1.6
9.96	--	--	16,136	630.9	16,136	632.7	1.8
9.97	C & NW RR BRIDGE	205	16,136	--	16,136	--	--
9.98	--	--	16,136	631.2	16,136	632.8	1.6
10.06	--	--	16,136	631.3	16,136	633.1	1.8
10.07	KLETZSCH PARK DAM	204	16,136	--	16,136	--	--
10.08	--	--	16,136	631.3	16,136	632.9	1.6
10.22	--	--	16,136	631.8	16,136	633.2	1.4
10.66	--	--	16,136	633.2	16,136	634.2	1.0
10.94	NORTH LIMIT--CITY OF GLENDALE AND SOUTH LIMIT--VILLAGE OF RIVER HILLS ON EAST BANK OF RIVER	--	16,136	633.5	16,136	634.4	0.9[c]
11.28	--	--	16,136	633.8	16,136	634.3	0.5
11.29	GREEN TREE ROAD BRIDGE	203	16,136	--	16,136	--	--
11.30	--	--	16,136	636.0	16,136	636.0	0.0
11.54	--	--	16,136	638.3	16,136	638.3	0.0
11.66	--	--	16,136	639.3	16,136	639.3	0.0
11.67	GOOD HOPE ROAD BRIDGE	201-201A 202-202B	16,136	--	16,136	--	--
11.68	--	--	16,136	639.4	16,136	639.4	0.0
11.86	--	--	16,136	640.6	16,136	640.6	0.0
12.21	--	--	16,136	642.1	16,136	642.1	0.0
12.49	NORTH LIMIT--CITY OF GLENDALE AND SOUTH LIMIT--VILLAGE OF BROWN DEER ON WEST BANK	--	16,136	--	16,136	--	--

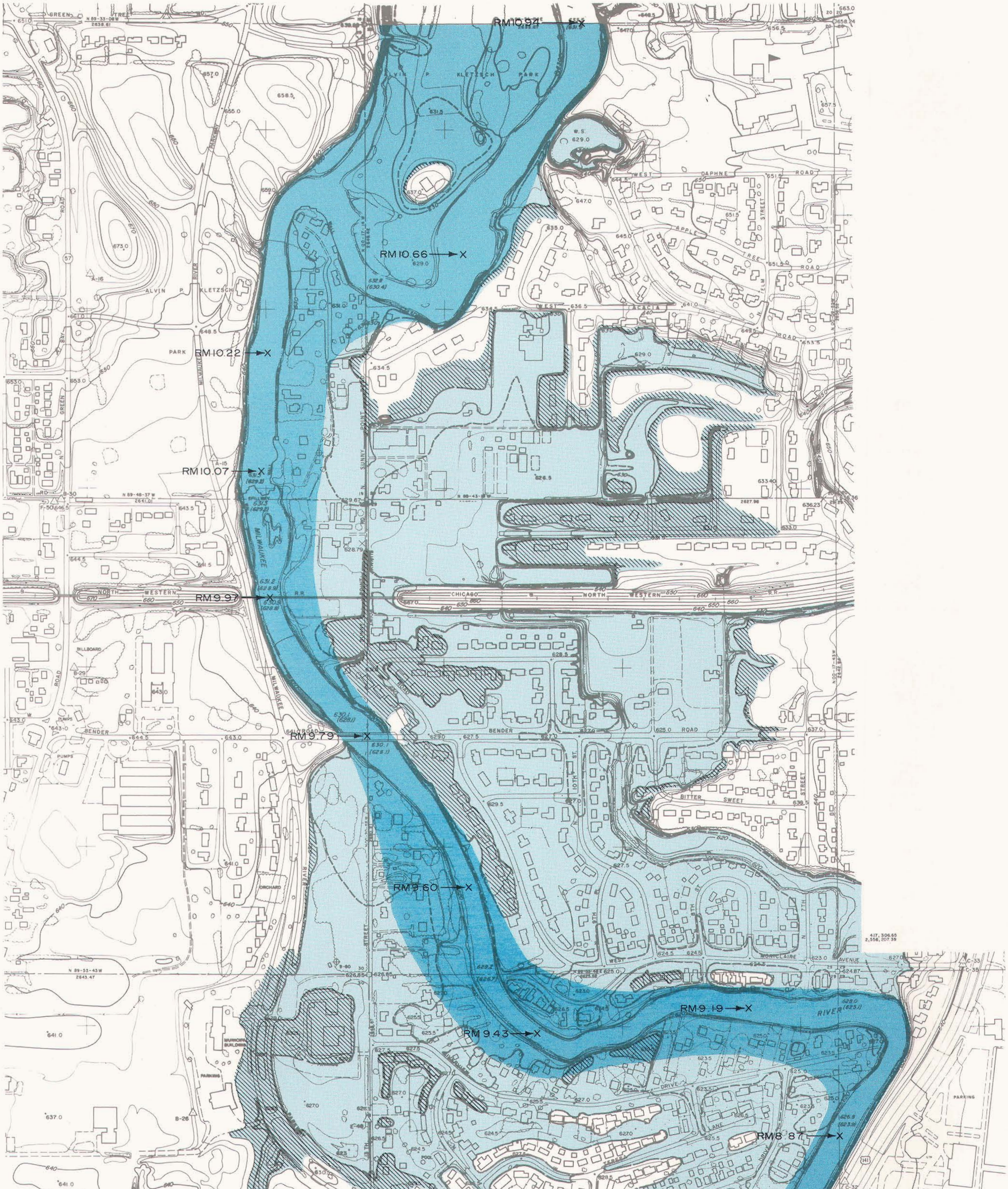
[a]THE TABULATED STATIONS CORRESPOND TO THAT PORTION OF THE CITY OF GLENDALE ON THE MILWAUKEE RIVER FOR WHICH LARGE SCALE TOPOGRAPHIC MAPPING (1" = 200' SCALE, 2' - 4' CONTOUR INTERVAL) IS AVAILABLE AND ALSO INCLUDE THE RIVERINE AREA WITHIN GLENDALE UPSTREAM OF THAT MAPPING. THE STATIONS WERE SELECTED FROM THOSE USED IN THE FLOOD FLOW SIMULATION MODEL AND LOCATIONS OF RIVER MILE STATIONS 7.98 THROUGH 10.94 ARE SHOWN ON MAPS 16 AND 17.

[b]FLOOD STAGES CORRESPONDING TO THE FLOODWAY ARE EQUAL TO OR GREATER THAN THE COMPARABLE STAGES FOR THE NATURAL SITUATION, THAT IS, THE CONDITION OF NO DESIGNATED FLOODWAY. THE STAGE INCREASE REPRESENTS THE HYDRAULIC EFFECT OF LATERALLY CONSTRICTING THE NATURAL CROSS-SECTION OF THE RIVER AT FLOOD FLOW SO AS TO CORRESPOND TO THE DESIGNATED FLOODWAY. FLOODLAND REGULATIONS BASED ON THE DESIGNATED FLOODWAY MUST INCORPORATE THE HIGHER FLOOD STAGES SINCE COMPLETION OF INTENSIVE URBANIZATION OF THE ASSOCIATED FLOODPLAINS WOULD MEAN THAT ESSENTIALLY ALL CONVEYANCE POTENTIAL WOULD BE REMOVED FROM THE FLOODPLAIN WHICH, IN EFFECT, WOULD FORCE THE RIVER, DURING THE 100-YEAR RECURRENCE INTERVAL FLOOD EVENT, TO PASS WITHIN THE FLOODWAY LIMITS AT INCREASED STAGE.

[c]STAGE INCREASES IN UPSTREAM COMMUNITIES SHOULD GENERALLY BE 0.5 FOOT OR LESS, AND, IF THAT STAGE INCREASE IS EXCEEDED, AS IN THE CASE OF THE POTENTIAL GLENDALE FLOODWAY, WHICH, AS SHOWN IN THE TABLE INCREASES THE 100-YEAR FLOOD STAGE 0.9 FOOT AT THE SOUTH CORPORATE LIMIT OF THE VILLAGE OF RIVER HILLS (RIVER MILE 10.94), THE CONCURRENCE OF THE UPSTREAM COMMUNITY MAY BE REQUIRED PRIOR TO ADOPTION OF FLOODLAND REGULATIONS BY THE DOWNSTREAM COMMUNITY.

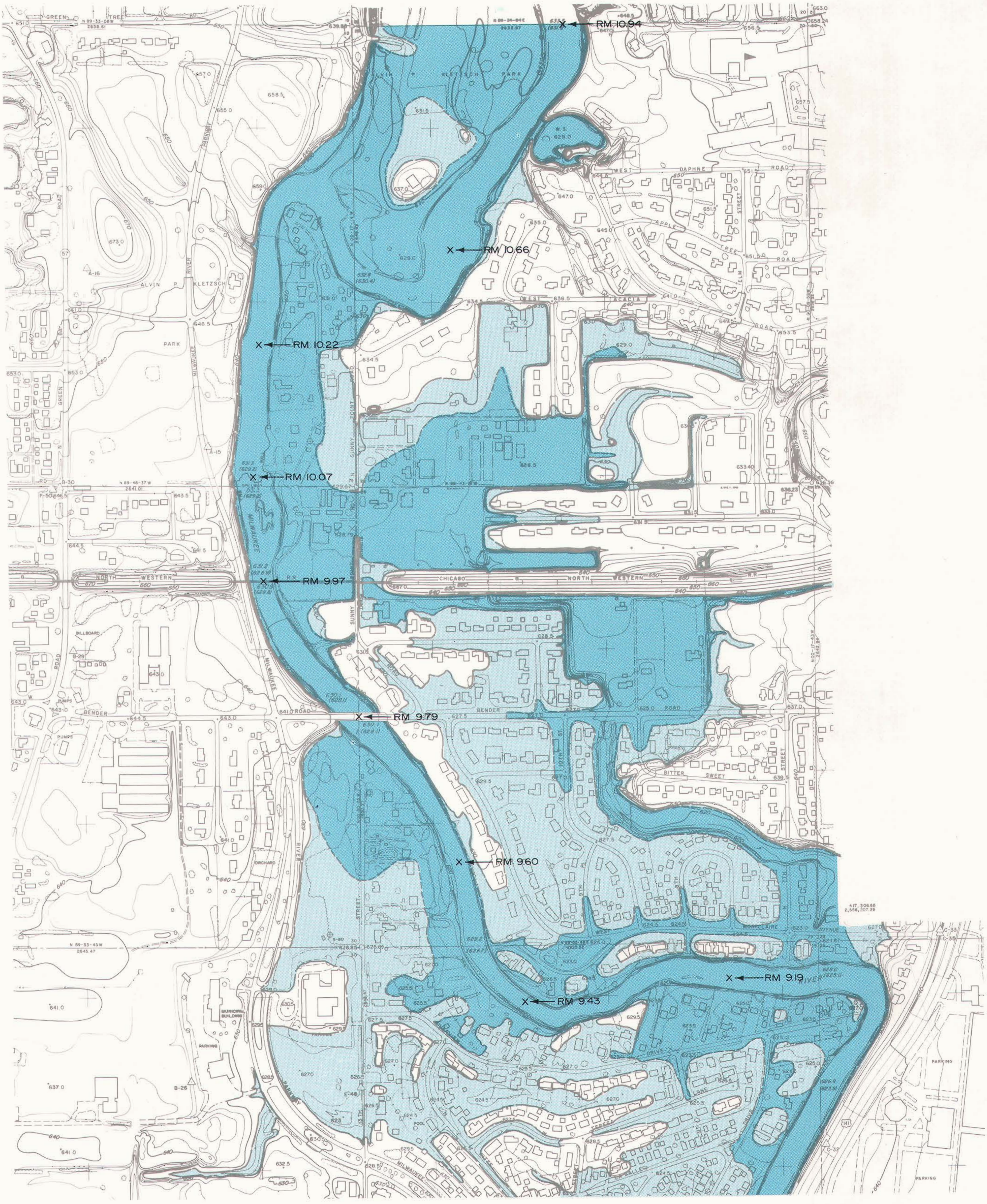
SOURCE- SEWRPC.

Map 16
TYPICAL DESIGNATED FLOODWAY AND CORRESPONDING FLOODPLAIN FOR THE CITY OF GLENDALE

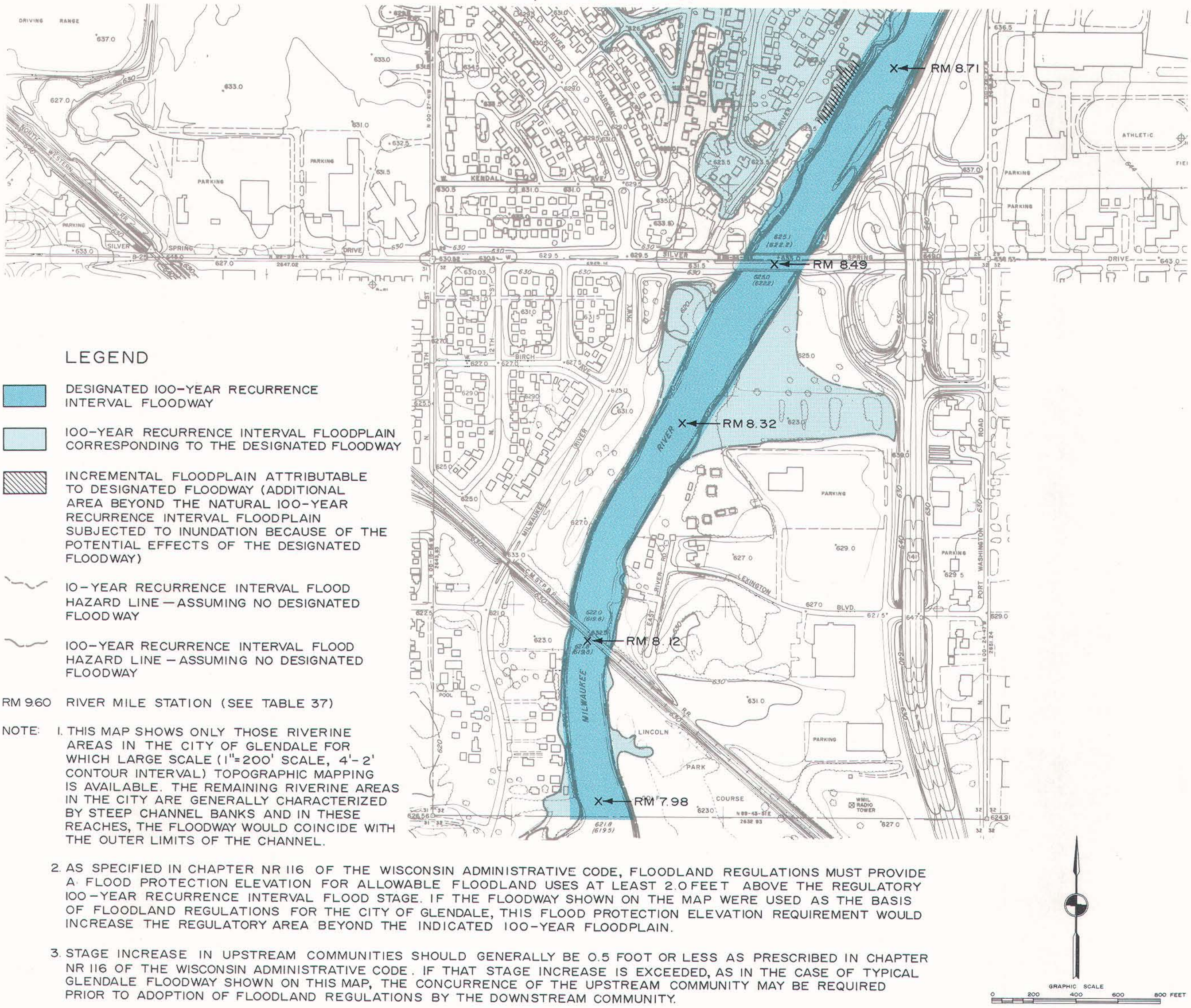


Map 17

10- AND 100-YEAR RECURRENCE INTERVAL FLOODPLAINS IN THE CITY OF GLENDALE



Map 16 (continued)



LEGEND

DESIGNATED 100-YEAR RECURRENCE INTERVAL FLOODWAY

100-YEAR RECURRENCE INTERVAL FLOODPLAIN CORRESPONDING TO THE DESIGNATED FLOODWAY

INCREMENTAL FLOODPLAIN ATTRIBUTABLE TO DESIGNATED FLOODWAY (ADDITIONAL AREA BEYOND THE NATURAL 100-YEAR RECURRENCE INTERVAL FLOODPLAIN SUBJECTED TO INUNDATION BECAUSE OF THE POTENTIAL EFFECTS OF THE DESIGNATED FLOODWAY)

10-YEAR RECURRENCE INTERVAL FLOOD HAZARD LINE—ASSUMING NO DESIGNATED FLOODWAY

100-YEAR RECURRENCE INTERVAL FLOOD HAZARD LINE—ASSUMING NO DESIGNATED FLOODWAY

RM 9.60 RIVER MILE STATION (SEE TABLE 37)

NOTE: 1. THIS MAP SHOWS ONLY THOSE RIVERINE AREAS IN THE CITY OF GLENDALE FOR WHICH LARGE SCALE (1"=200' SCALE, 4'-2' CONTOUR INTERVAL) TOPOGRAPHIC MAPPING IS AVAILABLE. THE REMAINING RIVERINE AREAS IN THE CITY ARE GENERALLY CHARACTERIZED BY STEEP CHANNEL BANKS AND IN THESE REACHES, THE FLOODWAY WOULD COINCIDE WITH THE OUTER LIMITS OF THE CHANNEL.

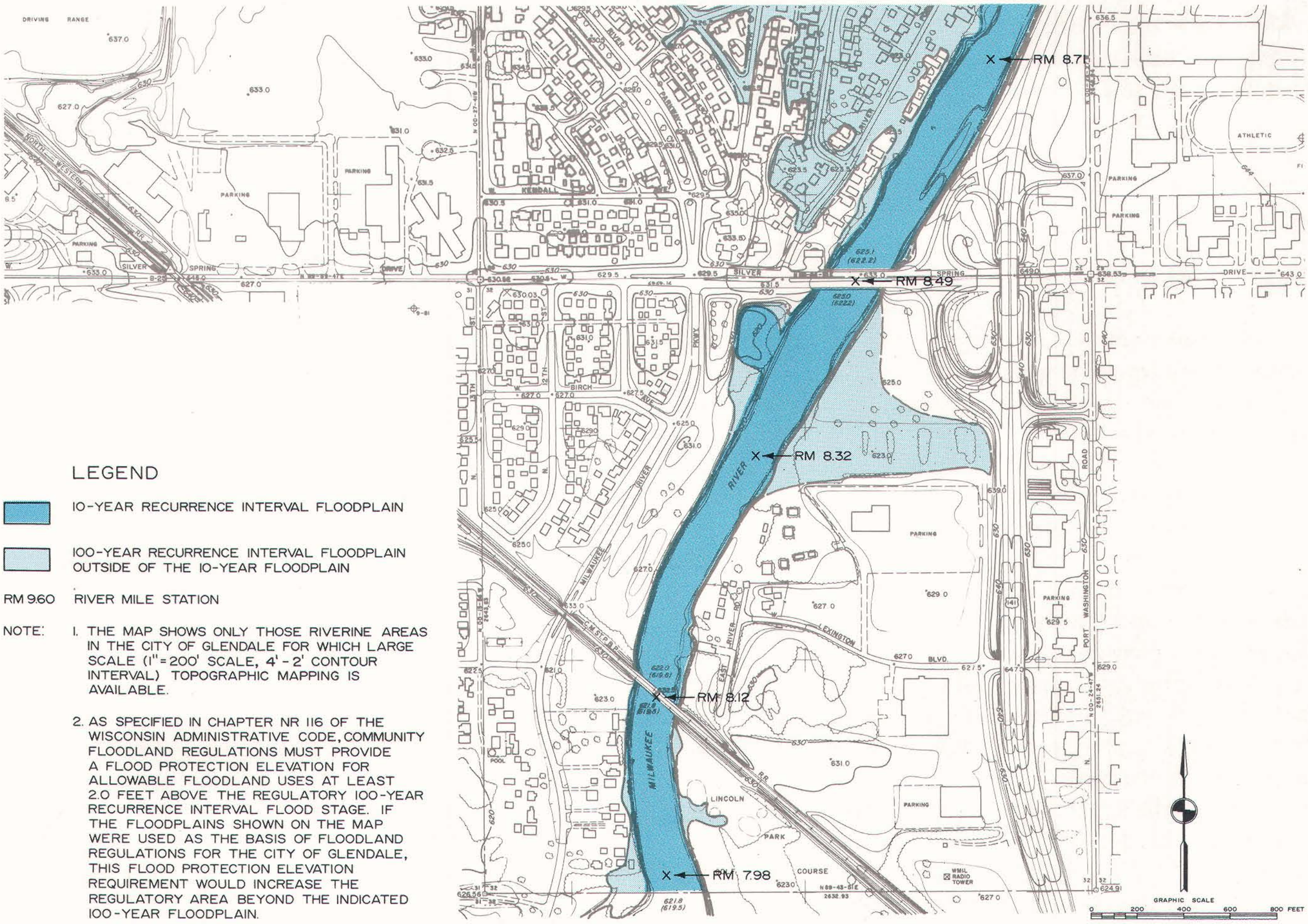
2. AS SPECIFIED IN CHAPTER NR 116 OF THE WISCONSIN ADMINISTRATIVE CODE, FLOODLAND REGULATIONS MUST PROVIDE A FLOOD PROTECTION ELEVATION FOR ALLOWABLE FLOODLAND USES AT LEAST 2.0 FEET ABOVE THE REGULATORY 100-YEAR RECURRENCE INTERVAL FLOOD STAGE. IF THE FLOODWAY SHOWN ON THE MAP WERE USED AS THE BASIS OF FLOODLAND REGULATIONS FOR THE CITY OF GLENDALE, THIS FLOOD PROTECTION ELEVATION REQUIREMENT WOULD INCREASE THE REGULATORY AREA BEYOND THE INDICATED 100-YEAR FLOODPLAIN.

3. STAGE INCREASE IN UPSTREAM COMMUNITIES SHOULD GENERALLY BE 0.5 FOOT OR LESS AS PRESCRIBED IN CHAPTER NR 116 OF THE WISCONSIN ADMINISTRATIVE CODE. IF THAT STAGE INCREASE IS EXCEEDED, AS IN THE CASE OF TYPICAL GLENDALE FLOODWAY SHOWN ON THIS MAP, THE CONCURRENCE OF THE UPSTREAM COMMUNITY MAY BE REQUIRED PRIOR TO ADOPTION OF FLOODLAND REGULATIONS BY THE DOWNSTREAM COMMUNITY.

Certain portions of the Milwaukee River watershed, such as the City of Glendale, contain extensive riverine areas in which urban development has been unwisely permitted to encroach onto the natural floodlands. In such areas the 10-year floodplain, as shown on Map 17 for comparative purposes, may not provide an acceptable approximation of the floodway; and, therefore, it may be desirable for floodland regulatory purposes to delineate a designated floodway and to establish the corresponding floodplain. The delineation of a designated floodway, together with the delineation of the associated floodplains, is a complex problem requiring the application of modern hydrologic and hydraulic engineering techniques; consideration of existing and proposed land uses; and the active participation in, and support of, community officials and leaders. This map shows an example of one of many possible floodways that could be delineated through the City of Glendale, together with the corresponding floodplains. A positive attribute of the floodway shown includes the minimization of the number of major structures located in the floodway whose smooth and continuous outer limits are intended to reflect the expected behavior of the river during a major flood event. It should be noted, however, that the designated floodway generally raises the peak stage of the 100-year recurrence interval regulatory flood and, therefore, increases the size of the area and, more importantly, the total number of structures subject to floodland regulations.

Source: SEWRPC.

Map 17 (continued)



This map depicts the kind of flood inundation information developed under the Milwaukee River watershed study as a basis for the enactment of floodland regulations by local units of government seeking to reconcile existing and planned community land uses with the natural conveyance and storage function of the river's floodlands. If development and fill are to be prohibited in the entire floodplain, the floodway may be approximated as that area subject to inundation by the 10-year recurrence interval flood. That approximation may not be acceptable in communities having large areas of concentrated floodland development, in which case the delineation of a designated floodway similar to that shown on Map 16 for part of the City of Glendale, may be necessary.

Source: SEWRPC.

such as parks, certain outdoor storage areas, and parking lots. The potential City of Glendale designated floodway illustrates this consideration, since, as shown on Map 16, the floodway includes much of Kletzsch Park. Planned open-space land use may also be incorporated in the floodway determination process, as well as committed flood control works, such as dikes and floodwalls, in which case the floodway limits might be coincident with the proposed dike or floodwall alignment, thereby minimizing the hydraulic analyses required for the floodway determination and simplifying, subsequent to dike and floodwall construction, modification of the interim floodland regulations to reflect the dikes and floodwalls.

In summary, the delineation of the designated floodway, together with the delineation of associated floodplains which may be extended because of the increased flood stages due to the floodway designation, is a complex problem requiring the application of modern hydraulic engineering techniques; the recognition of existing and proposed land uses; and the active participation in, and support of, community officials and leaders. It is important to stress that the designation of floodways should, within the context of a comprehensive planning effort, be considered very selectively and only as a last resort after all technical, economical, and environmental factors are evaluated. The decision as to whether or not to delineate a floodway in such intensively urbanized riverine areas must rest with the local community officials. The extensive hydraulic and hydrologic data generated in the Milwaukee River watershed study will be invaluable to local communities in the watershed in the determination of such designated floodways for selected urban reaches. Floodway designation, while technically feasible as a part of the watershed study, is more properly reserved for the plan implementation period, when local officials can provide detailed local inputs to the floodway selection process.

Extreme Flood Events on the Milwaukee River below the North Avenue Dam

The Milwaukee River from its junction with Lake Michigan at the harbor entrance through the central business district of Milwaukee to the North Avenue Dam has in the past served three basic purposes: drainage, navigation, and waste disposal. The latter use—waste disposal—would be, in effect, eliminated if the pollution abatement recommendations contained in other portions of this report are carried out. Due to relatively recent changes in land use along the lower river and due to changes in the economics of transportation, the importance of the lower river as a navigation facility has been greatly diminished in recent years.[33] The fixed span bridges carrying IH 794 across the Milwaukee River, constructed in 1968, provide a vertical clearance of only 29 feet above the average river stage. These bridges, therefore, limit navigation on the river above IH 794 to the movement of fire tugs, pleasure craft, and certain types of marine construction equipment and have essentially closed the river above IH 794 to large commercial cargo-carrying vessels. With the elimination of the combined sewer overflows, as recommended elsewhere herein, and with the discontinuance of commercial navigation, the function of the lower river in the future will be confined largely to its usefulness as a drainage facility serving a large urbanizing watershed and as a recreational and aesthetic resource. Because the most essential natural function of any river is its drainage function and because this natural function is the highest and best use of the Milwaukee River in relation to its watershed, the conveyance capacity of the Lower Milwaukee River should be carefully managed; and any proposal which might diminish that capacity should be considered with extreme caution.

In this respect it should be noted that, from 1846 until 1945, a period of almost 100 years, the channel depths along the Lower Milwaukee River from the Buffalo Street Bridge as far upstream as the Humboldt Avenue Bridge were maintained by the City of Milwaukee in order to facilitate commercial navigation. Records maintained by the City of Milwaukee Board of Harbor Commissioners indicate that the Milwaukee River has not been dredged upstream of the Buffalo Street Bridge, which bridge is the first river crossing above the confluence with the Menomonee River, since at least 1943, at which time it was dredged by the City. The Federal River and Harbor Act of 1945 authorized federal maintenance of river channels associated with Great Lakes ports. Pursuant to this revised federal policy, federal maintenance dredging programs were carried out on certain river channels associated with the

[33] *The Steamer Sierra was the last commercial vessel to navigate the Milwaukee River upstream of the confluence with the Menomonee River when, on November 11, 1959, this Great Lakes cargo ship delivered coal to a dock area near Humboldt Avenue. Source: The Milwaukee River, Milwaukee River Technical Study Committee, 1968, page 28.*

Milwaukee Harbor beginning in 1949; and the maintenance of the Lower Milwaukee River for navigation became a federal responsibility. The termination of commercial navigation above the IH 794 crossing of the Milwaukee River by the construction of the bridges for this crossing in 1968 has also terminated the federal responsibility to maintain channel depths from the IH 794 bridges to the Humboldt Avenue Bridge for commercial navigation purposes. The need to maintain the channel depths for drainage purposes, therefore, becomes an important local responsibility.

Analyses made under the watershed study and reported in Chapter VI of Volume 1 of this report indicate that the quantity of sediment transported annually by the Milwaukee River is relatively small considering the size and climate of the watershed. Moreover, if the soil conservation practices—both rural and urban—recommended in other portions of this report are implemented, this sediment load should be further reduced over time. If, moreover, the pollution abatement recommendations contained in other portions of this report are implemented, the sediment contribution from combined sewer overflows should also be virtually eliminated; and the lower river should require dredging only infrequently to maintain channel depths for drainage purposes. This conclusion is further supported by the fact that there has been no significant sediment accumulation in the Milwaukee River below the North Avenue Dam, as revealed by engineering surveys made for new bridge construction since 1943 and by hydrographic surveys conducted by the City of Milwaukee and by similar surveys conducted under the watershed study. Nevertheless, continuing surveillance of the channel depths is in order. Should such surveillance indicate that substantial shoaling was occurring, necessary dredging operations would have to be carried out.

For the same reason, it would appear unwise to permit dock lines, land reclamation projects, or proposed structures to intrude into the bed of the Lower Milwaukee River so as to restrict existing channel widths without careful quantitative evaluation of the effects of the proposed intrusion of the hydraulic capacity of the river channel. The river channel presently averages approximately 220 feet in width, varying from 160 feet in width at its narrowest points at the Wisconsin Avenue and Wells Street Bridges to 360 feet in width at its widest point near the harbor. Bridge structures and bridge abutments offer the only substantial constrictions to flow along the lower river, while land use development along the river banks would preclude widening of the channel.

As indicated in Chapter VIII of Volume 1 of this report, if that reach of the Milwaukee River downstream of the North Avenue Dam, which reach passes through the central business district of the City of Milwaukee, were to experience a rare flood event consisting of the 100-year recurrence interval discharge of 16,700 cfs occurring in combination with a Menomonee River flow of 10,000 cfs and a high Lake Michigan level at Elevation 583 feet Mean Sea Level (2.4 feet City of Milwaukee Datum), the resulting peak stages would cause only minor local overbank flooding.

The recommended flood protection elevation of the Milwaukee-Metropolitan Sewerage Commissions of 584.6 feet Mean Sea Level (4.0 feet City of Milwaukee Datum) is sufficient to provide protection without, however, any freeboard provision against the aforementioned flood event for riverine properties along the Milwaukee River from the harbor to the Cherry Street Bridge (see Figure 31, Volume 1, of this report). It is recommended that this flood protection elevation be raised to 586.6 feet Mean Sea Level (6.0 feet City of Milwaukee Datum) so as to include a minimum freeboard of 2.0 feet. It is further recommended that even higher flood protection elevations be used upstream of the Cherry Street Bridge, such elevations being determined by adding 2.0 feet of freeboard to the 100-year flood stages set forth in Appendices F and G of this volume.

There always exists the possibility, however rare, of the occurrence of a flood event larger than the aforementioned 100-year recurrence interval event. The channel of a river has a certain discharge capacity above which overbank flow will occur. It is particularly important to explore flood conditions that would precipitate such overflow along the Milwaukee River downstream of the North Avenue Dam, since this reach passes through the central business district of the City of Milwaukee; and, therefore, overbank flow could result in high monetary damages.

The U. S. Army Corps of Engineers, in their first flood control study report on the Milwaukee River watershed issued in 1942,[34] estimated a maximum

[34] *U. S. Army Engineer District, Milwaukee, Corps of Engineers, Preliminary Examination Report on Milwaukee River and Tributaries, Wisconsin, for Flood Control, September 1942.*

probable flood discharge[35] of 42,000 cfs for the Milwaukee River at the Estabrook Park gage, or about two and one-half times the 100-year recurrence interval discharge of 16,700 cfs for the Milwaukee River below the North Avenue Dam.

In a second, more detailed, flood control study report on the Milwaukee River watershed issued in 1964,[36] the U. S. Army Corps of Engineers presented a revised estimated maximum probable flood discharge of 56,000 cfs for the Milwaukee River at the Estabrook Park gage, or almost three and one-half times the 100-year recurrence interval discharge of 16,700 cfs for the Milwaukee River below the North Avenue Dam. Although larger than the value set forth in the 1942 Corps report, this maximum probable flood estimate is conservative considering the tributary drainage area when compared to estimates of maximum probable flood discharges prepared for other portions of the watershed under the Milwaukee River watershed study, which estimates included, as presented in this chapter, 50,000 cfs for the 407-square mile drainage area tributary to the Waubeka reservoir site; 38,000 cfs for the 255-square mile drainage area tributary to the Newburg reservoir site; and 21,000 cfs for the 98-square mile drainage area tributary to the Horns Corners reservoir site. Recognizing the problems inherent in quantifying the maximum probable flood, however, the Corps' estimate of a maximum probable flood discharge of 56,000 cfs for the watershed as a whole is reasonable and, therefore, acceptable.

[35] *The maximum probable flood is defined as the largest flood that can be expected, assuming maximum simultaneous occurrence of all theoretically possible flood-producing factors in the watershed area. No recurrence interval is assigned to this flood, which would be an extremely rare event; catastrophic in nature; and, for economic reasons, would have little bearing on floodland use regulation, or even on engineering design except for determining the spillway capacities of major dams.*

[36] *See U. S. Army Engineer District, Chicago, Corps of Engineers, Survey Report for Flood Control on the Milwaukee River and Tributaries, Wisconsin, November 1964. The Corps reports define the Milwaukee River drainage basin as consisting of the Milwaukee River watershed, as defined in the present report, plus the smaller Menomonee and Kinnickinnic River watersheds. The 56,000 cfs maximum probable flood estimate, however, applies to the Milwaukee River at the Estabrook Park gage and does not include flood flows from the Menomonee and Kinnickinnic River watersheds. The Corps reports do not include estimates of maximum probable flood flows from the latter two watersheds.*

The backwater submodel portion of the flood-flow simulation model was used to compute the effect of this maximum probable flood discharge on the Milwaukee River downstream of the North Avenue Dam under existing channel and bridge conditions. A simultaneous Menomonee River discharge of 10,000 cfs and a high Lake Michigan stage at Elevation 583 were assumed for purposes of the computations.[37] Under these extreme conditions, flood stages would remain at approximately Elevation 583.0 from the harbor to the Water Street Bridge, which bridge is located immediately downstream of the confluence with the Menomonee River. Only minor local overbank flooding would occur in this reach, and structures floodproofed to the recommended flood protection elevation of the Milwaukee-Metropolitan Sewerage Commissions of 584.6 feet Mean Sea Level (4.0 feet City of Milwaukee Datum) would not incur damage.

Immediately upstream of the Water Street Bridge, the flood stage profile would rise rapidly with distance along the channel so as to be positioned at elevations ranging from 587 to 588 feet Mean Sea Level through the one-half mile-long reach from the Water Street Bridge upstream to the Michigan Street Bridge. Between Water Street and Michigan Street, the flood stage profile would be parallel to, and about five feet above, that which would occur for the 100-year recurrence interval flood. Flood stages would exceed overbank elevations in about one-half of this reach, and flood damage could be expected to be incurred by structures located in close proximity to the river.

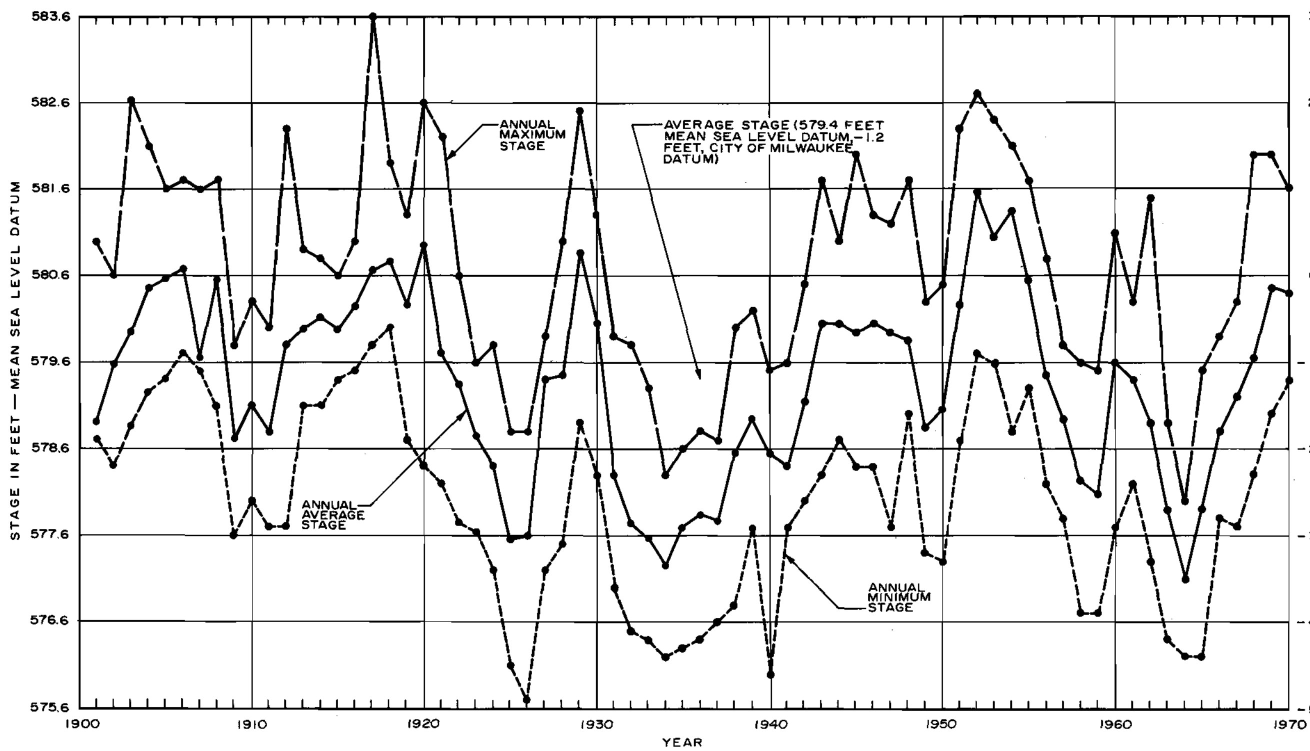
Another sharp rise in the flood stage profile would occur immediately upstream of the Michigan Street Bridge, with the result that the flood stage

[37] *The mean elevation of Lake Michigan at the Milwaukee Harbor, as determined from stage records maintained by the City of Milwaukee for the 70-year period from 1901 through 1970, is 579.3 feet Mean Sea Level Datum (MSL), U.S.C. and G.S. 1929 Adjustment, which is equivalent to -1.2 feet City of Milwaukee Datum (CMD). Fluctuations in the level of the lake, which strongly influence Milwaukee River stages downstream of the North Avenue Dam, have ranged from a low of 575.7 feet MSL (-4.9 feet CMD) in 1926 to a high of 583.6 feet MSL (+3.0 feet CMD) in 1917. The second highest lake level recorded was 582.7 feet MSL (+2.1 feet CMD) recorded in 1952. This fluctuation in lake levels at Milwaukee, which approximates 8.0 feet, is indicated in Figure 13, which figure shows the historic lake levels over the 70-year period of record as kept by the City of Milwaukee.*

Figure 13

RECORDED LAKE MICHIGAN STAGES IN THE MILWAUKEE HARBOR

1901 — 1970



NOTE: THE ANNUAL AVERAGE LAKE MICHIGAN STAGE FOR 1909 WAS OBTAINED BY INTERPOLATION

Source: City of Milwaukee Bureau of Engineering and SEWRPC.

profile would be located above Elevation 610 and over 25 feet above the profile corresponding to the 100-year recurrence interval flood throughout this reach from the Juneau Street Bridge to the North Avenue Dam. Overbank elevations would be exceeded at all points in the almost two-mile-long reach from Michigan Street to the North Avenue Dam, causing flooding of major proportions over a relatively large area of the central business district.

It should be noted that the aforementioned stage increases for the reach between Michigan Street to the North Avenue Dam are only approximate because of flood-flow modeling limitations in the highly developed commercial and industrial floodplain area of Milwaukee. In spite of these computational limitations, it may be expected that the City of Milwaukee would experience major flooding for a Milwaukee River maximum probable flood discharge of 56,000 cfs occurring simultaneously with a flow of 10,000 cfs on the Menomonee River and a high Lake Michigan level.

The above analysis suggests that, while the existing Milwaukee River channel downstream of the North Avenue Dam can readily accommodate, with only very minor local flooding, the 16,700 cfs 100-year recurrence interval flood under 1990 watershed land use conditions, considerable flood inundation and damage would result if a flood event of greater severity were to occur, such as the 56,000 cfs maximum probable flood. It is, however, not generally considered economically feasible to structurally control the flow of a river so as to provide protection against flood events greater than the 100-year recurrence interval event. There is, moreover, general agreement in current floodland regulation practice nationally that the use of the 100-year flood for regulatory purposes constitutes a desirable balance between excessive flood damage and overrestrictive regulation of land use.

It is recommended that the Milwaukee River below the North Avenue Dam be carefully managed so as to maintain its capability of accommodating floods up to and including the 100-year recurrence interval event. This is particularly important in this reach because the existing channel is just able to pass the 100-year flood discharge; and, therefore, even a moderately higher flood stage profile may be expected to cause flood damage to the central business district of the City of Milwaukee. This management should include a careful assessment of the hydraulic effect of all proposed major alterations to the river bank and bulkhead lines, as well as analyses of the hydraulic effect of proposed bridge replacement or major alterations.

Also important to the management of the Milwaukee River below the North Avenue Dam so as to maintain its capability to accommodate flood flows is maintenance of the existing river bottom elevations and channel cross sections. The river bottom elevation from the Lake Michigan shoreline to the North Avenue Dam should be maintained at the elevations shown in the river profiles reproduced in Appendix F or at elevations ranging from approximately 555 Mean Sea Level Datum (-26 City of Milwaukee Datum) at the harbor entrance to 558 Mean Sea Level Datum (-23 City of Milwaukee Datum) at the Humboldt Avenue Bridge.

Maintenance of Stream Gaging Stations

There are five established stream gaging stations within the watershed which should be maintained or upgraded to provide a long-term continuing record of streamflow at appropriate locations throughout the stream system of the watershed. This would require the continued maintenance of the continuous recording stream gaging stations located at Milwaukee (Estabrook Park), Waubeka, New Fane, and Fillmore and the upgrading of the existing staff gage at Kewaskum to a continuous recording gage. In addition, it is recommended that the recently discontinued Cedarburg gage on Cedar Creek be reestablished as a continuous recording gage.

Continuous recording stream gaging stations monitoring river flows at points strategically located within the watershed provide critical data required for the future rational management of the water resources of the watershed. The records from such gaging stations, particularly those stations located in headwater subwatersheds, may eventually be used as indicators of impending serious flood events in the downstream urbanized, and, therefore, flood-vulnerable, portions of the watershed. Discharge-frequency relationships derived from data provided by continuous recording stream gaging stations can be used to periodically refine the flood-flow simulation models developed under the watershed study. Such stream gaging records can also be used to periodically refine the water quality simulation models developed under the watershed study. Continuous streamflow records, primarily for the headwater areas of the watershed, would be very useful in the event that a decision is made beyond the plan design year to develop a multiple-purpose reservoir within the watershed, since the detailed engineering analysis preceding such development, as well as the subsequent operation of such a reservoir, would require streamflow data extensive both in its historic duration and in its spatial distribution within the watershed.

Flood Insurance

In 1968 the U. S. Congress enacted the National Flood Insurance Act and assigned its administration to the U. S. Department of Housing and Urban Development. The purpose of the act is to establish a flood insurance program that provides owners of flood-prone residences and small business concerns, located within eligible communities, the opportunity to obtain insurance against flood damage to the structures and their contents. A community's admittance to, and continuing eligibility for participation in, the national flood insurance program is contingent on the implementation of sound land use regulations that recognize the natural, necessary conveyance and storage function of river floodlands and that seek to discourage the erection of structures in floodplain lands.

The distribution of the insurance policies to property owners in a given community is accomplished by a duly licensed fire and casualty insurance agent or broker associated with one of the private insurance companies comprising the National Flood Insurers Association, an association formed specifically to facilitate underwriting of the flood insurance. This cooperative federal government-private industry program is presently (1971) operating under an initial two-year emergency phase that will terminate December 31, 1971. During this period flood insurance for existing structures may be obtained at established federally subsidized rates without prior determination of actuarial premium rates for the various flood-prone structures in a given community.

After completion of the emergency program, flood insurance will be available for existing and new flood-prone structures at actuarial premium rates based upon an hydraulic and hydrologic evaluation of the flood risks and attendant damages within each community. Subsidized premium rates for new or substantially improved structures are prohibited by the National Flood Insurance Act; however, affected property owners may still purchase such insurance, provided that they pay the entire actuarial premium rate.

While the ultimate decision to purchase flood insurance remains with individual property owners, initiative to establish the program within a particular community must be taken by the municipality having jurisdiction over zoning and building codes. That municipality must file a formal request with the U. S. Department of Housing and Urban Development for consideration for participation in the flood insurance program, including in its application an account of the community's historic flood problems and a map of the community on which is delineated those flood-prone areas for which insurance is desired. Furthermore, such applications must include copies of adopted floodland regulations and other adopted measures intended to prevent or reduce future flood damages. The community or unit of government must also submit assurances of future compliance, including resolutions indicating that flood problems will be continuously monitored and that such problems will be considered in all official actions affecting floodland use.

The Milwaukee River watershed study provides most of the aforementioned flood data and mapping required for participation in the national flood insurance program, with large-scale flood hazard mapping being available for communities having the most severe flood problems, including the Cities of Glendale and Mequon and the Villages of Saukville and Thiensville. It would be in the best interest of watershed communities to begin participating in the flood insurance program prior to the December 31, 1971, termination of the emergency program, since, by so doing, eligible property owners could purchase flood insurance almost immediately since actuarial premium rates would not have to be established prior to sale of the insurance.

Major Channel Modifications

The dike-floodwall system flood control alternative described in this chapter would include minor channel alterations, including straightening, shaping, lining, and clearing of vegetation, rocks, and miscellaneous debris. In addition to the use of minor channel modifications in combination with dikes and floodwalls, there is the technical possibility of achieving flood control through major channel modifications used singly, that is, not in conjunction with other structural flood control measures.

Major channel modifications would include widening, straightening, and possibly lowering the existing river channel and then lining all or part of the enlarged cross section with concrete so as to both increase the hydraulic capacity and to stabilize the altered channel. This type of major modification produces an artificial channel that can pass flood discharges at a lower stage than the natural channel because the altered channel has a larger cross-sectional area; a reduced flow resistance; and, in some cases, both a steeper channel gradient and a lower channel bottom elevation.

The Milwaukee-Metropolitan Sewerage Commission, in cooperation with the Milwaukee County Park Commission, has utilized major channel modifications to achieve flood control in those riverine areas of Milwaukee County where urbanization, with its attendant increased floodwater volumes and peak discharges, and floodplain encroachment, with its attendant removal of floodwater conveyance and storage potential, have proceeded to the point where major channel modifications are, in effect, the only remaining technically feasible structural means of achieving flood relief. In recent years some major channel modification proposals in Milwaukee County have met with citizen opposition on the grounds that they destroy, to various degrees, the beauty and aesthetic quality of the natural riverine environment. A commonly cited example used by such opposition to illustrate the potential negative aesthetic aspects of major channel alterations is the reach of the Kinnickinnic River extending from S. 6th Street to S. 16th Street in the City of Milwaukee. In this reach the natural channel has been replaced by a trapezoidal, concrete-lined channel with steep side slopes and is, in effect, no more than a large, open storm drain. In contrast, there are riverine areas in Milwaukee County where complete major channel modifications have been accomplished while retaining some of the aesthetic attributes of the natural channel and its floodplain. This has generally been achieved by paving only the lower portions of the modified cross section and then landscaping the remainder of the channel with grass, shrubbery, and trees. The Kinnickinnic River, just upstream of the aforementioned reach, serves as an example of such a channel modification.

Major channel modifications were not examined in detail as a flood control alternative for application in the Milwaukee River watershed primarily because such modifications would have to be very extensive and, therefore, would completely destroy the aesthetic attributes of the riverine areas. The aesthetic costs would probably exceed those of the dikes and floodwalls. For example, to accommodate the 16,100 cfs 100-year recurrence interval flood discharge in the City of Glendale so as to prevent overbank flow and attendant flood damage, it would be necessary to construct, at the existing channel grade, a rectangular concrete-lined channel about 260 feet wide and 9 feet deep, extending for a distance of about 2.5 miles from the Chicago and Northwestern Railroad Bridge in Lincoln Park upstream through the Sunny Point area. Although it is difficult to assign a monetary value to the aesthetic costs attendant to such an unsightly channel, those costs are, nevertheless, real. Such a proposal could be expected to be objectionable to residents and property owners in the City of Glendale or in any other riverine area where such major channel alterations would be proposed, particularly because many of these residents have undoubtedly purchased or constructed homes in the natural floodlands of the river because of the aesthetic amenities attendant to such a location.

A secondary reason for excluding a detailed analysis of major channel modifications from the watershed study was their high cost relative to the other major flood control measures. A concrete-lined channel, similar to that described above for the City of Glendale, would cost in excess of $1,000 per lineal foot of protected floodland, with that cost including and being primarily determined by land acquisition, excavation to widen the existing channel, and placement of concrete lining. In contrast, the dike-floodwall systems, as analyzed herein for the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville, have an estimated total cost of about $150 per lineal foot of protected floodland. The dike-floodwall systems were, as described in this chapter, found to be extremely uneconomical. Since major channel modifications would cost more than six times as much as the dike-floodwall systems, it follows that major channel modifications would be even more uneconomical than the dikes and floodwalls.

Engineering Investigations of Selected Dams

A reconnaisance-type field inspection of 48 man-made water control structures in the Milwaukee River watershed made under the watershed study and described in Chapter V of Volume 1 of this report identified four larger structures—the North Avenue Dam, the Woolen Mills Dam, the Schrauth's Mill Dam, and the Wire and Nail Factory Dam—requiring special attention either due to a poor state of repair or due to importance and location in the watershed. It is recommended that detailed engineering investigations, including soundings of the upstream pool and bore holes in the superstructure, foundation, and embankments, as described in detail in Chapter V of Volume 1, be conducted at the North Avenue Dam, owned by the City of Milwaukee, and the Woolen Mills Dam, owned by the City of West Bend. Such detailed engineering investigations of the North Avenue and the Woolen Mills Dams, which have estimated costs of $12,400 and $6,700, respectively, would define problems and needs at each dam site and provide the data necessary for possible corrective alterations and improvements. Repairs to the Schrauth's Mill Dam have been contracted for by the Town of Ashford and were expected to be completed in 1970. Finally, it is recommended that the Wire and Nail Factory Dam, owned by the Cedarburg Wire and Nail Company, be repaired so as to eliminate potentially serious piping[38] observed during the field inspection. The large tree growing near the right abutment should be removed, twice yearly downstream soundings should be made to determine if scour and undermining are endangering the stability of the Dam, and the concrete facing of the Dam should be regularly inspected for indications of failure of the internal wooden crib.

CONCLUDING REMARKS—ALTERNATIVE FLOOD CONTROL PLAN ELEMENTS

Six major structural and one major nonstructural flood control plan elements were considered in the Milwaukee River watershed study as possible adjuncts to the basic land use development proposals advanced to facilitate the attainment of regional and watershed development objectives. Each of these seven flood control plan elements

[38] *The term "piping," as used herein, refers to the gradual removal of granular material from beneath a dam superstructure by the movement of seepage water, resulting in the eventual failure of the structure.*

is subordinate to the basin-wide land use plan element, and their incremental benefits and costs can be separated from those of the basin-wide land use plan element. The physical characteristics and the single- or multiple-purpose function of each of the seven flood control plan elements, as well as the salient features of the economic analysis of each alternative, are set forth in Table 38.

Three basic types of structural flood control measures—reservoirs, dike-floodwall systems, and diversion of floodwaters to Lake Michigan—were considered and used to develop the six alternative predominantly structural flood control plan elements. The one nonstructural flood control plan element considered was that of structure floodproofing and removal. It is important to note that the enactment of floodland development regulations would necessarily accompany any of the foregoing structural and nonstructural flood control plan elements.

The seven major flood control alternatives may be categorized as being either single-purpose or multiple-purpose. Four of the six structural flood control alternatives are in the multiple-purpose category. Three of the four structural multiple-purpose flood control plan elements are single reservoirs, and one flood control plan element is a combination of two of the single reservoirs. These four alternatives were analyzed as multiple-purpose developments inasmuch as each could be expected to provide flood control, low-flow augmentation, water supply, recreation, and land enhancement benefits. The nonstructural flood control alternative may be considered, at least marginally, multiple-purpose in that it would provide some land enhancement and recreation, as well as flood control, benefits. In general, the multiple-purpose characteristic of the four structural alternatives, particularly their recreation potential, as is evident in Table 38, was such that the monetary benefits accruing from them exceeded the attendant costs. These four alterna-

Table 38

PRINCIPAL FEATURES AND COSTS AND BENEFITS OF ALTERNATIVE STRUCTURAL AND NON-STRUCTURAL FLOOD CONTROL PLAN ELEMENTS FOR THE MILWAUKEE RIVER WATERSHED[a]

	Function				Costs and Benefits						
							Percent of Annual Benefit Attributable to				
Alternative Flood Control Plan Element	Flood Control	Low Flow Augmentation and Water Supply[b]	Recreation	Land Enhancement	Annual Cost[c] ($)	Annual Benefit[d] ($)	Flood Control	Recreation	Land Enhancement	Annual Benefits Minus Annual Costs ($)	Benefit/Cost Ratio
Structural											
Waubeka Reservoir	X	X	X	X	2,514,000	3,442,000	4.3	92.7	3.0	928,000	1.37
Horns Corners Reservoir	X	X	X	X	2,539,600	3,053,000	1.8	96.6	1.6	513,400	1.20
Newburg Reservoir	X	X	X	X	2,074,000	2,432,300	2.4	96.2	1.4	358,300	1.17
Horns Corners-Newburg Reservoirs Combination[e]	X	X	X	X	4,885,300 3,663,800	5,521,300 2,835,400	2.7 5.3	95.8 93.3	1.5 1.4	636,000 -828,400	1.13 0.77
Diversion Channel to Lake Michigan	X	--	--	--	460,800	144,500	100.0	0.0	0.0	-316,300	0.31
Dike-Floodwall Systems with Supplemental Structure Removal and Floodproofing	X	--	--	--	403,600	124,300	100.0	0.0	0.0	-279,300	0.31
Non-Structural											
Structure Floodproofing and Removal	X	--	--[f]	X	297,000	129,950	96.5	0.0	3.5	-167,055	0.44

[a] Economic analyses are based on an annual interest rate of six percent and assume a 50 year amortization period and project life.

[b] Flow augmentation provided by the four reservoir alternatives could yield fishery, recreation, water supply, and aesthetic benefits downstream of the proposed impoundment site. The unpredictable nature of the demand for these benefits and their intangible monetary value, however, precludes assignment of a dollar value to the flow augmentation capability of the reservoirs, and thus flow augmentation benefits are not included in the estimated monetary benefits attendant to each reservoir.

[c] Annual cost includes amortization of capital cost plus estimated operation and maintenance expenditures.

[d] Annual benefits include flood control, recreation, and land value enhancement.

[e] The cost of recreation facilities and the benefits that would accrue to the Horns Corners-Newburg Reservoirs combination, as well as the land enhancement benefits, were identifiable only within certain limits. The upper limit of recreation and land enhancement benefits would be equal to the sum of the benefits that would accrue from each of the individual reservoir projects, while the lower limit was established by arbitrarily assuming that the attendant recreation and land enhancement benefits would be equal to one-half of the sum of the recreation and land enhancement benefits previously determined for the Horns Corners and Newburg Reservoirs as separate projects. The upper and lower limits of recreation facility costs were determined in a similar manner. There are, therefore, two entries in each column for the Horns Corners-Newburg Reservoirs combination, with the upper entry corresponding to the aforementioned upper limit and the lower entry corresponding to the lower limit.

[f] The structure removal and floodproofing alternative would vacate two relatively large areas of riverine land having potential for park development—a 125 acre area in the City of Glendale and a 100 acre area immediately south of CTH M in the City of Mequon. However, the required development costs as well as the recreation and aesthetic benefits that would accrue were not included in the economic analyses.

Source: Harza Engineering Company and SEWRPC.

tives, therefore, would be economically feasible, whereas the remaining two essentially single-purpose structural flood control plan elements, as well as the marginal multiple-purpose non-structural flood control plan element, were found to be uneconomical.

While the primary purpose of examining the seven major river control plan elements was the elimination or reduction of flood damage, the analyses described herein reveal that flood control benefits alone are not sufficient to economically justify any of the seven major flood control plan elements. Flood control can be economically achieved only if the flood control function is one of several functions of a multiple-purpose river control project, with recreation being the principal function in terms of monetary benefits. The technical, economic, and aesthetic characteristics of each of the seven major flood control alternatives, as described in detail in this chapter, are briefly summarized below. This summary of the salient features of the seven potential flood control plan elements is followed by recommendations pertaining to those plan elements.

Waubeka Reservoir

The 10,400-acre multiple-purpose Waubeka Reservoir impounded by a dam on the Milwaukee River immediately upstream of the unincorporated community of Waubeka was found to be the most desirable of the seven major flood control plan elements when those seven alternatives were evaluated solely on the basis of their technical, economic, and aesthetic features. Storage provided by the reservoir would eliminate all damage resulting from floods up to and including the 100-year recurrence interval event in the flood-prone areas along the Milwaukee River downstream from the reservoir. Land development around the reservoir could be controlled so as to assure the development of a high quality recreational resource, and modest drawdowns of the impoundment would provide low-flow augmentation water for enhancement of water quality in the lower reaches of the Milwaukee River. An excellent self-sustaining fishery could be developed at the reservoir. Water supply and land enhancement benefits would also accrue from the Waubeka Reservoir. The most attractive feature of the Waubeka Reservoir, and the principal reason for its very favorable benefit-cost ratio, is its potential for providing water-oriented recreation facilities to meet the existing and future needs of southeastern Wisconsin and northeastern Illinois. A wide spectrum of recreation activities could be provided for at the Waubeka reservoir development, including swimming, picnicking, boating, camping, fishing, hiking, and sightseeing.

Disadvantages of the Waubeka Reservoir include the required acquisition of about 14,500 acres of primarily privately owned land in predominantly rural use and the subsequent removal of 170 private residences. Approximately 9,700 acres, or 67 percent, of the site are presently in agricultural use. The reservoir would inundate approximately 2,650 acres of wetland and woodland wildlife habitat. A part of this loss would be eventually compensated for by new woodland and wetland wildlife habitat formed along certain portions of the reservoir shoreline reserved for that purpose. Wildlife diversity offered by the existing woodlands, swamps, and riverine shoreline areas would be destroyed, but no known unique or rare species of plant or animal life would be affected.

The present worth of the capital cost of the complete Waubeka Reservoir multiple-purpose development is estimated at $30,504,000; and the annual cost, which includes amortization of the capital cost, as well as operation and maintenance expenditures, is estimated at $2,514,000. Annual benefits, almost 93 percent of which would accrue from recreation, are estimated at $3,442,000, yielding an annual net benefit of $928,000 and a benefit-cost ratio of 1.37 (see Table 38).

Horns Corners Reservoir

The 5,000-acre multiple-purpose Horns Corners Reservoir impounded by a dam on Cedar Creek about eight miles upstream of the City of Cedarburg was found to be a marginal major flood control alternative that would, however, be economically sound because of benefits accruing from its multiple-purpose capability. Storage provided by the reservoir would completely control the 100-year recurrence interval flood runoff from that portion of the Cedar Creek subwatershed tributary to the reservoir, but the impoundment would provide very little abatement of flood damage to the flood-prone areas of the Lower Milwaukee River under conditions of a 100-year recurrence interval flood.

Land development around the reservoir could be controlled so as to assure the development of a moderate recreational resource, and modest drawdowns of the impoundment would provide low-flow augmentation water for enhancement of water quality in Cedar Creek and the lower reaches of the Milwaukee River. Water supply and land enhancement benefits would also accrue from the Horns Corners Reservoir. The most attractive feature of the Horns Corners Reservoir, and the principal reason for its favorable benefit-cost ratio, in spite of its relative ineffectiveness for abating flood damages, is its potential for providing water-oriented recreation facilities to meet the existing and future needs of southeastern Wisconsin and northeastern Illinois. A wide spectrum of recreation activities could be provided for at the Horns Corners reservoir development, including swimming, picnicking, boating, camping, fishing, hiking, and sightseeing.

Disadvantages of the Horns Corners Reservoir include the required acquisition of about 10,500 acres of primarily privately owned land in predominantly rural use and the subsequent removal of 90 private residences. Approximately 7,100 acres, or 68 percent, of the site are presently in agricultural use. The reservoir would inundate approximately 2,025 acres of wetland and woodland wildlife habitat. A part of this loss would be eventually compensated for by new woodland and wetland wildlife habitat formed along certain portions of the reservoir shoreline reserved for that purpose. A major disadvantage of the site is the inclusion of the Jackson Marsh in the area to be inundated. The Marsh is a large, state-owned wetland; and an equivalent area could not be established anywhere else in the watershed. Extensive areas of rooted vegetation, not necessarily detrimental to water quality, may be expected to develop in the Horns Corners Reservoir because much of the impoundment would be relatively shallow. Winterkill, a phenomenon common to lakes as shallow as the Horns Corners Reservoir, would probably preclude development of a self-sustaining fishery.

The present worth of the capital cost of the complete Horns Corners Reservoir multiple-purpose development is estimated at $28,526,000; and the annual cost, which includes amortization of the capital cost, as well as operation and maintenance expenditures, is estimated at $2,539,600. Annual benefits, 96.6 percent of which accrue from recreation, are estimated at $3,053,000, yielding an annual net benefit of $513,400 and a benefit-cost ratio of 1.20 (see Table 38).

Newburg Reservoir

The 2,300-acre multiple-purpose Newburg Reservoir impounded by a dam on the Milwaukee River about one mile upstream of the unincorporated community of Newburg was found to be a marginal major flood control alternative that would, however, be economically sound because of benefits accruing to its multiple-purpose capability. Storage provided by the reservoir would eliminate less than 40 percent of the flood damages along the lower reaches of the Milwaukee River under conditions of a 100-year recurrence interval flood.

Land development around the reservoir could be controlled so as to assure the development of a moderate quality recreational resource; and, furthermore, modest drawdowns of the impoundment would provide low-flow augmentation water for enhancement of water quality in the lower reaches of the Milwaukee River. Water supply and land enhancement benefits would also accrue from the Newburg Reservoir. The most attractive feature of the Newburg Reservoir, and the principal reason for its favorable benefit-cost ratio, in spite of its relative ineffectiveness for abating flood damages, is its potential for providing water-oriented recreation facilities to meet the existing and future needs of southeastern Wisconsin and northeastern Illinois. A wide spectrum of recreation activities could be provided for at the Newburg reservoir development, including swimming, picnicking, boating, camping, fishing, hiking, and sightseeing.

Disadvantages of the Newburg Reservoir include the required acquisition of about 6,500 acres of primarily privately owned land in predominantly rural use and the subsequent removal of 100 private residences. Approximately 4,200 acres, or 65 percent, of the site are presently in agricultural use. The reservoir would inundate approximately 640 acres of wetland and woodland wildlife habitat. A part of this loss would be eventually compensated for by new woodland and wetland wildlife habitat formed along certain portions of the reservoir shoreline reserved for that purpose. Wildlife diversity offered by the existing woodlands, swamps, and riverine shoreline areas would be destroyed; but no known unique or rare species of plant or animal life would be affected. Extensive areas of rooted vegetation, not necessarily detrimental to water quality, may be expected to develop in the Newburg Reservoir because much of the impoundment would be relatively shallow. Winterkill, a phenomenon common to lakes as shallow as the Newburg Reservoir, would probably preclude development of a self-sustaining fishery. Finally, the Newburg Reservoir would complicate and otherwise increase the cost of runway extensions at the West Bend Airport.

The present worth of the capital cost of the complete Newburg Reservoir multiple-purpose development is estimated at $23,554,000; and the annual cost, which includes amortization of the capital cost, as well as operation and maintenance expenditures, is estimated at $2,074,000. Annual benefits, 96.2 percent of which accrue from recreation, are estimated at $2,432,300, yielding an annual net benefit of $358,300 and a benefit-cost ratio of 1.17 (see Table 38).

Horns Corners-Newburg Reservoirs Combination

A multiple-purpose reservoir complex formed by hydraulically connecting, via open channels and the Saukville Depression, the Newburg Reservoir on the Milwaukee River to the Horns Corners Reservoir on Cedar Creek was found to be a very effective, potentially economically sound, major flood control alternative, since the resulting storage would eliminate all flood damage in the flood-prone areas along the Milwaukee River downstream from the reservoirs.

As was the case with each of the two component reservoirs, the reservoir combination land use development around the reservoir could be controlled so as to assure the development of a moderate quality recreational resource; and, furthermore, modest drawdowns of the impoundments would provide low-flow augmentation water for enhancement of water quality in Cedar Creek and the lower reaches of the Milwaukee River. Water supply and land enhancement benefits would also accrue from the Horns Corners-Newburg reservoirs complex. The most attractive feature of the Horns Corners-Newburg reservoirs complex is its potential for providing extensive water-oriented recreation facilities to meet the existing and future needs of southeastern Wisconsin and northeastern Illinois. A wide spectrum of recreation activities could be provided for at the combined reservoir development, including swimming, picnicking, boating, camping, fishing, hiking, and sightseeing.

Disadvantages of the Horns Corners-Newburg reservoirs combination include the required acquisition of a total of about 17,700 acres of primarily privately owned land in predominantly rural use and the subsequent removal of over 190 private residences. Approximately 11,300 acres, or 66 percent, of the site are presently in agricultural use. The combined reservoirs would inundate approximately 2,700 acres of wetland and woodland wildlife habitat. Part of this loss would be eventually compensated for by new woodland and wetland wildlife habitat formed along certain portions of the reservoir shoreline reserved for that purpose. The Jackson Marsh, a large, state-owned wetland, would be inundated by the Horns Corners reservoir portion of the combined reservoir system. An area equivalent to the Marsh could not be established anywhere in the watershed. The likelihood of fish winterkill, a phenomenon common to shallow lakes and reservoirs, would preclude the development of a self-sustaining fishery within the reservoir complex. Finally, the Newburg reservoir portion of the reservoir combination would complicate and otherwise increase the cost of runway extensions at the West Bend Airport.

Dam and reservoir costs, exclusive of recreation facilities, were readily determined, as were flood control benefits. The economic analysis of the Horns Corners-Newburg reservoirs combination was complicated, however, by the fact that the cost of recreation facilities and the benefits that would accrue, as well as the land enhancement benefits, were identifiable only within certain limits. The upper limit of recreation and land enhancement benefits would be equal to the sum of the benefits that would accrue from each of the two individual reservoir projects, while the lower limit was established by arbitrarily assuming that the attendant recreation and land enhancement benefits would be equal to one-half of the sum of the recreation and land enhancement benefits determined for the Horns Corners and Newburg Reservoirs as separate projects. The upper and lower limits of recreation facility costs were determined in a similar manner.

Under conditions of the upper limit of development, in which case the Horns Corners-Newburg reservoir complex would be economically sound, the annual cost, which includes amortization of the capital cost, as well as operation and maintenance expenditures, is estimated at $4,885,300. Annual benefits, 95.8 percent of which would accrue from recreation, are estimated at $5,521,000, yielding an annual net benefit of $636,000 and a benefit-cost ratio of 1.13. In contrast, under conditions of the lower limit of development, the Horns Corners-Newburg reservoir complex would be economically unsound in that the annual cost, which includes amortization of the capital cost, as well as operation and maintenance expenditures, is estimated at $3,663;800, while the annual benefits, 93.3 percent of which would accrue from recreation, are estimated at $2,835,400, for an annual excess of costs over benefits of $828,400 and a benefit-cost ratio of 0.77 (see Table 38). The actual degree of development would probably lie somewhere between the aforementioned lower and upper limits; and, therefore, the Horns Corners-Newburg reservoirs complex would at best be a marginal economic endeavor.

Saukville Diversion Channel

A three-mile-long single-purpose diversion channel, as originally proposed by the U. S. Army Corps of Engineers, extending from the Milwaukee River at the Village of Saukville to Lake Michigan at a point about one and one-half miles south of the City of Port Washington, was found to be a technically effective major flood control alternative. The diversion of flood flows from the Milwaukee River at Saukville would eliminate all flood damage, with the exception of minor damage upstream of Saukville, in the flood-prone areas along the lower reaches of the Milwaukee River.

The diversion channel, classified as a single-purpose facility inasmuch as its only function is that of flood control, was found to be extremely uneconomical. The updated annual cost, which includes amortization of construction costs, as well as operation and maintenance expenditures, is estimated at $460,800, while the updated annual benefits are estimated at $144,500, for an annual excess of costs over benefits of $316,300 and a benefit-cost ratio of 0.31 (see Table 38).

Dike-Floodwall Systems with Supplemental Structure Removal and Floodproofing

Single-purpose dike-floodwall systems, supplemented with the removal of selected flood-prone structures and the floodproofing of the remaining structures not protected by the dikes and floodwalls, were found to be a technically effective major flood control alternative for the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville, which communities are subject to relatively high monetary damages from a 100-year recurrence interval flood event. This flood control alternative would require a total of 32,500 lineal feet of earth dikes and 19,300 lineal feet of concrete floodwalls, supplemented by the floodproofing of 59 major structures and the removal of 55 major structures, and would eliminate all damage resulting from floods as severe as the 100-year recurrence interval event in the highly developed floodland areas that would be protected.

Highly undesirable aesthetic conditions would be created by the dike-floodwall systems due to their generally great height necessitated by high peak flood stages relative to existing riverine area topography and by freeboard requirements set forth in the watershed development standards in Chapter II of this volume of at least two feet above that stage. Riverine residents protected by the dikes and floodwalls, particularly those property owners living near the river, would generally have the existing view of the river blocked and would encounter difficulty in gaining access to the river because most of the dikes and floodwalls would have their tops at a height of six feet or more above the existing ground elevation at the river's edge. The dike-floodwall system proposal could be expected to be objectionable to the residents and property owners of riverine property in the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville, particularly because many of these residents have undoubtedly purchased or constructed homes in the natural floodlands of the river for the aesthetic amenities attendant to such a location and may well prefer to live with the risk of flood damage in preference to a reduction of the aesthetic enjoyment of their property.

The dike-floodwall system, classified as a single-purpose major flood control alternative inasmuch as its only function is that of flood control, was found to be extremely uneconomical. The total capital cost of the dike-floodwall systems for the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville is estimated at $6,117,300; and the aggregate annual cost, which includes operation and maintenance expenditures, is estimated at $403,600. Total annual benefits, all of which accrue from flood control, are estimated at $124,300, for an annual excess of costs over benefits of $279,300 and an aggregate benefit-cost ratio of 0.31 (see Table 38). In addition to being economically unsound in its totality, each component part of the dike-floodwall system is also uneconomical, yielding benefit-cost ratios of 0.30 for the City of Glendale, 0.40 for the City of Mequon, 0.19 for the Village of Thiensville, and 0.13 for the Village of Saukville.

Structure Floodproofing and Removal

The one nonstructural major flood control alternative considered in the watershed study, that of structure floodproofing and removal, would involve the floodproofing of 559 major structures and the eventual removal on a voluntary basis of an additional 246 major structures, all located in the natural floodlands of the Lower Milwaukee River, and would, therefore, eliminate flood damage to major structures in that portion of the watershed for floods up to and including the 100-year recurrence interval event. Similar protection could be achieved for flood-prone structures scattered throughout the remainder of the watershed by the floodproofing of 162 major structures and by the eventual removal on a voluntary basis of another 225 major structures. Such floodproofing and removal measures would be accompanied by appropriate floodland development regulations which would provide the basic framework for the necessary floodproofing and removal actions.

The structure floodproofing and removal alternative, classified as a marginally multiple-purpose proposal, because it would provide minor recreational and land value enhancement benefits in addition to flood control benefits, was found to be uneconomical. The total capital cost of this alternative for the Lower Milwaukee River is estimated at $4,690,000; and the aggregate annual cost, which consists entirely of amortization of the capital cost, is estimated at $297,000. Total annual benefits, 96 percent of which would accrue from flood control, are estimated at $129,545, for an annual excess of costs over benefits of $167,055 and a benefit-cost ratio of 0.44 (see Table 38).

Although structure floodproofing and removal was found to be uneconomical when applied to the lower Milwaukee River watershed in its totality, this alternative was found to be economical for two reaches of the riverine areas of the lower watershed—the Village of Thiensville, for which the benefit-cost ratio was estimated at 1.67, and that portion of the City of Mequon extending from STH 167 upstream to the southwest corner of Section 18, Town 9 North, Range 22 East, where the benefit-cost ratio was estimated to be 1.22. When applied to the floodlands of the upper watershed, this flood control alternative, based on the aforementioned economic analyses for the lower watershed, also may be expected to be uneconomical.

Action of the Milwaukee Watershed Committee

The detailed analysis of the six practicable major structural flood control alternatives and of the one major nonstructural alternative, as described herein, indicates that the multiple-purpose Waubeka Reservoir would be the most desirable of the seven alternatives considered when evaluated solely on the basis of the technical, economic, and aesthetic features. The reservoir would be a very effective flood control facility in that the storage provided by the reservoir could be expected to eliminate all damages along the flood-prone reaches of the Lower Milwaukee River resulting from floods up to and including the 100-year recurrence interval event. The benefits accruing from flood control, however, would comprise only about 4 percent of the total benefits. Benefits accruing from the Waubeka Reservoir would be dominated by its recreational function, which would account for about 93 percent of the total benefits. Low flow augmentation and water supply benefits would also accrue but were not quantified.

In spite of the favorable technical findings of the watershed study staff regarding the Waubeka Reservoir, the Milwaukee River Watershed Committee, after lengthy and careful deliberation, decided to delete the reservoir from the recommended plan on the grounds that the flood control benefits constitute a very small proportion of the total benefits to be derived from such a reservoir and would, in and of themselves, not economically justify construction of the reservoir; that there was neither the institutional structure available for, nor, at present, the public support required to create such an institutional structure for, the development of a reservoir having primarily recreational benefits; that construction of the reservoir, by reducing the frequency and extent of flooding, would alter the natural characteristics of the environmental corridors below the dam, and encourage the development of those corridors for intensive urban use by removing one of the principal constraints on such development and thereby make the preservation of these corridors more difficult; and that it was unwise to include as a major plan element, upon which the nature and effectiveness of other major plan elements depend, a facility the construction of which would be highly improbable in the face of the growing discontent of conservation interests with reservoir proposals of any kind, the longstanding local public opposition to a reservoir project in the upper Milwaukee

River watershed, the high cost of the project, and the apparent inability of the Federal Government to participate significantly in the funding of the project under existing legislation. It should be noted, however, that the Waubeka Reservoir remains a technically, economically, and aesthetically sound alternative when viewed on a comprehensive, multiple-purpose basis provided that the water pollution abatement recommendations contained in the plan are fully implemented.

The Committee did recommend for inclusion in the comprehensive watershed plan the essential features of the one nonstructural major flood control alternative considered during the course of the study, namely, that of structure floodproofing and removal. Such floodproofing and removal would be accomplished within the framework of floodland land use development regulations designed not only to carry out the watershed plan recommendations but also to meet the requirements for effective local floodland management, as set forth in the 1965 State Water Resources Act. In this respect, it is important to note that, even if the watershed plan were to contain a structural flood control element, such as the Waubeka Reservoir, it would be necessary for local communities affected by that element to enact floodland zoning regulations to meet the state requirements; and such regulations would have to be imposed and would have to remain in effect, as an interim measure, until such time as the structural flood control plan element was actually implemented. The inclusion of a structural flood control element in a watershed plan does not, then, exempt affected communities from compliance with the state floodland zoning requirements until such time as the flood control facility is actually placed into operation.

More specifically, the Committee recommended that, in order to conserve the floodwater storage and conveyance capacity of the natural floodways and floodplains, in order to abate future flood hazards and monetary flood damages, in order to reduce the existing hazards to human health and safety caused by unwise occupation of the floodways, in order to reduce the expenditure of public funds to secure the health and safety of floodland residents during periods of flooding, and in order to promote sound land use development and natural resource base protection, several interrelated land use control measures be instituted by the local governments. These measures would include:

1. In those areas of the floodlands lying within the 100-year recurrence interval flood hazard lines, that are presently neither developed for urban use nor committed to such development by the recordation of land subdivision plats and installation of municipal improvements, such as street pavements and sewer and water utility lines, the prohibition of all future incompatible intensive urban development through appropriate local floodland zoning. This measure would complement the recommendation made in Chapter III of this volume that all undeveloped and uncommitted floodlands in urban areas and along the main stem of the Milwaukee River be purchased by public agencies in order to assure permanent preservation of major portions of the primary environmental corridors of the watershed.

2. In those areas of the floodlands lying between the outer limits of the river channel and the outer limits of the 10-year recurrence interval flood hazard lines, which are presently either developed for intensive urban use or committed to such development by the recordation of land subdivision plats and the installation of municipal improvements, the prohibition through appropriate local floodland zoning of the construction of any new buildings, or additions, but not repairs, to existing buildings; and the gradual removal of the existing buildings on an entirely voluntary basis. Such gradual removal would be accomplished through the purchase of the existing structures for public use at fair market value as the structures come onto the real estate market, thereby providing current owners an alternative to the sale of those structures in the private market. Such existing structures would, in addition, be rendered nonconforming uses under the local floodplain zoning ordinances and, as such, would be subject to the state law on nonconforming uses, which provides that nonconforming structures destroyed by fire, flood, windstorm, or other disaster cannot, if such destruction exceeds 50 percent of the assessed value, be rebuilt.

   No condemnation power would be used to effect the structure removal. Instead, the Committee recommended that the appropriate county agency in each county adopt a policy of being ready and willing to purchase structures recommended for eventual removal so that the owners would have an alternative to the sale of such structures on the private real estate market. Such a policy would recognize that the local units of government have in the past been a party to the unwise development of floodplain lands through zoning acts, approval of subdivision plats, and issuance of building permits and, therefore, should now be willing in the interest of equity to offer an alternative to the private real estate market for the sale of existing structures located in the floodways. Any such floodlands purchased should be eventually utilized for park and open space uses.

In making this recommendation, the Committee recognized that the local communities may wish to utilize a designated floodway to determine the area affected instead of the 10-year recurrence interval flood hazard lines. The utilization of such a floodway in already intensively urbanized reaches of the river system would satisfy the areawide floodland development objectives, as well as utilization of the 10-year recurrence interval flood hazard lines, and may be viewed locally as superior to the use of such lines.

3. In those areas of the floodlands lying between the 10- and 100-year recurrence interval flood hazard lines, which are either developed for intensive urban use or committed to such urban use by the recordation of land subdivision plats and the installation of municipal improvements, that the construction of new structures be permitted provided that such new structures be floodproofed and constructed with the first floor elevation two feet above the elevation of the 100-year recurrence interval flood.

Floodproofing requirements could be included in local housing codes or in local ordinances enacted pursuant to the general grant of power given to municipalities to regulate for the purposes of public health, safety, and welfare. All new buildings constructed on already platted lots in those floodplain areas, as well as structural modifications to existing buildings, should be floodproofed, which may include raising the structures to an elevation at least two feet above the elevation of the 100-year recurrence interval flood.

Finally, the Committee recognized that the Waubeka reservoir site is the only site remaining in the Milwaukee River watershed which could accommodate a reservoir large enough to provide for extensive recreational benefits, for complete flood control, and for extensive amounts of low-flow augmentation with a minimum amount of drawdown. The Committee further recognized that the loss of this site to intensive urban land uses would deprive future generations of virtually any options to develop an economically sound multiple-purpose reservoir within the watershed, should changing development factors and public attitudes warrant or necessitate such a reservoir in the future. Accordingly, the Committee recommended that the entire reservoir site be zoned in such a manner as to prevent encroachment by intensive urban land uses and to encourage continued agricultural and low-density residential land uses.

SUMMARY

Based on the analyses presented in this chapter, and in accordance with the actions of the Milwaukee River Watershed Committee described above, the following flood control plan elements are recommended for inclusion in the comprehensive Milwaukee River watershed plan:

1. The floodproofing, as a condition of continued occupance of the floodplains, of all existing homes and other major structures located in the floodplains of the watershed which are not subject to first-floor inundation by the 100-year recurrence interval flood and which lie between the 10- and 100-year recurrence interval flood inundation lines. A total of 721 homes and other major structures located in these floodplains would, therefore, require floodproofing. In addition, any new homes or other structures which may be constructed on existing platted lots in such floodplain areas, which areas are already heavily committed to urban development through public works construction resulting in street and utility installation, should be constructed with the first-floor elevation at least two feet above the elevation of the 100-year recurrence interval flood.

2. The eventual voluntary removal, supported by acquisition programs established by appropriate public agencies, of all existing structures in the 10-year recurrence interval floodplains of the watershed or in designated floodways which may eventually be determined by the various local communities. There are 471 homes and other major structures now located within the 10-year recurrence interval floodplain which would require removal as nonconforming uses over a long period of time. The cleared sites should then be converted to park and related open-space uses. It is not recommended that condemnation powers be utilized to effect such removal; rather, all such properties should be zoned for nonconforming use status with the properties being purchased for public use only if offered for such use by the homeowners. It is, however, important that the local units of government concerned adopt an official posture of willingness to purchase homes located in the floodways of the watershed so that owners of such homes would have an alternative to selling in the private real estate market.

3. The adoption of local floodland zoning and other floodland regulatory ordinances intended to implement the foregoing structure floodproofing and removal policies, as well as to prohibit any further intrusion of urban land use development into the undeveloped and unplatted 100-year recurrence interval floodplains of the watershed (see Map 18).

4. Protection of the Waubeka reservoir site from encroachment by intensive urban land uses in order to preserve that area in essentially open land uses, including agricultural land uses, thus providing flexibility to meet changing recreation, flood control, and water quality management needs in the Milwaukee River watershed beyond the design year of the plan. The 14,500-acre Waubeka reservoir site is shown on Map 18. It is important to note that the site is the only location remaining in the Milwaukee River watershed which could accommodate a reservoir large enough to provide for the combination of extensive recreational benefits, complete Lower Milwaukee River flood control, and extensive amounts of low-flow augmentation with a minimum amount of drawdown of the reservoir itself.

5. The replacement or modification of 33 public bridges and culverts on the major, perennial stream system which have inadequate hydraulic capacities, as determined by the applicable water control facility standards set forth in Chapter II of Volume 2 of this report, when such replacement or modification is required as part of the highway improvement program (see Table 36).

6. The continued maintenance of the four existing continuous recording stream gages located on the Milwaukee River at Milwaukee and Waubeka, on the North Branch at Fillmore, and on the East Branch at New Fane, together with the reestablishment of the Cedarburg gage on Cedar Creek as a continuous recording gage and the upgrading of the existing staff gage at Kewaskum on the Milwaukee River as a continuous recording gage.

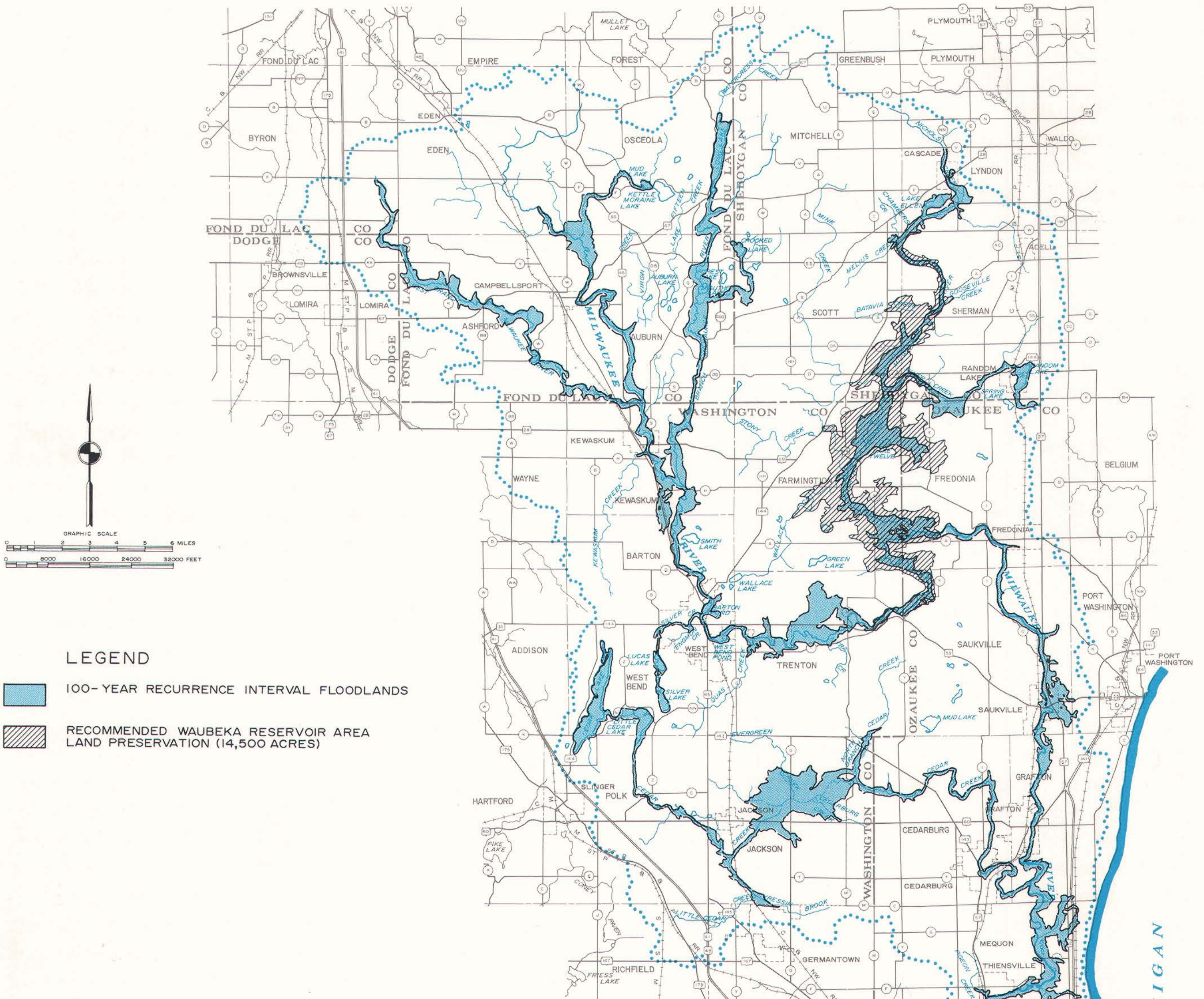
7. Voluntary participation by watershed communities having existing flood-prone urban development in the national flood insurance program administered by the U. S. Department of Housing and Urban Development.

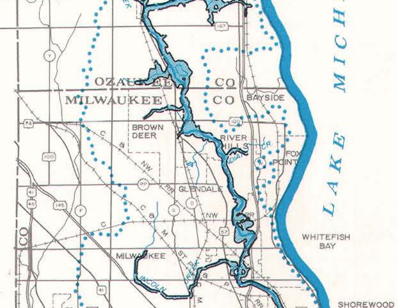
8. Management of the Milwaukee River downstream of the North Avenue Dam so as to maintain its capability of accommodating floods up to and including the 100-year flood. It is recommended that this management include assessment of the potential hydraulic effect of all proposed major alterations to the channel, analyses of the hydraulic effect of proposed bridge replacement or major alterations, and establishment of flood protection elevations at least 2.0 feet above the 100-year flood stage profiles established in the watershed study (see Appendices F and G of this volume).

9. The undertaking of detailed engineering investigations, including sounding of the upstream pool and bore holes in the superstructure, foundation, and embankments of the North Avenue and Woolen Mills Dams, in order to define problems and needs at each dam site and provide the data necessary for possible corrective alterations and improvements.

Map 18

FLOODLANDS IN THE MILWAUKEE RIVER WATERSHED





Floodlands constitute only about 7 percent of the total area of the Milwaukee River watershed and are, because of their susceptibility to recurrent inundation and their critical function as natural floodwater conveyance and storage areas, generally unsuited for intensive urban development, particularly when considered relative to the large expanse of watershed lands lying at higher elevations outside the floodplains. Urbanization within the Milwaukee River watershed should, therefore, be directed to those areas outside the floodlands that are more suitable for urban development. Population growth and attendant urbanization generate a need for readily accessible park and open-space areas in order to provide recreational opportunities and to maintain and enhance the overall quality of the environment. Unoccupied riverine lands, including the floodways and floodplains, provide an excellent natural resource base to meet these recreational and aesthetic needs. The flood-prone characteristics of such lands are completely consistent with recreational use and aesthetic enjoyment. The presence of the river enhances the overall experience; and, the linear continuous nature of riverine lands provides space areas close to, and readily accessible to, urban residents.

Source: Harza Engineering Company and SEWRPC.

Chapter V

ALTERNATIVE SURFACE WATER POLLUTION CONTROL PLAN ELEMENTS

INTRODUCTION

Chapter IX, Volume 1, of this report described the existing surface water quality conditions within the Milwaukee River watershed; set forth the water use objectives and standards established by the state for the streams within the watershed; and described the factors affecting existing and probable future levels of surface water quality, including an identification of major sources of surface water pollution within the watershed.

The inventories indicated that, although stream water quality conditions vary greatly from the upper to the lower reaches of the watershed, potential pathogenic contamination and nutrient pollution, as indicated by coliform count and phosphorus concentrations, are serious problems throughout almost all of the watershed. Organic pollution, as indicated by biochemical oxygen demand (BOD), is not yet as serious a problem in the Milwaukee River watershed as in some other watersheds of the Region, particularly the Root and Fox River watersheds; but, nevertheless, dissolved oxygen levels below the minimum levels required to sustain a healthy fishery occur along relatively long reaches of the river system during the nighttime hours of the summer months. Inorganic pollution is not known to be widespread but constitutes a constant danger, while aesthetic pollution is clearly in evidence, particularly in the lower reaches of the watershed.

Existing stream water quality conditions do not, considering the watershed as a whole, meet the standards for the state-established water use objectives. These objectives include the maintenance of a warm-water fishery and whole-body-contact recreational use for all streams in the watershed except Lincoln and Indian Creeks and that part of the Milwaukee River below the North Avenue Dam and, in addition, industrial and cooling water use of the entire main stem of the Milwaukee River and of Cedar Creek at Cedarburg. For that part of the Milwaukee River below the North Avenue Dam, the water use objectives include industrial and cooling water use and partial-body-contact recreational use. For Lincoln Creek, the water use objectives include partial-body-contact recreational use. For Indian Creek, the water use objectives include only minimum standards.

Over 84 miles, or about 85 percent of the total length of the main stem of the Milwaukee River, from its source in the Town of Osceola in Fond du Lac County to its discharge in the Lake Michigan estuary at the North Avenue Dam in Milwaukee, presently do not meet one or more of the standards for one or more of the state-established water use objectives. Similarly, over 44 miles, or about 20 percent of the total length of the 29 major tributaries of the Milwaukee River, do not meet one or more of the standards for one or more of the state-established water use objectives. Stream water pollution, while generally occurring throughout the watershed, is particularly severe below the Milwaukee County line; and the Milwaukee River and its tributaries in this lower reach of the watershed may be considered to be grossly polluted.

The major sources of stream water pollution within the watershed are effluents from municipal sewage treatment plants, urban and agricultural runoff, and sewer overflows. Industrial waste sources, although of significance locally, represent a relatively minor contribution to the overall deterioration of surface water quality within the watershed. Twelve major municipal sewage treatment plants, all of which provide secondary treatment, discharge effluents to surface waters of the Milwaukee River watershed. Ninety-one separate sewer overflow devices and 62 combined sewer overflow devices discharge raw sewage to surface waters of the Milwaukee River watershed. The major pollutants associated with these discharges are oxygen-demanding organic material, potential pathogenic bacteria, and nutrients. Drainage and runoff from both urban and agricultural lands contribute pollutants in the form of silt, nutrients, pesticides, and oxygen-demanding organic materials. Thirty-nine industrial waste sources exist within the watershed, with 26 being concentrated in the vicinity of Lincoln Creek and along the Milwaukee River downstream from the Milwaukee County line. Major pollutants associated with these industrial outfalls are oxygen-demanding organic materials, toxic chemicals, and heat.

Of the estimated 111,200 pounds of nutrient (phosphorus) per year contributed to the Milwaukee River above the Milwaukee County line, about 54 percent, or 60,000 pounds, is contributed by the 12 municipal sewage treatment plants operating within the watershed; 40 percent, or 44,200 pounds, by agricultural and urban runoff; and 6 percent, or 7,000 pounds, from miscellaneous sources, including industrial waste discharges. In direct contrast, only 18 percent, or 60,000 pounds, of the nutrient loading below the Milwaukee County line above the North Avenue Dam is contributed by the sewage treatment plants, 20 percent, or 66,400 pounds, by runoff, 60 percent, or 198,000 pounds, by sewer overflows, and 2 percent, or 7,000 pounds, from miscellaneous sources. Of the 198,000 pounds of phosphorus contributed by sewer overflows upstream of the North Avenue Dam, about 15 percent, or 30,000 pounds, are contributed by combined sewer overflows. A similar situation exists with respect to organic waste loading (BOD), with over 90 percent of the total average annual organic waste loading contributed to the river system by sanitary sewerage systems above the North Avenue Dam being contributed by sewer overflows. Of the more than 6 million pounds of oxygen-demanding organic material per year contributed to the river above the North Avenue Dam by sewer overflows, about 85 percent is contributed by separate sanitary sewer overflows and 15 percent by combined sewer overflows. Consequently, if water pollution abatement efforts within the watershed are to be effective, these efforts must be primarily directed at controlling the waste contribution from the municipal sewage treatment plants and agricultural runoff in the upper watershed. In the lower watershed, these efforts must be primarily directed at controlling the waste contributions from the sewer overflows, both separate and combined.

Forecasts of future water quality conditions indicate that, in the absence of a sound surface water management plan and plan implementation program, pollution may be expected to cause water quality levels throughout much of the watershed to further deteriorate and to become unsuitable for most beneficial uses. The connected population served by municipal sewage treatment plants discharging to the Milwaukee River system above the Milwaukee County line may be expected to increase from about 38,000 persons at the present time to about 64,000 persons by 1990, and the average rate at which these plants discharge treated sewage to the stream network may be expected to increase from the present level of 7 cfs to almost 21 cfs. This increase may be expected to take place even though the Mequon and Thiensville areas may be connected to the Milwaukee metropolitan system. The future major surface water quality problem may be expected to continue to be excessive fertilization, with its associated algae and weed growths, which will severely limit the use of all of the surface waters of the watershed below West Bend for recreational use and even aesthetic enjoyment. In addition, over 20 percent of the total length of the main stem of the river may be expected to have dissolved oxygen levels below those required for the maintenance of a fishery.

With respect to lake water quality, the study found that six of the 21 major lakes within the watershed—Little Cedar, Mauthe, Mud (Fond du Lac County), Random, Smith, and Twelve—are highly eutrophic, as indicated by high phosphorus contents, low dissolved oxygen contents, and excessive growths of algae and aquatic weeds. Coliform levels and concentrations of ions indicative of pollution were found to be high in only two of the 21 major lakes of the watershed—Ellen and Little Cedar—and may be attributed to domestic sewage discharges from urban-type land use development around these lakes. Overfertilization has occurred in all of the major lakes within the watershed, with the result that nuisance growths of algae and aquatic weeds have interfered with recreational water uses. The primary cause of this overfertilization is the nutrients being supplied from agricultural runoff and, in some cases, malfunctioning septic tank sewage disposal systems. The recommended water use objectives for all of the major lakes include the maintenance of a warm-water fishery and whole-body-contact recreation use. Although all of the major lakes, despite existing water quality problems, presently are suitable for these uses, unless appropriate action is taken, the number of lakes suitable for various types of recreational activities may be expected to decrease sharply in the future.

Because the surface water drainage system of a watershed is made up of a network of streams and watercourses, some of which begin at, or flow through, lakes, and because pollution sources at individual locations have varying effects on downstream water quality levels, water quality management within the watershed is a most complex problem. Many alternative management possibilities exist, each with a different performance level and attendant cost. In order to select the best scheme from among these alternatives, it is necessary to evaluate the potential measures in terms of both cost and performance. Accordingly, this chapter describes the alternative plans for water quality management considered in the Milwaukee River watershed study, together with an evaluation of each alternative's cost and performance and of its ability to meet the recommended water use objectives and water quality standards set forth in Chapter II of this volume.

For convenience the alternative water quality management plan elements will be discussed under three major groups: those associated with stream water quality management in the lower watershed below the Milwaukee County line, where abatement of the pollution from sewer overflows is the principal problem; those associated with stream water quality management in the upper watershed above the Milwaukee County line, where the abatement of pollution from municipal sewage treatment plants and agricultural runoff are the principal problem; and those associated with lake water quality management.

ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENTS—LOWER WATERSHED

As noted above, the major sources of stream water pollution in the lower watershed are the numerous combined and separate sanitary sewer overflow devices discharging raw sewage directly to the streams of the watershed. The Milwaukee-Metropolitan Sewerage Commissions have had underway for a number of years an extensive program of trunk and relief sewer construction designed to abate stream water pollution resulting from the separate sanitary sewer overflows. For the purposes of the watershed study, it was assumed that this program, together with the complementary local relief sewer construction programs which must be carried out by municipalities in Milwaukee County to make the metropolitan trunk sewer construction program effective, would be carried to completion and that this source of water pollution in the lower watershed would thereby be effectively controlled.

The major efforts in the watershed study were, therefore, directed at exploring means for the abatement of the pollution resulting from the combined sewer overflows. Three basic alternative stream water quality management plan elements for abating and controlling this source of water pollution in the lower watershed were considered in the watershed study: storage of the combined sewer overflows and slow release for conventional waste treatment at existing sewage treatment facilities; flow-through and in-flow treatment of the combined sewer overflows; and complete separation of the combined sanitary-storm sewer system to eliminate overflows from this source. A total of 10 different storage alternatives were explored, along with three different methods of flow-through and in-flow treatment, and two different methods of combined sewer separation. In all, then, a total of 15 different alternatives were considered for the abatement of water pollution in the lower watershed due to the discharge of sewage from combined sewer outfalls.

Preliminary Identification and Rating of Combined Sewer Pollution Abatement Alternatives

Because of the large number of alternatives to be considered, it was necessary to utilize a preliminary screening process to select the best alternatives for further, more detailed study and evaluation. The screening process was initiated by establishing four design criteria to be used both to identify various possible combined sewer overflow pollution abatement measures which would be capable of at least physically accommodating the combined sewer overflow in terms of discharge rate and total volume, and then to determine the overall size, physical configuration, and cost of such measures. The measures so identified and sized were then screened by qualitatively evaluating each one on the basis of five selected rating factors. The design criteria and rating factors utilized in the screening process are described in detail below. The results of the initial screening of the 15 alternatives considered for control of the combined sewer overflows are summarized in Table 39.

Design Criteria: The four design criteria used to identify and then to prepare, with cost estimates, a preliminary plan design for each of the 15 combined sewer overflow pollution abatement alternatives are as follows: the combined sewer tributary areas to be served, the minimum system conveyance capacity, the minimum system storage capacity, and the minimum evacuation time of the system storage.

Tributary Area: Each of the combined sewer pollution abatement alternatives was designed and costed to serve one or both of two potential combined sewer areas: the 2,100-acre combined

Table 39

SUMMARY OF ALTERNATIVE COMBINED SEWER OVERFLOW POLLUTION ABATEMENT PLAN ELEMENTS FOR THE LOWER MILWAUKEE RIVER WATERSHED

ALTERNATIVE PLAN ELEMENT			SPACE AVAILABLE IN ACRES			GENERAL PERFORMANCE	AESTHETIC CHARACTERISTICS	DISRUPTIVE EFFECT	LIKELIHOOD OF PUBLIC ACCEPTANCE
NUMBER DESIGNATION	TYPE	DESCRIPTION	2,100 ACRES	5,800 ACRES	17,200 ACRES				
1A & 1B	STORAGE	BURIED CONCRETE STORAGE TANKS IN PARKS	YES	NO	NO	EXCELLENT FOR SMALL AREA	EXCELLENT	LOW	EXCELLENT
2A & 2B	STORAGE	FLOATING CONCRETE STORAGE TANKS IN LAKE MICHIGAN	YES	YES	YES	EXCELLENT	POOR	HIGH (CONVEYANCE)	POOR
3A & 3B	STORAGE	COLLAPSIBLE RUBBER STORAGE TANKS ALONG THE MILWAUKEE RIVER	YES	NO	NO	EXCELLENT FOR SMALL AREAS	POOR	LOW	FAIR
4A, 4B, & 4C	STORAGE	BURIED CONCRETE STORAGE TANKS UNDER THE MILWAUKEE RIVER	YES	YES	YES	EXCELLENT	EXCELLENT	HIGH	EXCELLENT
5A & 5B	STORAGE	DIKED STORAGE LAGOON IN LAKE MICHIGAN	YES	YES	YES	EXCELLENT	POOR	HIGH (CONVEYANCE)	POOR
6	STORAGE	BURIED CONCRETE STORAGE TANK IN MAITLAND FIELD	YES	YES	YES	EXCELLENT	EXCELLENT	HIGH (CONVEYANCE)	EXCELLENT
7A & 7B	STORAGE	DEEP TUNNEL CONVEYANCE AND MINED STORAGE BENEATH THE MILWAUKEE HARBOR	YES	YES	YES	EXCELLENT	EXCELLENT	LOW	EXCELLENT
8	STORAGE	OPEN STORAGE RESERVOIRS ALONG THE MILWAUKEE RIVER BANKS	YES	NO	NO	GOOD	FAIR	HIGH	POOR
9	STORAGE	STORAGE UNDER PIERS AND WATER-FRONT STRUCTURES	NO	NO	NO	POOR	EXCELLENT	MODERATE	FAIR
10	STORAGE	CONVEYANCE OF SEWAGE TO NORTH AVENUE DAM FOR RELEASE TO THE MILWAUKEE RIVER	YES	NO	NO	GOOD	FAIR	LOW	POOR
11	FLOW-THROUGH	ALLIS CHALMERS ROTATING BIOLOGICAL CONTACTOR	YES	YES	YES	POOR	GOOD	MODERATE	POOR
12	FLOW-THROUGH	REX CHAINBELT SCREENING/DISSOLVED-AIR FLOTATION SYSTEM	YES	YES	YES	GOOD	EXCELLENT	MODERATE	EXCELLENT
13	IN-FLOW	INSTREAM TREATMENT	YES	YES	YES	FAIR	EXCELLENT	LOW	POOR
14	SEPARATION	SEWER SEPARATION BY PRESSURIZED SEWERS	YES	YES	YES	GOOD	EXCELLENT	HIGH	EXCELLENT
15	SEPARATION	SEWER SEPARATION BY GRAVITY	YES	YES	YES	GOOD	EXCELLENT	HIGH	EXCELLENT

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

sewer service area within the Milwaukee River watershed upstream of the North Avenue Dam and the entire 5,800-acre combined sewer service area within the watershed (see Map 19). In addition, the potential applicability of each alternative to the entire 17,200-acre combined sewer service area within the Milwaukee urbanized area was tentatively evaluated.

System Conveyance Capacity: The maximum rate of combined sewer overflow to be accommodated by the conveyance works of the various alternatives was prescribed at 0.5 inch of runoff per hour, or its equivalent of 0.5 cfs per acre. This discharge rate was selected as generally exceeding the estimated present maximum conveyance capacity of the existing combined sewer system, thereby shifting the limiting constraint on the system from the delivery rate of combined sewer overflow to the total volume of overflow to be accommodated. It should be noted, however, that, in actual application of any of the alternative plan elements discussed in this chapter, it would be necessary to conduct field surveys and analyses to define more precisely the delivery capacities of the individual outfall sewers, thereby adjusting this design criteria.

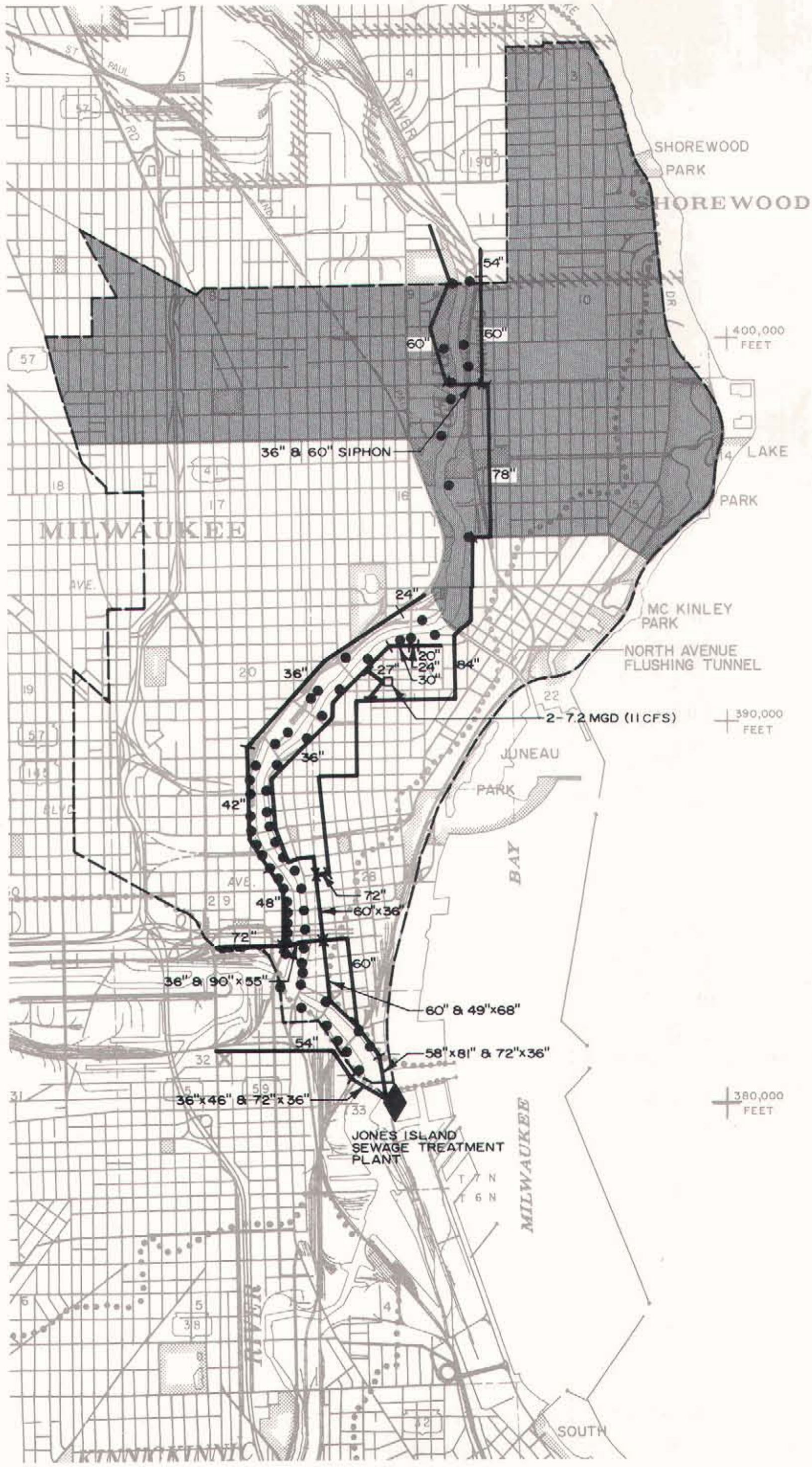
System Storage Capacity: The maximum volume of combined sewer overflow to be accommodated by the storage facilities of the various alternatives was prescribed at two inches of runoff from the tributary drainage areas. This storage volume was selected on the basis of an analysis of the historic hourly rainfall records for the Milwaukee area covering the 20-year period from 1950 through 1969. These analyses were supplemented by similar findings for the Chicago area. The provision of storage for two inches of runoff would, according to these hydrologic analyses, reduce the frequency of combined sewer overflows from an average of about 52 occurrences per year to an average of about one occurrence in three years.

Map 19

COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED 1970

LEGEND

- 5,800 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED
- 2,100 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED UPSTREAM OF THE NORTH AVENUE DAM
- EXISTING INTERCEPTING SEWER
- COMBINED SEWER OUTFALL
- EXISTING LIFT STATION



GRAPHIC SCALE
0 2000 4000 6000 FEET

About one-third of the total area served by combined sanitary and storm sewers in Milwaukee County is tributary to the Milwaukee River. Combined sewer overflows, which occur on the average of about 52 times per year, are a serious water pollution problem in the Milwaukee River watershed. In the preparation of the Milwaukee River watershed plan, a total of 15 different alternatives for the abatement of this pollution were considered, including storage of combined sewer overflows for later release and treatment, immediate flow-through treatment, and sanitary-storm sewer separation.

Source: Harza Engineering Company and SEWRPC.

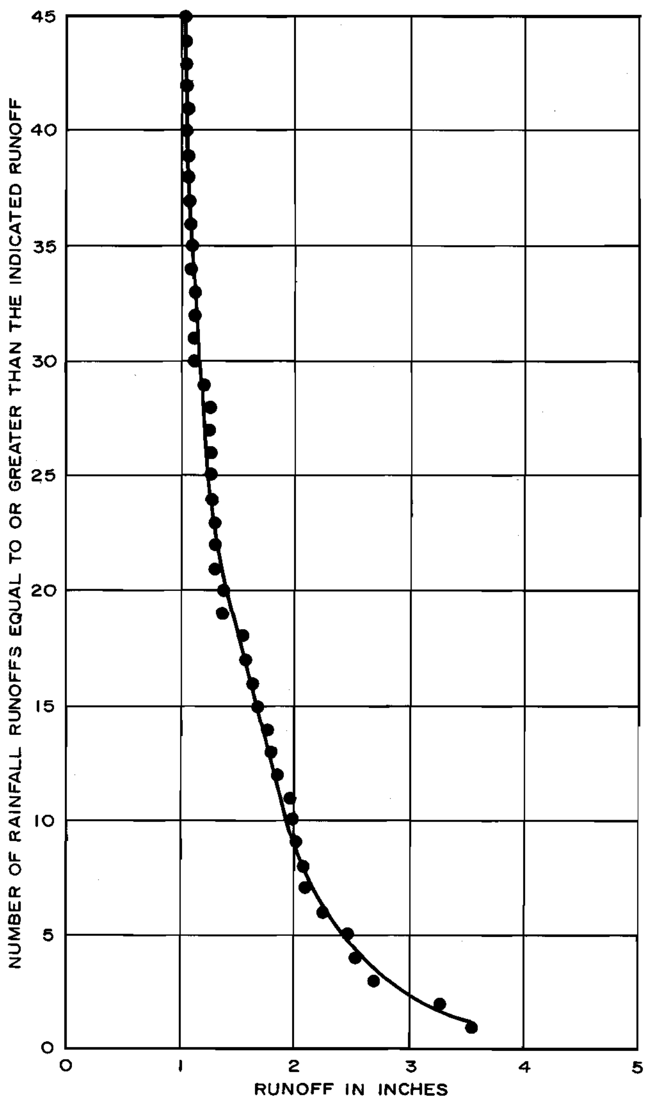
Storage Requirements Based on Analysis of Milwaukee Data

Historic weather records for the Milwaukee area were analyzed in order to establish the minimum storage requirements for those combined sewer overflow abatement measures that incorporated storage facilities. Maximum monthly rainfall events for the Milwaukee area, each event being identified as the single, continuous period of rainfall within each month having the greatest total depth, for the 20-year period of January 1950 through December 1969 were transformed to maximum monthly runoff volumes. The 40 largest runoff values were then used to construct Figure 14, which graphically shows the relationship between the number of occurrences and runoff. A change occurs in the shape of the graph at a runoff depth of about two inches, which may be expected to be reached or exceeded on an average of once every three years. This abrupt change in slope indicates that an increment of runoff storage below two inches would be more effective in eliminating combined sewer overflows than would an equal increment of runoff storage above two inches, because a larger number of runoff events would be eliminated. For example, a 1.00 inch increment of storage immediately below the two inch level would eliminate 36 major overflow events, contrasted with the elimination of only seven such events with the addition of a 1.00 inch increment of storage immediately above the two inch level. The provision of runoff storage volume in excess of two inches should be provided only if the reduction in the probability of discharge to surface waters in conjunction with the additional cost warrants it. The probability of discharge to surface waters associated with various amounts of storage above two inches is developed below.

A detailed analysis of the magnitude and occurrence of the aforementioned maximum monthly rainfall events, as measured at the Milwaukee National Weather Service station, demonstrated that the larger rainfall events were concentrated in the May through October, or summer periods, of the years of record. Another significant difference between this summer period and the six-month November through April winter period, affecting the runoff characteristics of an area, is that, in the latter period, rain will generally fall on snow-covered or frozen ground and then enter the combined sewer system with little volume reduction, while rain occurring during the summer period would be reduced by infiltration, plant interception, surface retention, and evapotranspiration prior to entering the combined sewer system. Because of these differences in the rainfall volumes and in the runoff conditions, rainfall-runoff relationships were developed separately for the summer and winter periods.

Figure 14

FREQUENCY AND MAGNITUDE OF RUNOFF FROM THE COMBINED SEWER AREA IN MILWAUKEE, WISCONSIN



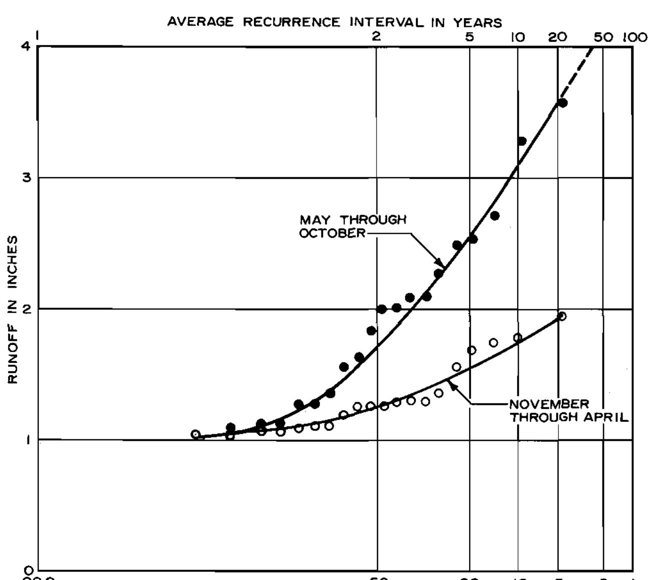
NOTE: BASED ON MILWAUKEE PRECIPITATION DATA AND MAXIMUM MONTHLY RAINFALL RUNOFFS ESTIMATED FOR THE 20 YEAR PERIOD JANUARY 1950 THROUGH DECEMBER 1969.

Source: SEWRPC.

Based on 1990 land use projections, approximately 68 percent of the entire 17,200-acre combined sewer service area within Milwaukee County could be expected to be comprised of impervious surfaces, with the remainder being comprised of pervious surfaces. Major rainfalls occurring on the pervious surfaces during the summer period were reduced by 1.5 inches prior to runoff to the combined sewer system. This extraction is composed of 0.1 inch of water each for vegetal interception, surface depression retention, and evapotranspiration and 1.2 inches for infiltration, based on an average infiltration rate of 0.1 inch per hour for 12 hours, the approximate median duration of the 20 largest annual summer rainfall events. Rainfall on impervious areas during that period was reduced 0.2 inch prior to runoff to reflect volume reduction attributed to surface depression retention and evaporation. These extractions for the pervious and impervious portions of the combined sewer service areas were applied to the 20 largest annual summer rainfall event depths to develop the runoff frequency curve shown in Figure 15. The curve indicates the frequency at which various runoff depths could be expected to be discharged to surface waters during the summer period, assuming the complete discharge of all rainfall entering the combined sewer system.

Figure 15

RUNOFF-FREQUENCY CURVES FOR THE COMBINED SEWER AREA IN MILWAUKEE, WISCONSIN



NOTE: BASED ON MILWAUKEE PRECIPITATION DATA AND A PARTIAL SERIES ANALYSIS OF ESTIMATED MAXIMUM MONTHLY RAINFALL RUNOFFS FOR THE 20 YEAR PERIOD JANUARY 1950 THROUGH DECEMBER 1969.

Source: SEWRPC.

Rainfall occurring during the winter periods was assumed to enter the combined sewer system undiminished in volume due to the likelihood of frozen ground or of snow cover during this period, as determined from data in the 1970 Wisconsin Statistical Reporting Service report, entitled Snow and Frost in Wisconsin. The 20 largest winter rainfall events were used to construct the rainfall-runoff frequency curve shown in Figure 15. It is important to note that rainfall is relatively ineffective in melting snow that has accumulated on the ground; and, therefore, the occurrence of rain on snow-covered ground during the winter period does not necessarily indicate the simultaneous occurrence of a significant amount of snowmelt runoff. The report Snow and Frost in Wisconsin includes an analysis of a typical rainfall occurring on snow-covered ground and demonstrates that, if one inch of 40^{o}F rain cools to 32^{o}F, on contact with ice or snow at that temperature, melting would produce less than 0.05 inch of water.

Examination of the curve for the winter period indicates that, above about 2.0 inches of runoff, the probability of occurrence becomes very low, as compared to similar runoff events during the summer period. For example, there is a 0.37 probability that a rainfall-runoff event equal to or greater than 2.00 inches will occur during the summer period of any year, while the probability of the occurrence of such an event during the winter period is only 0.04.

An additional factor that must be considered for the winter period is the possibility of the occurrence of large runoffs generated by snowmelt or a snowmelt-rainfall combination. The runoff frequency curve of Figure 15 for this interval does not include such a situation, since it is based only on rainfall events. The snowmelt phenomenon requires a combination of snow or ice accumulation on the ground and thawing conditions of sufficient intensity and duration to produce rapid snowmelt and runoff. Based on these criteria and Milwaukee climatological data presented in the report Snow and Frost in

Wisconsin, March is the only month exhibiting a significant snowmelt potential. There is a 4.4 percent probability of having five inches or more of snow cover, or about one inch or more of water equivalent, on the ground in March; a 3.6 percent probability of having two inches or more of water equivalent; and a 0.0 chance of having three inches or more of water equivalent, based on 69 years of snow cover records at Milwaukee. The average monthly temperature for March is just above 32°F, and the month has on an average 25 days with daily maximum temperatures above the freezing point. A greater probability of snow accumulation exists in February but the month lacks sufficient snowmelt temperatures, having an average monthly temperature of only 24°F and on an average only 13 days with daily maximum temperatures above 32°F. In contrast, April is characterized by favorable temperature conditions but is deficient in snow accumulation, there being a 0.0 percent probability of having one inch or more of water equivalent on the ground. Conservatively assuming that the probability of snowmelt is equivalent to the probability of snow accumulation during March, the prime snowmelt month, it is apparent that winter snowmelt runoff would exhibit very small probabilities of occurrence relative to similar rainfall runoff events in the May through October period.

In summary, then, the May through October runoff frequency curve of Figure 15 may be used to estimate the probability of the occurrence of a runoff in any given year equal to or greater than some value in the 2.0 to 4.0 inch range. Table 40, based on the runoff frequency curve, summarizes the effectiveness of various storage volumes in terms of the corresponding probabilities of discharge from the combined sewer system to the surface waters. As indicated by the table, the selected design runoff of two inches would serve to reduce the present estimated frequency of combined sewer overflows from about 52 occurrences per year to about one occurrence in three years. Moreover, the pollutional effects of the overflow during these relatively rare events would be greatly reduced due to capture and storage of the initial flush of pollutants from buildings, streets, and sewers prior to the filling of the storage system and occurrence of overflow. The capacity of the streams to assimilate this reduced pollution loading would also be increased considerably by the high streamflows accompanying large runoff events and the relatively long recovery time provided between events.

Storage Requirements Based on Analysis of Chicago Data

The Harza Engineering Company previously had examined the magnitude and frequency of combined sewer overflows for the Chicago area for the purpose of establishing the minimum storage, expressed in terms of inches of runoff, that should be provided in a combined sewer overflow abatement system for that city. Although the assumptions and detailed procedures of that study differed somewhat from those used in the analysis of the Milwaukee area data, as described herein, the conclusions with regard to the amount of storage to be provided were similar; that is, combined sewer outfall pollution abatement alternatives employing storage should be designed to accommodate at least two inches of runoff. Storage of that magnitude would reduce the frequency of overflows to an average of about once every three years. Inasmuch as the land use and precipitation patterns for the Chicago and Milwaukee urban areas may be expected to be quite similar, the results of the Chicago analysis serve to substantiate the conclusions drawn from the study of Milwaukee precipitation data.

Table 40

ESTIMATED FREQUENCY OF COMBINED SEWER OVERFLOW DISCHARGE TO SURFACE WATERS FOR VARIOUS STORAGE VOLUMES, MILWAUKEE, WISCONSIN

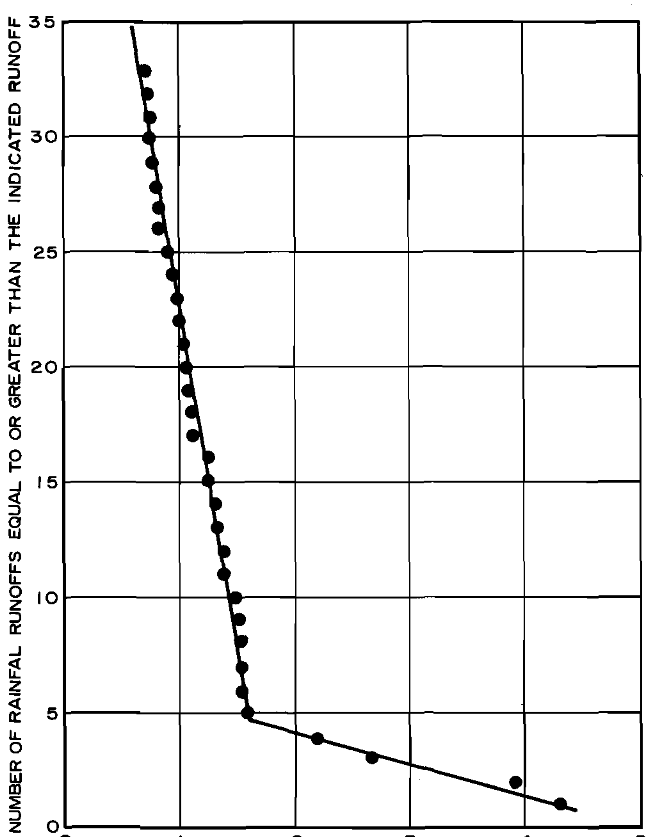
VOLUME OF STORAGE IN INCHES	PROBABILITY OF DISCHARGE TO SURFACE WATERS IN ANY YEAR	RECURRENCE INTERVAL OF DISCHARGE TO SURFACE WATERS IN YEARS
2.00	0.37	2.7
2.50	0.21	4.8
3.00	0.112	8.9
3.50	0.055	18.2
4.00	0.026	39.5

SOURCE- SEWRPC.

The most severe rainstorms of the past 100 years at Chicago occurred during the 16-year period from 1949 to 1964. These records included 837 rainfall events in excess of 0.06 inch, the rainfall depth at which runoff was assumed to occur for the Chicago area. Thirty-four major storms of this group, or those producing more than 0.75 inch of runoff, were used to construct Figure 16, which graphically shows the relationship between the number of occurrences and runoff. A change in slope occurs in the graph at a runoff depth of about 1.6 inches, estimated to be a runoff event with a three-year recurrence interval, indicating that incremental storage provided for runoff above 1.6 inches would be much less effective than storage up to that point. The estimated 1.6 inches of storage required to reduce the frequency of Chicago area combined sewer overflows to an average of about once in three years was increased 0.4 inch to account for sanitary sewage and for system leakage estimated for the Chicago area. In summary then, the analysis of Chicago precipitation data also indicated that combined sewer pollution abatement systems employing storage should be sized to accommodate at least two inches of runoff and that this storage would reduce overflow frequency to an average of about once every three years.

Figure 16

FREQUENCY AND MAGNITUDE OF RUNOFF FROM THE COMBINED SEWER AREA IN CHICAGO, ILLINOIS



NOTE: BASED ON CHICAGO PRECIPITATION DATA AND RAINFALL RUNOFFS ESTIMATED FOR THE 16 YEAR PERIOD 1949 THROUGH 1964.

Source: Harza Engineering Company.

Storage Evacuation Time: The rate at which waste-water would be evacuated from the storage facilities was, for the purpose of the preliminary design of combined sewer pollution abatement alternatives having storage facilities and applying only to the 2,100-acre combined sewer service area upstream of the North Avenue Dam, assumed to be primarily determined by the maximum rate at which the existing intercepting sewer system could accept the stored waste-water during periods of dry weather flow. This maximum rate was estimated to be 20 cfs, or 13 mgd. For the purpose of the preliminary design of combined sewer pollution abatement alternatives having storage facilities and applying to the entire 5,800-acre combined sewer service area tributary to the Milwaukee River watershed, the rate of evacuation was assumed to be primarily determined by the maximum rate at which the existing Jones Island sewage treatment plant could accept, in addition to its normal waste-water loading, flow from the storage facility. This maximum rate was estimated to be 59 cfs, or 38 mgd. It was further assumed in both cases that reservoir evacuation would be confined to a period of 18 hours of each 24-hour day in order to permit use of less costly off-peak electric power and to avoid contributing flow to the Jones Island sewage treatment plant during peak daily hydraulic loadings. Based on an evacuation rate of 20 cfs for 18 hours of each day, the evacuation time for two inches of runoff from the 2,100-acre combined sewer service area is about 11 days. Based on an evacuation rate of 59 cfs for 18 hours of each day, the evacuation time for two inches of runoff from the 5,800-acre combined sewer service area is also about 11 days.

Rating Criteria: In the screening process, the 15 combined sewer pollution abatement alternatives considered were comparatively evaluated with respect to five major criteria: 1) the ability of the alternatives to meet the recommended stream water use objectives, 2) the relative aesthetic characteristics of each alternative, 3) the potential disruptive effect of implementation of the alternatives upon the urban environment, 4) the anticipated potential public acceptance of each alternative, and 5) costs. In addition, each alternative was generally evaluated in the initial screening process on the basis of its potential for application to the entire 17,200-acre combined sewer service area within Milwaukee County, as opposed to the more limited service areas of 2,100 and 5,800 acres within the Milwaukee River watershed and, if necessary, to the abatement of stream pollution from separate, as well as combined, sewer overflows.

Potential for Meeting Water Quality Objectives: Each combined sewer pollution abatement alternative was examined to determine its potential for meeting the recommended stream water use objectives and supporting water quality standards, as set forth in Chapter II of this volume. The alternatives were also examined with respect to their ability to meet the effluent standards recommended by the federal Lake Michigan Enforcement Conference and the State of Wisconsin for waste discharges to streams tributary to Lake Michigan. These effluent standards require, in addition to the provision of secondary waste treatment,[1] removal of 85 percent of the total phosphorus (P) content of the waste-waters tributary to the sewerage systems within the drainage basin[2] and post-chlorination for disinfection of the effluent prior to discharge to the receiving waters.

Aesthetic Characteristics: The relative aesthetic characteristics of the alternatives were evaluated by considering the locational requirements and visibility of the necessary water quality control structures, with those alternatives requiring structures to be located at or above ground level being rated lower than those alternatives permitting structures to be located below ground level. Alternatives requiring visible structures in Lake Michigan were rated low, as were any alternatives requiring either a large number of small, but visible fixed or collapsible tanks at or near sewer outlets with the attendant potential for the creation of unsightly conditions.

Disruptive Effect: With respect to the potential disruptive effect upon the urban environment of each alternative, the alternatives were evaluated based upon the relative degree to which implementation of the alternative could be expected to interfere with the flow of traffic, daily social and economic intercourse, and the provision of utility services and whether or not the alternative would require improvements to be made on private property and within buildings, as well as within public rights-of-way.

Likelihood of Public Acceptance: The various alternatives were also subjectively rated with respect to relative potential public acceptance,

---

[1] *Secondary waste treatment has been defined by the Wisconsin Department of Natural Resources utilizing two separate sets of criteria--one for treatment facilities continuously in operation (daily service) and one for treatment facilities designed to operate intermittently following periods of high runoff. For sewage treatment plants in daily service, secondary treatment must provide 90 percent removal of five-day biochemical oxygen demand (BOD) and total suspended solids determined as a monthly average of samples analyzed daily, with the monthly average five-day BOD and total suspended solids concentration in the treatment plant effluent not to exceed 35 mg/l. For sewage treatment plants in intermittent service, secondary treatment must provide 85 percent removal of five-day BOD and total suspended solids determined as a "monthly average" of samples composited and analyzed daily during the periods of operation. (See letter from Dr. Thomas G. Frangos, Administrator, Division of Environmental Protection, to Dr. Kurt W. Bauer, Executive Director, SEWRPC, dated March 31, 1971.)*

[2] *The Wisconsin Department of Natural Resources requires 85 percent phosphorus removal at all sewage treatment facilities serving communities having a population or population equivalent of 2,500 persons. The Department has indicated, with respect to the combined sewer overflow problem in Milwaukee County, that it would be necessary to remove 85 percent of the influent phosphorus at any intermittent sewage treatment facilities that may be constructed at combined sewer overflow locations. The Department has also indicated, however, that lesser levels of phosphorus removal would be acceptable at any proposed combined sewer overflow treatment facilities in Milwaukee County if it could be demonstrated that, on an overall basis, a cumulative 85 percent phosphorus removal level could be achieved on an annual average basis by consistently removing more than 85 percent of the influent phosphorus at the Jones Island and/or South Shore sewage treatment plants. (See letter from Dr. Thomas G. Frangos, Administrator, Division of Environmental Protection, to Dr. Kurt W. Bauer, Executive Director, SEWRPC, dated March 31, 1971.)*

based primarily upon perceived public attitudes toward intrusion of major public works construction into the streams and watercourses and associated shorelands of the watershed and particularly into Lake Michigan.

Cost: Comparative cost estimates were prepared for each of the alternatives considered. With respect to the storage alternatives, the costs included four comparable components for each alternative: collector-conveyance facilities to the storage facilities, the storage facilities themselves, aeration and cleaning facilities, and pumps and conveyance facilities for evacuation of the stored waste waters from the storage facilities. Because the storage alternatives would all basically utilize the same existing or additional new sewage treatment plant facilities to treat overflows of the same composition and volume, the costs of treatment were assumed to be identical for all comparable alternatives and were not, therefore, included in the total costs during the initial screening process. With respect to the flow-through or in-flow treatment alternatives, the costs were derived from unit treatment cost data developed under actual pilot demonstration projects of the type of facilities being considered and, therefore, included only the cost of the treatment facilities needed. With respect to the combined sewer separation alternatives, the costs included the reconstruction of existing sewerage facilities both within private buildings and on private property and within public rights-of-way.

Combined Sewage Storage Alternatives

A total of 10 different alternative plan elements were considered for the abatement of pollution from combined sewer overflows in the Milwaukee River watershed by temporarily storing the overflow sewage for subsequent release and treatment at the existing Jones Island sewage treatment plant. These 10 storage alternatives were: 1) buried concrete storage tanks located in selected existing public parks along the stream valley; 2) floating concrete storage tanks located in Lake Michigan; 3) collapsible rubber storage tanks located along the banks of the Milwaukee River; 4) buried concrete storage tanks located under the Milwaukee River; 5) diked storage lagoons located in Lake Michigan; 6) a buried concrete storage tank located in Maitland Field; 7) a mined storage area located beneath the Milwaukee Harbor combined with deep tunnel intercepting sewers for sewage conveyance; 8) covered storage reservoirs located along the banks of the Milwaukee River; 9) storage tanks located under piers and waterfront structures; and 10) conveyance of sewage to the North Avenue Dam for release to the estuary portion of the Milwaukee River (see Table 41). Not all of these alternatives are applicable to both the 2,100-acre and 5,800-acre combined sewer service study areas located in the Milwaukee River watershed (see Map 19), nor to the total 17,200-acre combined sewer service area within the Milwaukee urbanized area. All, however, were investigated in the preliminary screening process with the results reported here.

Alternative 1—Buried Concrete Storage Tanks in Parks: The first storage alternative considered for abatement of the pollution from the combined sewer overflows was the provision of relatively small concrete storage tanks buried under two existing public parks located along the Milwaukee River. Because of park space limitations, this storage alternative was considered to be applicable only to the 2,100-acre combined sewer service area located upstream from the North Avenue Dam. Overflows from the 10 existing combined sewer outfalls located upstream from the North Avenue Dam would be conveyed by gravity flow in concrete pipes buried in the river bed to lift stations and underground storage tanks located in Kern and Riverside Parks (see Map 20). The conveyance pipes would be 6 to 12 feet in diameter and have capacities ranging from 100 to 750 cfs. The lift station at Kern Park would have a capacity of 9,400 kilowatts to lift 900 cfs from the conveyance pipes into a 300 acre-foot concrete storage tank. The storage tank in Kern Park would be 809 feet square and 21 feet deep, adequate to store 2 inches of runoff from the 1,800-acre tributary combined sewer service area located north of Locust Street. The lift station at Riverside Park would have a capacity of 880 kilowatts to lift 150 cfs from the conveyance pipes into a 50 acre-foot concrete storage tank. The storage tank in Riverside Park would be 330 feet square and 20 feet deep, adequate to store 2 inches of runoff from the 300-acre tributary combined sewer service area located south of Locust Street.

Both storage tanks would be equipped with aeration facilities to provide agitation and sufficient oxygen to maintain aerobic conditions in the stored sewage during the required maximum storage period of 11 days. The agitation would be provided to keep solid materials in suspension so that such material could be pumped out with the liquid during tank evacuation.

Table 41

PRELIMINARY COST ESTIMATES--ALTERNATIVE COMBINED SEWER OVERFLOW STORAGE POLLUTION ABATEMENT PLAN ELEMENTS FOR THE LOWER MILWAUKEE RIVER WATERSHED

Alternative Storage Plan Element: Number Designation	Alternative Storage Plan Element: Description	Applicable Combined Sewer Service Area (acres)	Capital Cost (Construction): Reservoir	Conveyance to Reservoir	Pumping Plant	Conveyance to Jones Island Sewage Treatment Plant	Sludge Removal	Aeration	Lining and Protection	Total
1A	Buried Concrete Storage Tanks in Parks--Conveyance in Existing Intercepting Sewer System	2,100	$17,100,000	$ 2,800,000	$ 6,100,000	$ --	$ --	$ --	$ --	$26,000,000
1B	Buried Concrete Storage Tanks in Parks--Conveyance in New Gravity Flow Sewer	2,100	17,100,000	2,800,000	6,100,000	1,800,000	--	--	--	27,800,000
2A	Floating Concrete Storage Tanks in Lake Michigan--Conveyance in New Gravity Flow Sewer	2,100	31,500,000	7,400,000	300,000	800,000	--	--	--	40,000,000
2B	Floating Concrete Storage Tanks in Lake Michigan--Conveyance in New Gravity Flow Sewer	5,800	86,900,000	27,000,000	10,300,000	--	--	--	--	124,200,000
3A	Collapsible Rubber Storage Tanks Along the Milwaukee River--Conveyance in Existing Intercepting Sewer System	2,100	8,400,000	300,000	4,300,000	--	--	--	--	13,000,000
3B	Collapsible Rubber Storage Tanks Along the Milwaukee River--Conveyance in New Gravity Flow Sewer	2,100	8,400,000	300,000	4,300,000	1,800,000	--	--	--	14,800,000
4A	Buried Concrete Storage Tanks Under the Milwaukee River--Conveyance in Existing Intercepting Sewer System	2,100	30,400,000	--	300,000	--	--	--	--	30,700,000
4B	Buried Concrete Storage Tanks Under the Milwaukee River--Conveyance in New Gravity Flow Sewer	2,100	30,400,000	--	--	1,100,000	--	--	--	31,500,000
4C	Buried Concrete Storage Tanks Under the Milwaukee River--Conveyance in Storage Tanks	5,800	80,300,000	--	400,000	--	--	2,750,000	--	83,450,000
5A	Diked Storage Lagoon in Lake Michigan	2,100	2,400,000	7,400,000	200,000	800,000	--	--	900,000	11,700,000
5B	Diked Storage Lagoon in Lake Michigan	5,800	11,800,000	23,500,000	8,400,000	--	--	1,900,000	1,700,000	47,300,000
6	Buried Concrete Storage Tank in Maitland Field	5,800	52,000,000	18,500,000	6,200,000	200,000	--	1,400,000	--	78,300,000
7A	Deep Tunnel Conveyance and Mined Storage Beneath the Milwaukee Harbor	5,800	16,100,000	31,100,000	2,600,000	--	1,400,000	2,100,000	1,400,000[a]	54,700,000
7B	Deep Tunnel Conveyance and Diked Surface Storage Reservoirs	5,800	8,000,000	32,500,000	83,100,000	1,300,000	--	1,900,000	1,900,000	128,700,000
8	Open Storage Reservoirs Along the Milwaukee River Banks[b]	2,100	--	--	--	--	--	--	--	--
9	Storage Under Piers and Waterfront Structures[c]	5,800	--	--	--	--	--	--	--	--
10	Conveyance of Sewage to North Avenue Dam for Release to the Milwaukee River	2,100	--	6,200,000	--	--	--	--	--	6,200,000

An estimate was made of the volume of settleable solids that would accumulate in the storage tanks if such solids suspension were not provided. The estimate, based on data and analyses presented in Chapter IX of Volume 1 of this report, was made for a total overflow volume of 2,300 acre-feet, with a settleable solids concentration of 238 ppm, and indicated a yield of about 24,500 cubic feet of solids per year. This would amount to a sludge blanket about 0.4 inch in depth over the bottom of both tanks; and, if no action were taken to inhibit settling of solids, it would take about 30 years for one foot of sediment to accumulate in the bottom of the tanks. Provision of the aeration system included in this alternative would materially reduce actual accumulations below this estimate. It was concluded, therefore, that mechanical cleaning devices would not be essential in the storage tanks. Consequently, the attendant costs of such devices were not included in the cost estimates for this or any other of the 10 storage alternatives examined in the initial screening process.

The top of the tanks would be covered with a minimum of five feet of soil to permit continued use of the storage site areas as public parks. The stored sewage would flow by gravity from the tanks into an existing intercepting sewer as capacity became available and by gravity via this sewer to the existing Jones Island sewage treatment plant for treatment (see Map 20). The average combined rate of flow from the two

Table 41 (continued)

ALTERNATIVE STORAGE PLAN ELEMENT		APPLICABLE COMBINED SEWER SERVICE AREA (ACRES)	PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL			ANNUAL COST PER ACRE	CAPITAL COST PER ACRE
NUMBER DESIGNATION	DESCRIPTION		CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL		
1A	BURIED CONCRETE STORAGE TANKS IN PARKS--CONVEYANCE IN EXISTING INTERCEPTING SEWER SYSTEM	2,100	$ 27,890,000	$ 2,090,000	$ 29,980,000	$ 1,769,000	$ 133,000	$ 1,902,000	$ 906	$ 12,381
1B	BURIED CONCRETE STORAGE TANKS IN PARKS--CONVEYANCE IN NEW GRAVITY FLOW SEWER	2,100	29,690,000	2,170,000	31,860,000	1,883,000	138,000	2,021,000	962	13,238
2A	FLOATING CONCRETE STORAGE TANKS IN LAKE MICHIGAN--CONVEYANCE IN NEW GRAVITY FLOW SEWER	2,100	41,100,000	1,890,000	42,990,000	2,600,000	120,000	2BM208/00	1,295	19,048
2B	FLOATING CONCRETE STORAGE TANKS IN LAKE MICHIGAN--CONVEYANCE IN NEW GRAVITY FLOW SEWER	5,800	127,160,000	10,260,000	137,420,000	8,067,000	651,000	8,718,000	1,503	21,414
3A	COLLAPSIBLE RUBBER STORAGE TANKS ALONG THE MILWAUKEE RIVER--CONVEYANCE IN EXISTING INTERCEPTING SEWER SYSTEM	2,100	15,750,000	1,220,000	16,970,000	999,000	77,000	1,076,000	512	6,190
3B	COLLAPSIBLE RUBBER STORAGE TANKS ALONG THE MILWAUKEE RIVER--CONVEYANCE IN NEW GRAVITY FLOW SEWER	2,100	17,550,000	1,380,000	18,930,000	1,113,000	88,000	1,201,000	572	7,048
4A	BURIED CONCRETE STORAGE TANKS UNDER THE MILWAUKEE RIVER--CONVEYANCE IN EXISTING INTERCEPTING SEWER SYSTEM	2,100	31,320,000	1,390,000	32,710,000	1,987,000	88,000	2,075,000	988	14,619
4B	BURIED CONCRETE STORAGE TANKS UNDER THE MILWAUKEE RIVER--CONVEYANCE IN NEW GRAVITY FLOW SEWER	2,100	32,120,000	1,440,000	33,560,000	2,038,000	91,000	2,129,000	1,014	15,000
4C	BURIED CONCRETE STORAGE TANKS UNDER THE MILWAUKEE RIVER--CONVEYANCE IN STORAGE TANKS	5,800	85,100,000	4,030,000	89,130,000	5,298,000	256,000	5,554,000	958	15,367
5A	DIKED STORAGE LAGOON IN LAKE MICHIGAN	2,100	12,130,000	570,000	12,700,000	765,000	36,000	801,000	381	6,048
5B	DIKED STORAGE LAGOON IN LAKE MICHIGAN	5,800	50,050,000	5,880,000	55,930,000	3,175,000	373,000	3,548,000	612	8,155
6	BURIED CONCRETE STORAGE TANK IN MAITLAND FIELD	5,800	80,300,000	6,190,000	86,490,000	5,094,000	393,000	5,487,000	946	13,500
7A	DEEP TUNNEL CONVEYANCE AND MINED STORAGE BENEATH THE MILWAUKEE HARBOR	5,800	56,150,000	3,350,000	59,500,000	3,562,000	213,000	3,775,000	651	9,431
7B	DEEP TUNNEL CONVEYANCE AND DIKED SURFACE STORAGE RESERVOIRS	5,800	148,840,000	6,790,000	155,630,000	9,442,000	431,000	9,873,000	1,702	22,190
8	OPEN STORAGE RESERVOIRS ALONG THE MILWAUKEE RIVER BANKS[b]	2,100	--	--	--	--	--	--	--	--
9	STORAGE UNDER PIERS AND WATERFRONT STRUCTURES[c]	5,800	--	--	--	--	--	--	--	--
10	CONVEYANCE OF SEWAGE TO NORTH AVENUE DAM FOR RELEASE TO THE MILWAUKEE RIVER	2,100	6,200,000	290,000	6,490,000	393,000	18,000	411,000	196	2,952

[a] GROUND WATER RECHARGE SYSTEM.

[b] THE SIGNIFICANT REDUCTION OF FLOOD CARRYING CAPACITY OF THE MILWAUKEE RIVER CHANNEL WITH THE CONCOMITANT INCREASE IN THE RISK OF FLOOD DAMAGES WITH THIS STORAGE ALTERNATIVE AND THE EXTREME DISRUPTION OF EXISTING URBAN DEVELOPMENT WHICH WOULD OCCUR DURING CONSTRUCTION OF THE PROPOSED RESERVOIRS WERE DEFICIENCIES THAT WERE CONSIDERED TO BE SO SERIOUS THAT THIS ALTERNATIVE WAS NOT FULLY EVALUATED AND, THEREFORE, NO COST ESTIMATES WERE PREPARED.

[c] PRELIMINARY INVESTIGATION INDICATED THAT THE VOLUME OF SEWAGE STORAGE REQUIRED WOULD BE GREATER THAN THE SPACE AVAILABLE BENEATH THE EXISTING WATERFRONT STRUCTURES AND PIERS. THIS DEFICIENCY WAS CONSIDERED TO BE SO SERIOUS THAT THIS ALTERNATIVE WAS NOT FULLY EVALUATED AND, THEREFORE, NO COST ESTIMATES WERE PREPARED.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

tanks would be 20 cfs, or about 20 percent of the 0. 8 full capacity of the existing intercepting sewer through which the stored sewage would eventually be routed.

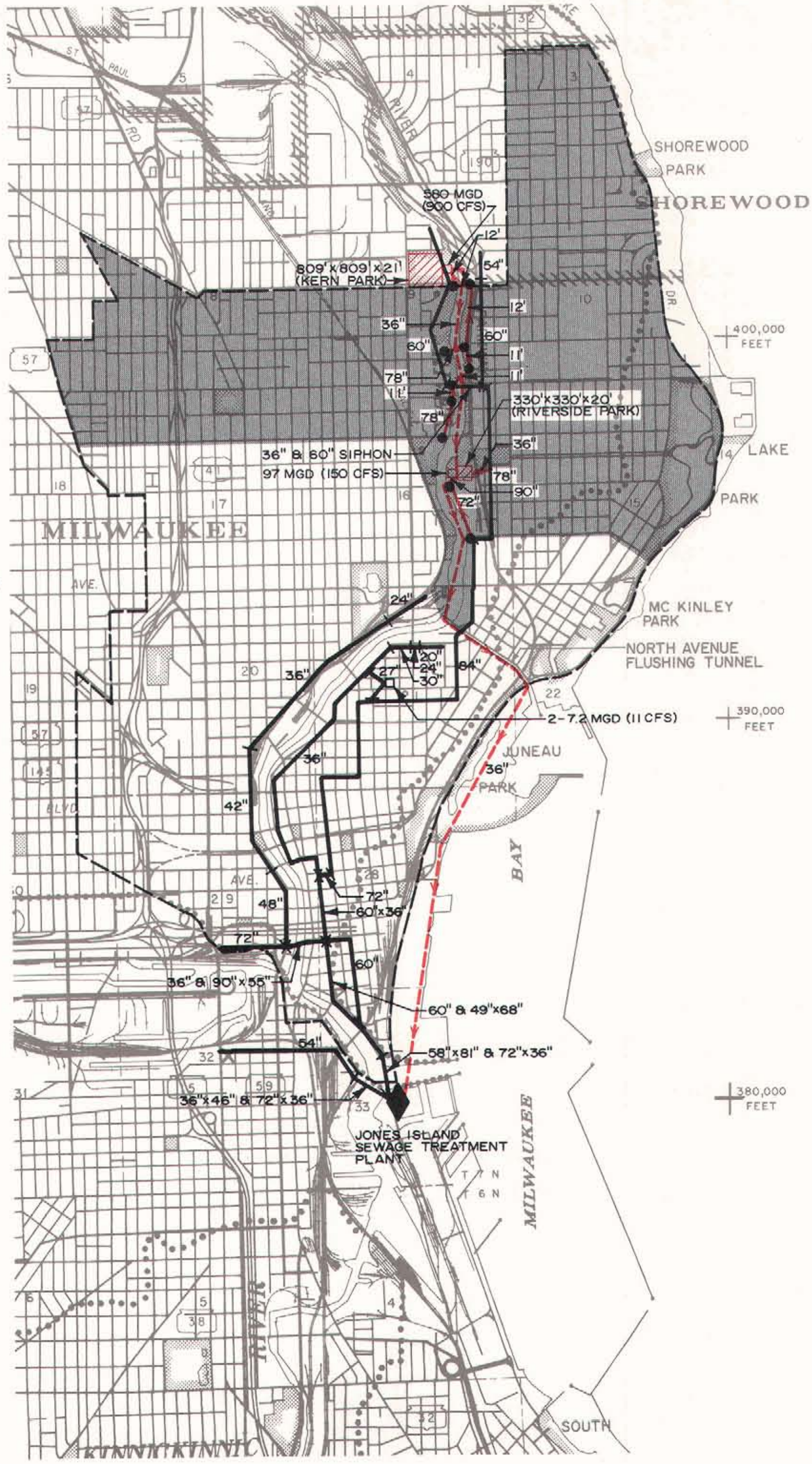
This alternative would entail an estimated initial capital cost of $26.0 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $1.9 million, or $906 per acre served. The present worth of this alternative for 50 years at 6 percent interest is $30.0 million (see Table 41). These cost estimates include the costs of all required construction, operation, and maintenance, except for treatment facilities and land. No land acquisition costs would be entailed, since the conveyance facilities would be located in the river beds and the storage tanks under existing public park lands.

An alternative to the evacuation of the stored sewage through the existing intercepting sewers to the Jones Island sewage treatment plant would be to construct a separate conveyance facility for such evacuation in the form of a 36-inch diameter gravity flow pipeline having a capacity of 20 cfs from the storage tanks along the bed of the Milwaukee River, through the existing North Avenue flushing tunnel, and thence through publicly owned lands along the shore of Lake Michigan to Jones Island. The cost of this alternative conveyance facility is estimated at $1.8 million. No land acquisition costs would be entailed.

Map 20

COMBINED SEWAGE STORAGE ALTERNATIVES IA AND IB

BURIED CONCRETE STORAGE TANKS UNDER PARKS--2,100 ACRE COMBINED SEWER SERVICE AREA



The first alternative combined sewer overflow pollution abatement plan element considered in the watershed is based upon the use of small concrete storage tanks buried under existing park lands along the Milwaukee River. Overflows would be intercepted, stored in these tanks, and later released for treatment at the Jones Island sewage treatment plant either through the existing intercepting sewer system or through a new conveyance pipe. Because of the lack of conveniently located open sites below the dam, this alternative was evaluated only with respect to the 2,100-acre combined sewer service area located upstream from the North Avenue Dam. Because the storage tanks would be buried, this alternative was considered to have excellent aesthetic characteristics and, hence, an excellent potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

This storage alternative would meet the state-established water use objectives for the Milwaukee River above the North Avenue Dam assuming that pollution from the separate sanitary sewer overflow devices outside the combined sewer area is controlled by the trunk and relief sewer construction program of the Milwaukee-Metropolitan Sewerage Commissions and by relief sewer construction programs in the local municipalities served by the Commissions. Water use objectives would not be met below the North Avenue Dam. This alternative was considered to have a relatively low potential for disrupting the existing urban environment, would have no adverse aesthetic effects, and was considered to have a relatively high potential for public acceptance. As noted above, however, this alternative would not be applicable to either the entire 5,800-acre combined sewer service area in the Milwaukee River watershed or to the entire 17,200-acre Milwaukee combined sewer service area because of space limitations. This alternative would have potential, should it ever be needed, for application to the control of overflows from the separate sanitary sewers in the watershed, with the required storage tanks being located in Lincoln and Estabrook Parks.

Alternative 2—Floating Concrete Storage Tanks in Lake Michigan: The second storage alternative considered for abatement of the pollution from the combined sewer overflows was the provision of floating concrete storage tanks anchored in Lake Michigan outside the Milwaukee Harbor breakwater. There would be no practical limitation on the amount of storage space which could be provided under this alternative; and this alternative would, therefore, be applicable to the 2,100- and 5,800-acre combined sewer service areas in the Milwaukee River watershed, to the entire 17,200-acre Milwaukee combined sewer service area, and to the control of overflows from the separate sanitary sewers, should that ever be necessary. Only its applicability to the smaller combined sewer service areas in the watershed, however, was examined in the initial screening process.

With respect to the 2,100-acre combined sewer service area located upstream from the North Avenue Dam, this alternative would intercept overflows from the 10 existing combined sewer outfalls upstream from the Dam and convey the overflow sewage by gravity flow in reinforced concrete pipes buried in the river bed and by way of the existing North Avenue flushing tunnel to floating reinforced concrete storage tanks located outside the north shore connected harbor breakwater (see Map 21). The gravity flow conveyance would be constructed of precast reinforced concrete pipe, 12 to 17 feet in diameter, and would have a capacity ranging from 750 to 1,050 cfs.

Each of the floating concrete tanks would be 50 feet wide by 100 feet long by 21 feet deep. A total of 153 tanks would be required to store 350 acre-feet, or 2 inches of runoff, from the 2,100-acre combined sewer service area. The tanks would be fastened by connectors to form a single unit 1,600 feet long by 500 feet wide enclosed within a diked area. When empty, the tanks would float with their tops 10 feet above lake level. When full, the tanks would rest on the anchorage bottom. The anchorage for the tanks would be enclosed by a breakwater to prevent wave damage to the tanks. The depth of the water in the anchorage would be approximately 20 feet, so that, even when full, the tops of the tanks would be above lake level. The tanks could be disassembled and floated to other locations for other uses as changing needs might dictate.

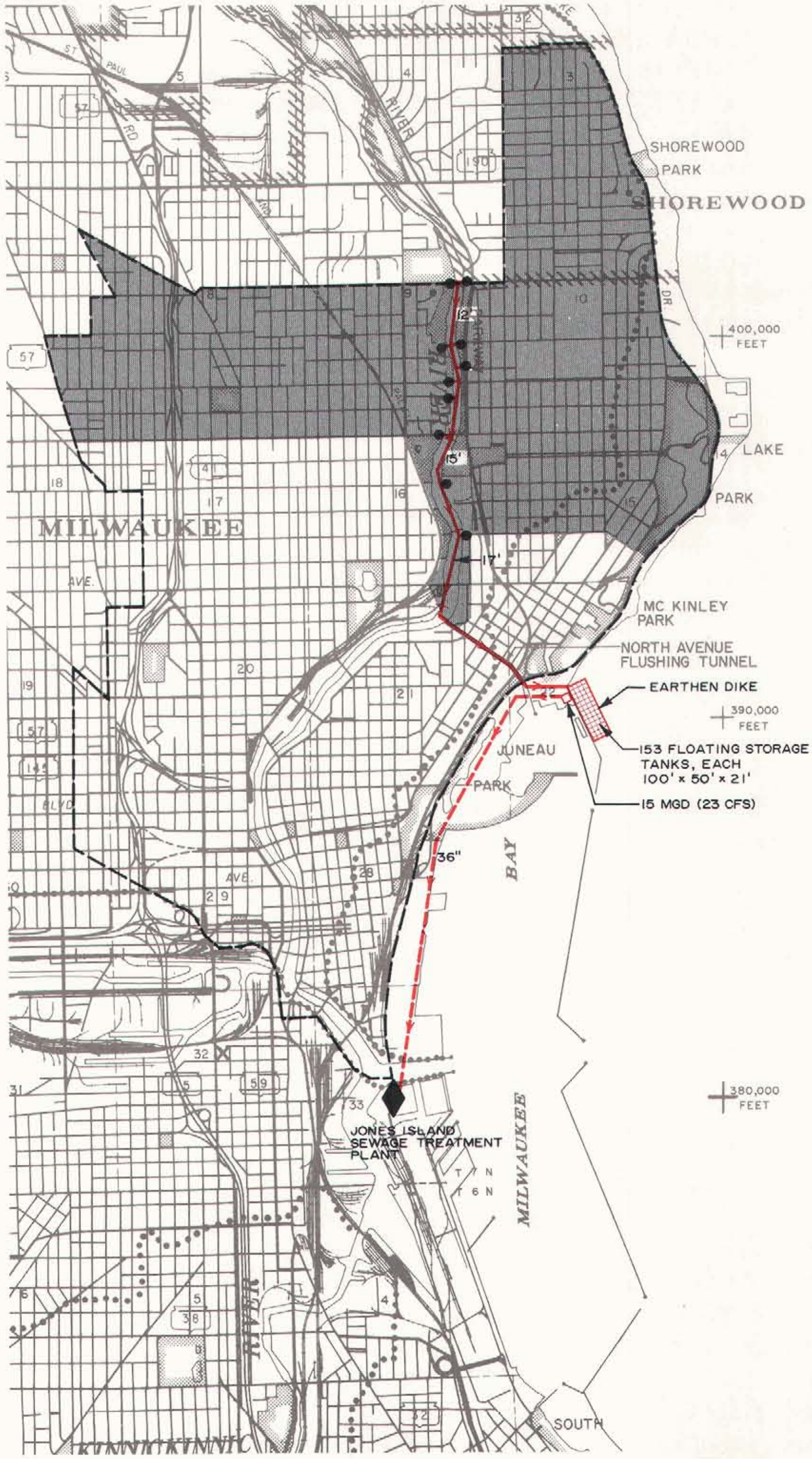
The tanks would be equipped with an aeration system which would provide agitation to avoid the need for mechanical cleaning devices in the tanks and sufficient oxygen to maintain aerobic conditions in the stored sewage. The stored sewage would be conveyed to the Jones Island sewage treatment plant through a 36-inch diameter gravity flow sewer constructed of reinforced concrete pipe and located along the lake shoreline. A 15 mgd (23 cfs) lift station would be required at the tank anchorage to lift the sewage from the conveyance pipe and distribute it to the floating tanks.

This alternative for the 2,100-acre combined sewer service area would entail an estimated initial capital cost of $40.0 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $2.7 million, or $1,295 per acre served. The present worth for this alternative for 50 years at 6 percent interest is $43.0 million. These estimates include the costs of all required construction, operation, and maintenance, except for treatment facilities and land (see Table 41). No land acquisition costs would be entailed, since the conveyance facilities would be located in the river bed and lake bottom or on publicly owned lands and since the storage tanks would be anchored in the lake.

Map 21

COMBINED SEWAGE STORAGE ALTERNATIVE 2A

FLOATING CONCRETE STORAGE TANKS IN LAKE MICHIGAN -- 2,100 ACRE COMBINED SEWER SERVICE AREA



LEGEND

- 5,800 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED
- 2,100 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED UPSTREAM OF THE NORTH AVENUE DAM
- COMBINED SEWER OUTFALL
- PROPOSED OVERFLOW CONVEYANCE CONDUIT TO TEMPORARY STORAGE TANKS
- PROPOSED OVERFLOW CONVEYANCE CONDUIT TO SEWAGE TREATMENT PLANT
- PROPOSED LIFT STATION

GRAPHIC SCALE
0 2000 4000 6000 FEET

The second alternative combined sewer overflow pollution abatement plan element considered is based upon the use of floating concrete storage tanks anchored in Lake Michigan outside the Milwaukee Harbor breakwater near the McKinley Park marina. The combined sewer overflows would be intercepted at the outfall points and conveyed to the floating storage tanks. When the tanks were empty they would float with their tops about 10 feet above the surface of Lake Michigan. When full, the tanks would rest on the lake bottom. The stored sewage would, as treatment plant capacity became available, be conveyed to the Jones Island sewage treatment plant through a new conveyance pipe located along the lake shoreline. The above map illustrates how this alternative would be applied to the 2,100-acre combined sewer service area above the North Avenue Dam. Because of the relatively poor aesthetic characteristics created by the visual impact of permanent floating tanks in Lake Michigan, this alternative was considered to have a relatively poor potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

With respect to the 5,800-acre combined sewer service area in the Milwaukee River watershed, this alternative would intercept overflows from all 62 existing combined sewer outfalls located along the Milwaukee River (see Map 22) and convey such flows by gravity to a lift station located at the storage tanks. This lift station would have a capacity of 18,900 kilowatts to lift 2,900 cfs from the conveyance pipe and distribute the sewage to the floating tanks. The conveyance pipes would be constructed of reinforced concrete pressure pipe, 12 to 17 feet in diameter, and have capacities ranging from 750 to 2,900 cubic feet per second. A total of 423 storage tanks would be required to store 967 acre-feet, or 2 inches of runoff, over the 5,800-acre tributary combined sewer service area. The floating platform formed by the top of the tanks would measure about 1,000 feet by 2,200 feet.

The stored sewage would be pumped to the Jones Island sewage treatment plant back through the inflow conveyance conduit at a maximum rate of 59 cubic feet per second, or 38 mgd. The pumping plant would serve the dual purpose of pumping the discharge from the storage tanks to the Jones Island sewage treatment plant and of lifting the overflows from the conveyance pipe from the 5,800-acre combined sewer service area into the storage tanks. The conveyance pipe from the 2,100-acre combined sewer service area would operate by gravity flow.

This alternative for the 5,800-acre combined sewer service area would entail an estimated capital cost of $124.2 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $8.7 million, or $1,503 per acre served. The present worth of this alternative for 50 years at 6 percent interest is $137.4 million. These estimates include the costs of all required construction, operation, and maintenance, except for treatment facilities and land (see Table 41). No land acquisition costs would be entailed, since the conveyance facilities would be located in the river bed and lake bottom and on publicly owned lands and the storage tanks would be anchored in the lake.

If applied to the 2,100-acre combined sewer service area, this storage alternative would meet the state-established water use objectives for the Milwaukee River above, but not below, the North Avenue Dam, assuming that pollution from the separate sanitary sewer overflows devices outside the combined sewer service area is controlled by the trunk and relief sewer construction program of the Milwaukee-Metropolitan Sewerage Commissions and by relief sewer construction programs in the local municipalities served by the Commissions. If applied to the entire 5,800-acre combined sewer service area in the Milwaukee River watershed, this storage alternative would meet the state-established water use objectives for the Milwaukee River both above and below the North Avenue Dam. As noted above, this alternative would also be applicable to the entire 17,200-acre Milwaukee combined sewer service area and to the control of overflows from the separate sanitary sewers, should this ever be necessary. This alternative was considered to have a relatively low potential for disrupting the existing urban environment for the 2,100-acre combined sewer service area and a moderately high potential for disruption for the 5,800- and 17,200-acre service areas due to the disruption of river traffic in the Lower Milwaukee River. It would have relatively poor aesthetic characteristics because of the visual impact of the floating tanks in Lake Michigan and was considered to have a relatively poor potential for public acceptance.

Alternative 3—Collapsible Rubber Storage Tanks along the Milwaukee River: The third storage alternative considered for abatement of the pollution from the combined sewer overflows was the provision of flexible butyl rubber storage tanks located at the combined sewer outfalls along the Milwaukee River. Because it would be extremely difficult to find sufficient site areas for such tanks in the reaches of the Milwaukee River below the North Avenue Dam, this storage alternative was considered to be applicable only to the 2,100-acre combined sewer service area located upstream from the Dam.

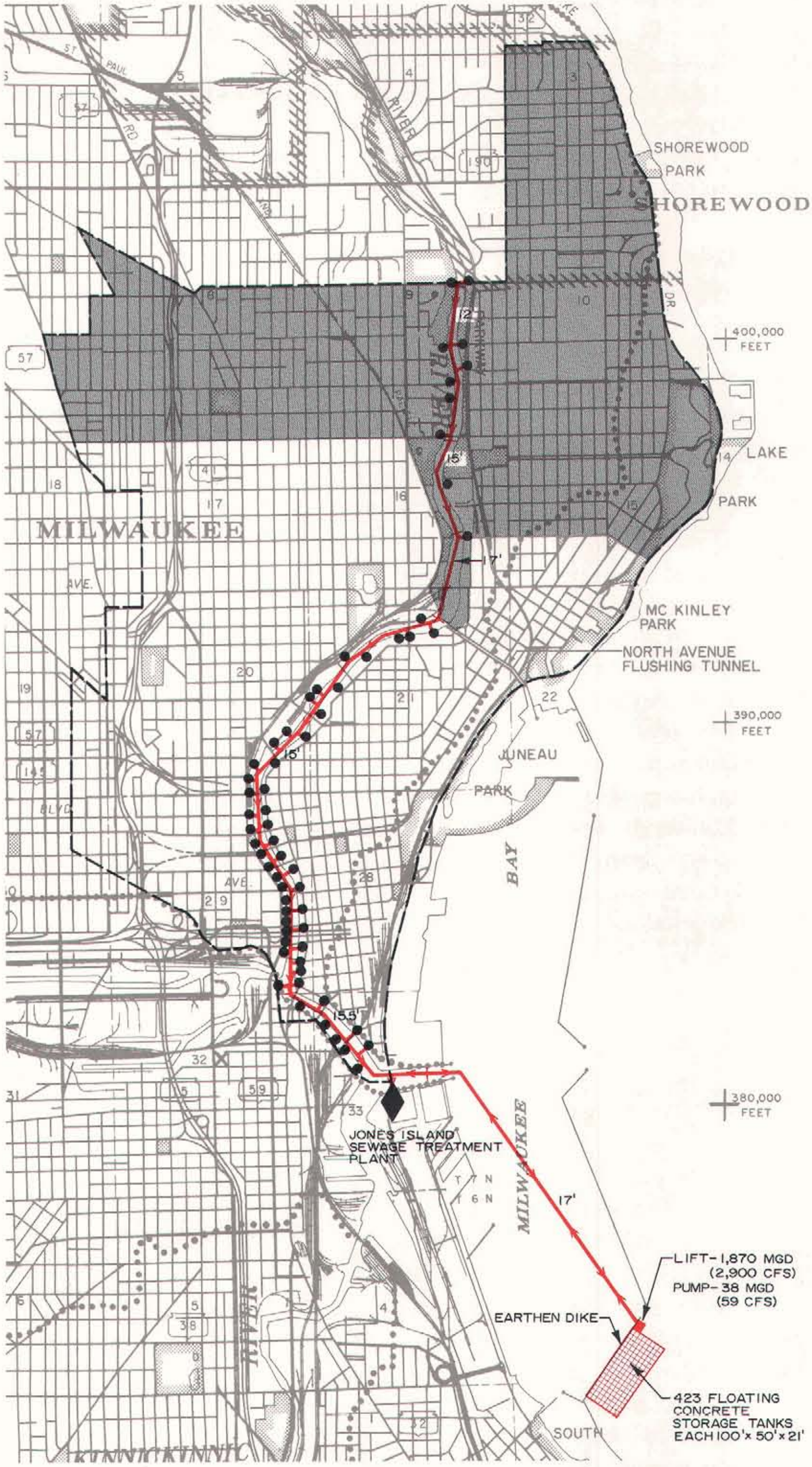
In this alternative, flexible rubber storage tanks supported by earthen dikes would be provided at each of the 10 existing combined sewer outfalls located upstream from the North Avenue Dam. The sewage overflows would be intercepted and raised by lift stations into the tanks. Each of the 10 lift stations would have a capacity of 140 kilowatts to lift approximately 105 cfs from the combined sewer outfall into the storage tank. Each rubber tank, when full, would measure about 115 feet square and 12 feet deep. According to information provided by the Firestone Coated Fabrics Company of Akron, Ohio,[3]

[3] *Communication to Harza Engineering Company from Firestone Coated Fabrics Company, Akron, Ohio, July 1969.*

Map 22

COMBINED SEWAGE STORAGE ALTERNATIVE 2B

FLOATING CONCRETE STORAGE TANKS IN LAKE MICHIGAN -- 5,800 ACRE COMBINED SEWER SERVICE AREA



LEGEND

- 5,800 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED
- 2,100 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED UPSTREAM OF THE NORTH AVENUE DAM
- COMBINED SEWER OUTFALL
- PROPOSED OVERFLOW CONVEYANCE CONDUIT TO TEMPORARY STORAGE TANKS AND TO SEWAGE TREATMENT PLANT
- PROPOSED LIFT AND PUMPING STATION

GRAPHIC SCALE
0 2000 4000 6000 FEET

This map illustrates how the floating concrete storage tank combined sewer overflow pollution abatement alternative would be applied to the entire 5,800-acre combined sewer service area tributary to the Milwaukee River. All combined sewer overflows at the 62 outfall points along the river would be collected in a new gravity flow sewer and conveyed to the storage tanks located near South Shore Park for temporary storage until the sewage could be released for treatment at the Jones Island sewage treatment plant. Because of the relatively poor aesthetic characteristics created by the visual impact of permanent floating tanks in Lake Michigan, this alternative was considered to have a relatively poor potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

such tanks would be the largest size which could be expected to be available in the foreseeable future. Storage for the 350 acre-feet of runoff above the North Avenue Dam would require 114 tanks and a total site area of 90 acres. The rubber tanks would be equipped with aeration facilities to provide agitation and sufficient oxygen to maintain aerobic conditions in the stored overflows and avoid the need for sedimentation removal.

The stored sewage would flow by gravity from the rubber tanks by way of existing combined sewers into an existing intercepting sewer as capacity became available and by gravity via this sewer to the existing Jones Island sewage treatment plant for treatment (see Map 23). This storage alternative would entail an estimated initial capital cost of $13.0 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $1.1 million, or $512 per acre served. The present worth of this alternative for 50 years at 6 percent interest is $17.0 million (see Table 41). These cost estimates include the costs of all required lands, construction, operation, and maintenance, except for treatment facilities. Land costs are estimated at $450,000.

An alternative to the evacuation of the stored sewage through the existing intercepting sewers to the Jones Island sewage treatment plant would be to construct a separate conveyance facility for such evacuation in the form of a 36-inch diameter gravity flow pipeline having a capacity of 20 cfs from the rubber storage tanks along the bed of the Milwaukee River, through the existing North Avenue flushing tunnel, and thence through publicly owned lands along the shore of Lake Michigan to Jones Island. The cost of this alternative conveyance facility is estimated at $1.8 million. No land acquisition costs would be entailed.

This storage alternative would meet the water use objectives for the Milwaukee River above the North Avenue Dam, assuming that pollution from the separate sanitary sewer overflow devices outside the combined sewer area is controlled by the trunk and relief sewer construction program of the Milwaukee-Metropolitan Sewerage Commissions and by relief sewer construction programs in the local municipalities served by the Commissions. Water use objectives would not be met below the North Avenue Dam. This alternative was considered to have a low potential for disrupting the existing urban environment, would have relatively poor aesthetic characteristics because of the visual impact of the rubber tanks, and was considered to have only a relatively fair potential for public acceptance. As noted above, this alternative would not be applicable to either the total 5,800-acre combined sewer service area in the Milwaukee River watershed or the entire 17,200-acre Milwaukee combined sewer service area because of space limitations, nor to the control of overflows from the separate sanitary sewers, should such control ever be necessary.

Alternative 4—Buried Concrete Storage Tanks under the Milwaukee River: The fourth storage alternative considered for abatement of the pollution from the combined sewer overflows was the provision of a long, sinuous, reinforced concrete storage tank with a rectangular cross section buried in the bed of the Milwaukee River. This storage alternative would be applicable to the 2,100- and the 5,800-acre combined sewer service areas in the Milwaukee River watershed and to the entire 17,200-acre Milwaukee combined sewer service area, as well as to the storage of overflows from the separate sanitary sewers. Only the applicability of this alternative to the smaller combined sewer service areas in the watershed, however, was examined in the initial screening process of the watershed study.

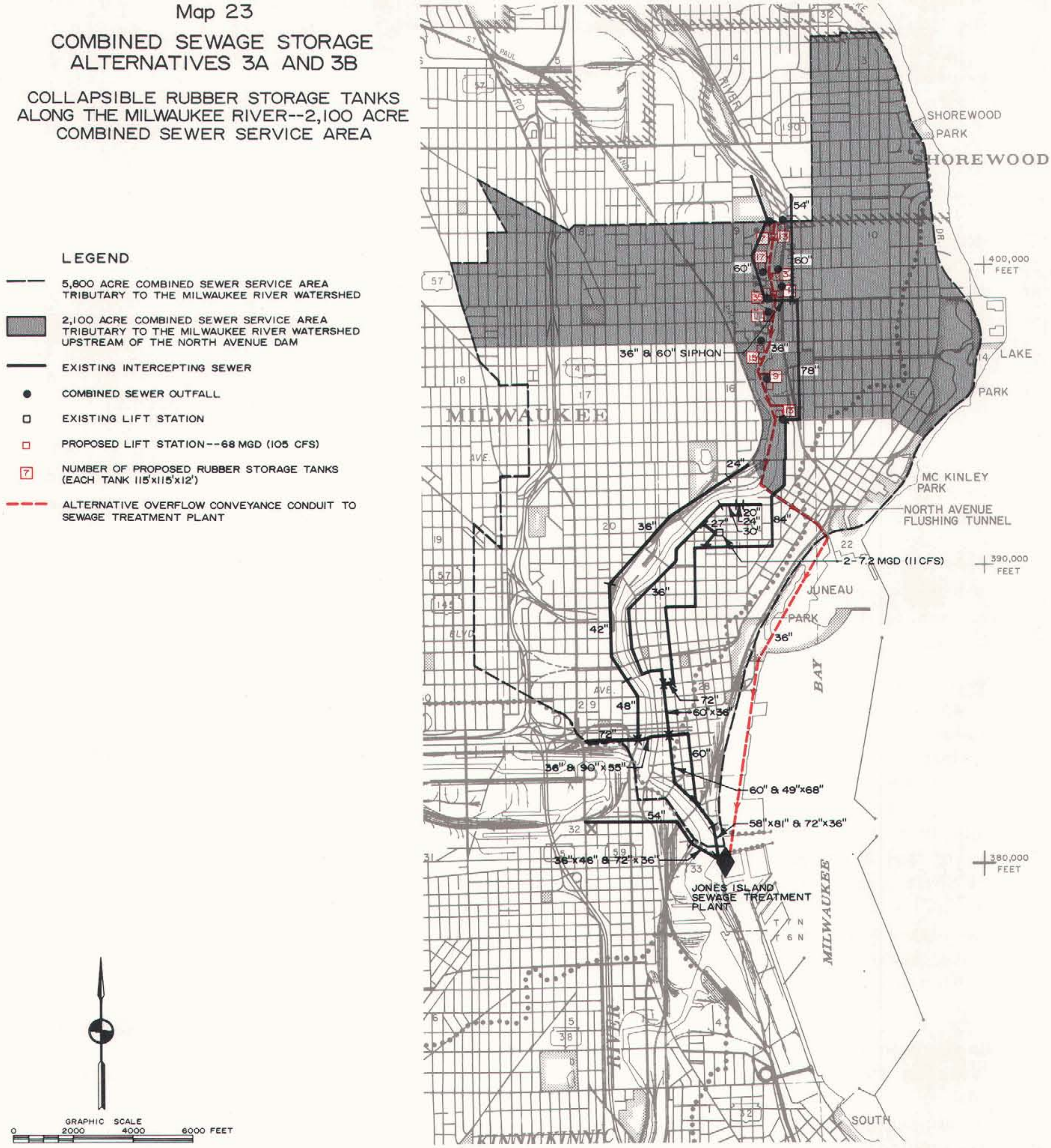
With respect to the 2,100-acre combined sewer service area located upstream from the North Avenue Dam, this alternative would intercept overflows from the 10 existing combined sewer outfalls and convey the overflow sewage by gravity flow directly into the storage tank. The tank would extend along the river for a distance of about 9,100 feet from Keefe Avenue to the North Avenue Dam (see Map 24). The tank would be 84 feet wide and 20 feet high. A sump with a small cross-sectional area would be formed along the bottom of the tank to facilitate cleaning and conveyance of the stored sewage to the evacuation point. The tank would be buried below the bottom of the channel so that the present channel flow capacities would be maintained. The tank would be equipped with aeration facilities to provide agitation to avoid the need for cleaning facilities and sufficient oxygen to maintain aerobic conditions in the stored overflows.

The stored sewage would be pumped from the buried concrete tank to an existing intercepting sewer as capacity became available and conveyed by gravity via this sewer to the Jones Island

Map 23

COMBINED SEWAGE STORAGE ALTERNATIVES 3A AND 3B

COLLAPSIBLE RUBBER STORAGE TANKS ALONG THE MILWAUKEE RIVER--2,100 ACRE COMBINED SEWER SERVICE AREA



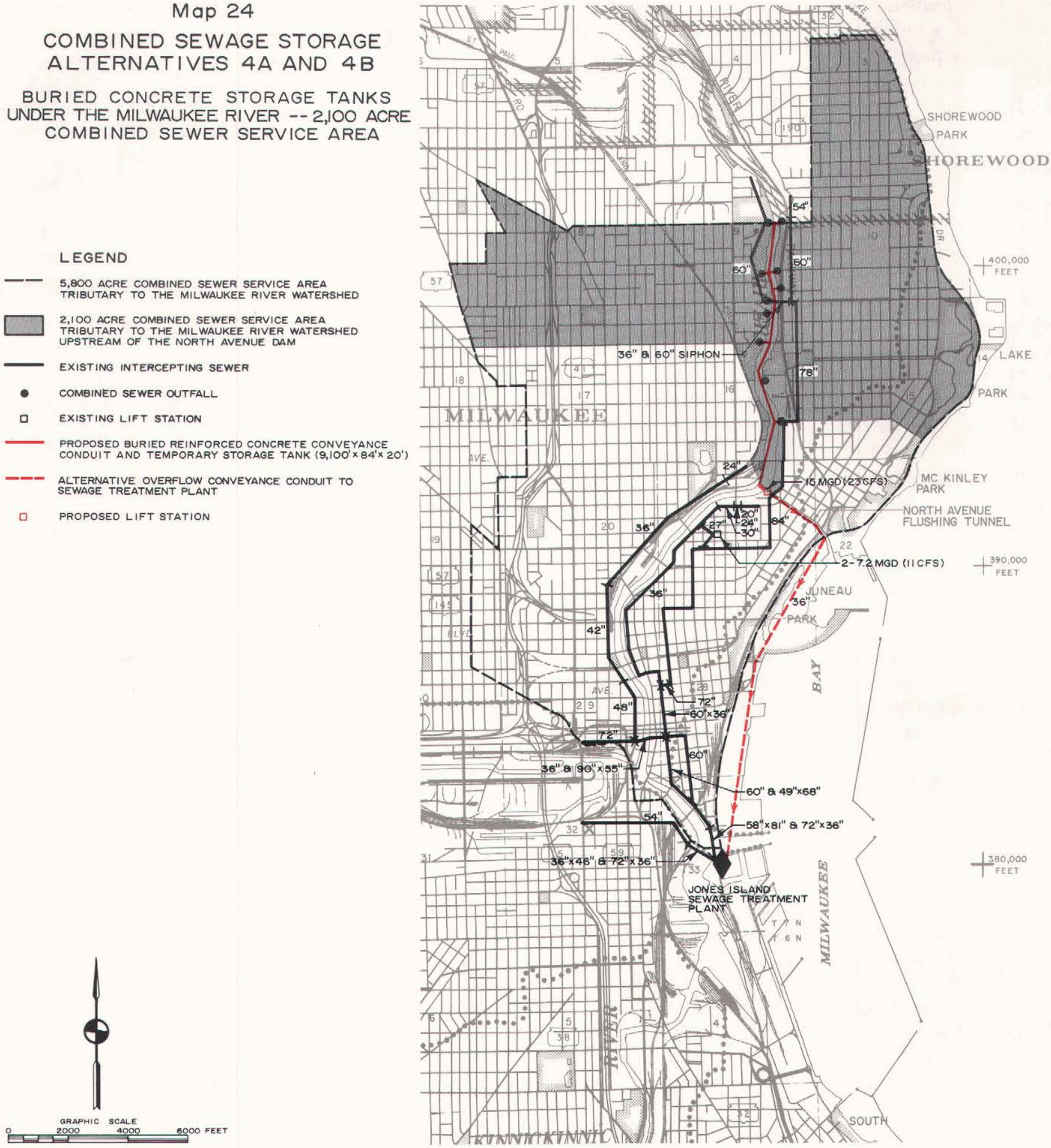
The third alternative combined sewer overflow pollution abatement plan element considered is based upon the use of flexible rubber storage tanks along the Milwaukee River banks to temporarily store combined sewer overflows. Because of space limitations, this alternative was considered to be applicable only to the 2,100-acre combined sewer service area upstream of the North Avenue Dam. Each rubber tank when full would measure about 115 feet square and 12 feet deep. Conveyance of the stored sewage to the Jones Island sewage treatment plant would be accomplished either through release to the existing intercepting sewers or through a new conveyance facility. This alternative would have relatively poor aesthetic characteristics because of the visual impact of the rubber tanks and was considered to have only a relatively fair potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

Map 24

COMBINED SEWAGE STORAGE ALTERNATIVES 4A AND 4B

BURIED CONCRETE STORAGE TANKS UNDER THE MILWAUKEE RIVER -- 2,100 ACRE COMBINED SEWER SERVICE AREA



The fourth alternative combined sewer overflow pollution abatement plan element considered is based upon the use of a long, sinuous, concrete storage tank buried in the bed of the Milwaukee River. The combined sewer overflows would be intercepted at the outfall points and stored in the tank for later release to the Jones Island sewage treatment plant. Conveyance to the treatment plant could be accomplished either through the existing intercepting sewer system or through a new conveyance pipe. The above map illustrates how this alternative would be applied to the 2,100-acre combined sewer service area above the North Avenue Dam.

Source: Harza Engineering Company and SEWRPC.

sewage treatment plant for treatment. The pumping station located at the downstream end of the tank would have a capacity of about 90 kilowatts to lift 23 cfs from the storage tank into the existing intercepting sewer.

This alternative for the 2,100-acre combined sewer service area would entail an estimated initial capital cost of $30.7 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $2.1 million, or $988 per acre served. The present worth of this alternative for 50 years at 6 percent interest is $32.7 million (see Table 41). These cost estimates include the cost of all required construction, operation, and maintenance, except for treatment facilities and land. No land acquisition costs would be entailed, since the tank would be located in the river bed.

An alternative to the evacuation of the stored sewage through the existing intercepting sewers to the Jones Island sewage treatment plant would be to construct a separate conveyance facility for such evacuation in the form of a 36-inch diameter gravity flow pipeline having a capacity of 20 cfs from the buried concrete storage tank along the bed of the Milwaukee River, through the existing North Avenue flushing tunnel, and thence through publicly owned lands along the shore of Lake Michigan to Jones Island. The cost of this alternative conveyance facility is estimated at $1.1 million. No land acquisition costs would be entailed.

With respect to the 5,800-acre combined sewer service area in the Milwaukee River watershed, this alternative would intercept overflows from all 62 existing combined sewer outfalls located along the Milwaukee River and convey the overflow sewage by gravity flow directly into a long, sinuous, reinforced concrete storage tank buried in the bed of the Milwaukee River. The tank would extend along the river for a distance of about 25,600 feet from Keefe Avenue to Jones Island and would be 83 feet wide and 21 feet high (see Map 25). The tank would not only provide the 967 acre-feet of storage required but would also serve as the primary conveyance from the combined sewer outfalls to the existing Jones Island sewage treatment plant. The tank would be buried below the bottom of the channel so that the present channel flow capacities would be maintained.

The stored sewage would be lifted to the Jones Island sewage treatment plant by a new lift station located at the downstream end of the tank at the Jones Island sewage treatment plant. This lift station would have a capacity of 503 kilowatts to lift 59 cfs of sewage from the storage tank to the sewage treatment plant. This alternative would entail an estimated initial capital cost of $83.5 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $5.6 million, or $958 per acre served (see Table 41). The present worth of this alternative for 50 years at 6 percent interest is $89.1 million. These cost estimates include the cost of all required construction, operation, and maintenance, except for treatment facilities and land. No land acquisition cost would be entailed, since the tank would be located in the river bed.

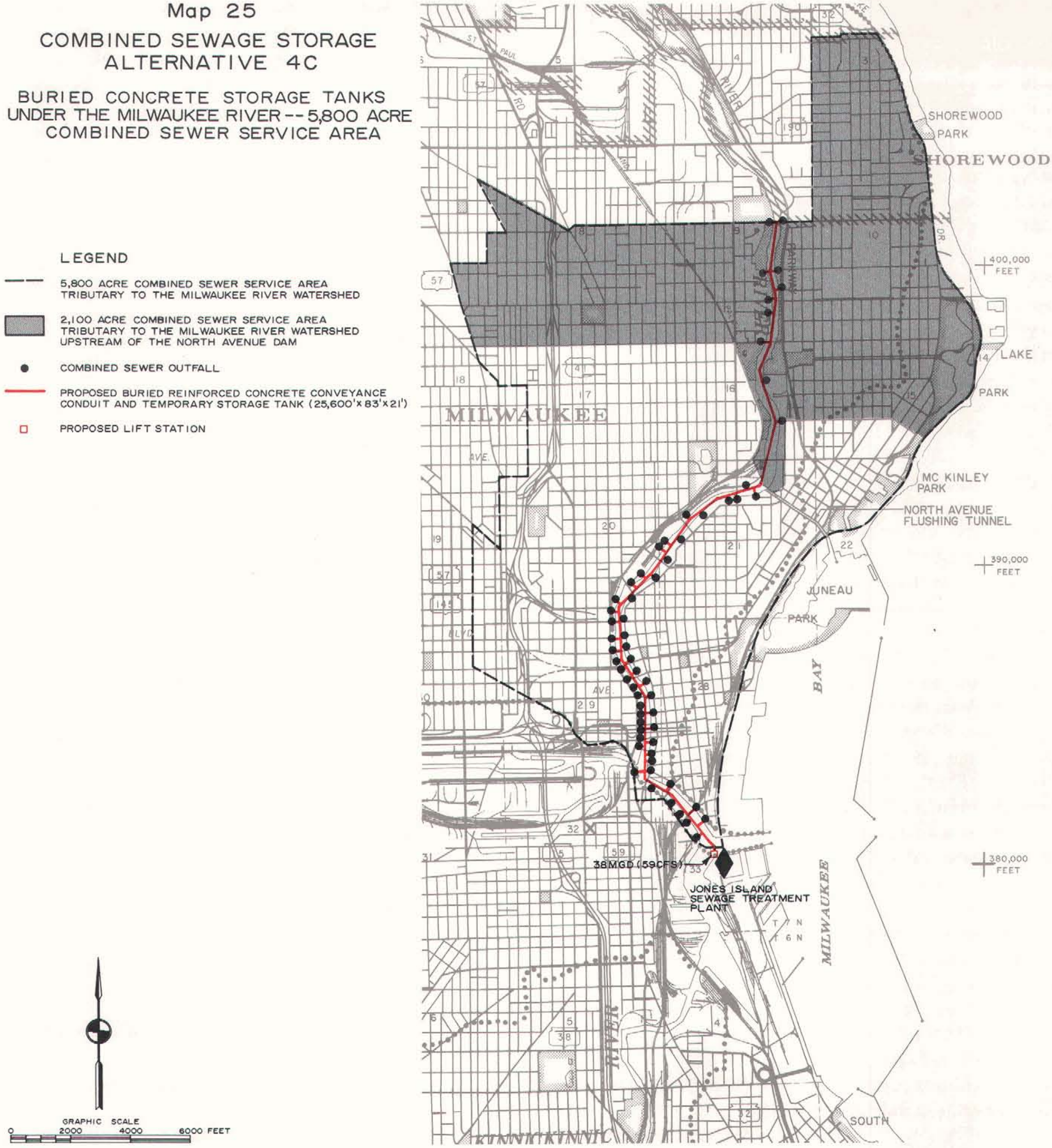
If applied to the 2,100-acre combined sewer service area, this storage alternative would meet the water use objectives for the Milwaukee River above the North Avenue Dam, assuming that pollution from the separate sanitary sewer overflow devices outside the combined sewer area is controlled by the trunk and relief sewer construction program of the Milwaukee-Metropolitan Sewerage Commissions and by relief sewer construction programs in the local municipalities served by the Commissions. Water use objectives would not be met below the North Avenue Dam. If applied to the entire 5,800-acre combined sewer service area in the Milwaukee River watershed, this storage alternative would meet the water use objectives for the Milwaukee River both above and below the North Avenue Dam. As noted above, this alternative would also be applicable to the entire 17,200-acre Milwaukee combined sewer service area and could also serve to store the overflows from the separate sanitary sewers should that ever be necessary. This alternative was considered to have a high potential for disrupting the urban environment if the river traffic were disrupted on the Lower Milwaukee River, would have no adverse aesthetic effects, and was considered to have a high potential for public acceptance.

<u>Alternative 5—Diked Storage Lagoon in Lake Michigan</u>: The fifth storage alternative considered for abatement of the pollution from the combined sewer overflows was the provision of an open storage reservoir or lagoon located in Lake Michigan. This storage alternative would have no practical restrictive space limitations and would,

Map 25

COMBINED SEWAGE STORAGE ALTERNATIVE 4C

BURIED CONCRETE STORAGE TANKS UNDER THE MILWAUKEE RIVER--5,800 ACRE COMBINED SEWER SERVICE AREA



A concrete storage tank buried in the river bed could also be used to abate pollution from combined sewer overflows from throughout the 5,800-acre combined sewer service area tributary to the Milwaukee River. Under this application, the long, sinuous, concrete storage tank buried in the bed of the river would not only provide the required storage of the combined sewer overflows but would also serve as the conveyance facility to the existing Jones Island sewage treatment plant. Because the entire concrete storage tank would be buried under the bed of the Milwaukee River, this alternative would have no adverse aesthetic effects and was considered to have a high potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

therefore, be applicable to both the 2,100- and 5,800-acre combined sewer service areas in the Milwaukee River watershed and the entire 17,200-acre Milwaukee combined sewer service area, as well as to storing the overflows from the separate sanitary sewer systems should this ever become necessary. Only its applicability to the smaller areas in the Milwaukee River watershed, however, was examined in the initial screening process.

With respect to the 2,100-acre combined sewer service area located upstream from the North Avenue Dam, this alternative would intercept overflows from the 10 existing combined sewer outfalls and convey the overflow sewage by means of a gravity flow reinforced concrete pipeline buried in the river bed and through the existing North Avenue flushing tunnel to the storage lagoon located in Lake Michigan (see Map 26). The conveyance pipes would be 12 to 17 feet in diameter and have capacities ranging from 750 to 1,050 cfs. The storage lagoon or reservoir would be located adjacent to, and outside of, the north shore connected harbor breakwater. It would extend along the breakwater for a distance of about 1,400 feet and would be 600 feet wide, with an average depth of 18 feet. The storage lagoon would have the capacity to store 350 acre-feet, or 2 inches of runoff, from the 2,100 acres of tributary combined sewer area. The core of the dike creating the storage lagoon would consist of a slurry trench seepage barrier. A hydraulic gradient would always exist from Lake Michigan into the lagoon, as the design water surface elevation of the lagoon would be below lake level. The lagoon would be equipped with an aeration system which would provide agitation to avoid the need for mechanical cleaning devices and sufficient oxygen to maintain aerobic conditions in the lagoon. The stored sewage would be lifted out of the storage lagoon by a lift station having a capacity of 91 kilowatts to lift 23 cfs of sewage into a 36-inch gravity flow pipeline located along the lakeshore line which would convey the stored sewage to the Jones Island sewage treatment plant for treatment.

This alternative for the 2,100-acre combined sewer service area would entail an estimated initial capital cost of $11.7 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $801,000, or $381 per acre served (see Table 41). The present worth of this alternative for 50 years at 6 percent interest is $12.7 million. These estimates include the cost of all required construction, operation, and maintenance, except for treatment facilities and land. No land acquisition costs would be entailed, since the conveyance pipes and the reservoir would be located on the river bed and the lake bottom.

With respect to the 5,800-acre combined sewer service area in the Milwaukee River watershed, this alternative would intercept overflows from all 62 existing combined sewer outfalls located along the Milwaukee River and convey the overflow sewage by means of a gravity flow reinforced concrete pipeline buried in the river bed to a combination lift and pumping station and storage lagoon located in Lake Michigan (see Map 27). The conveyance pipes would be 12 to 17 feet in diameter and have capacities ranging from 750 to 2,900 cfs. The storage reservoir or lagoon would be located adjacent to, and outside of, the main harbor breakwater. The lagoon would extend along the breakwater for a distance of about 1,775 feet and would be 700 feet wide, with an average depth of 34 feet. The lagoon would have the capacity to store 967 acre-feet, or 2 inches of runoff, from the 5,800 acres of tributary combined sewer area. The required lift station would have a capacity of about 18,900 kilowatts to lift 2,900 cfs from the sewage conveyance pipe into the storage lagoon.

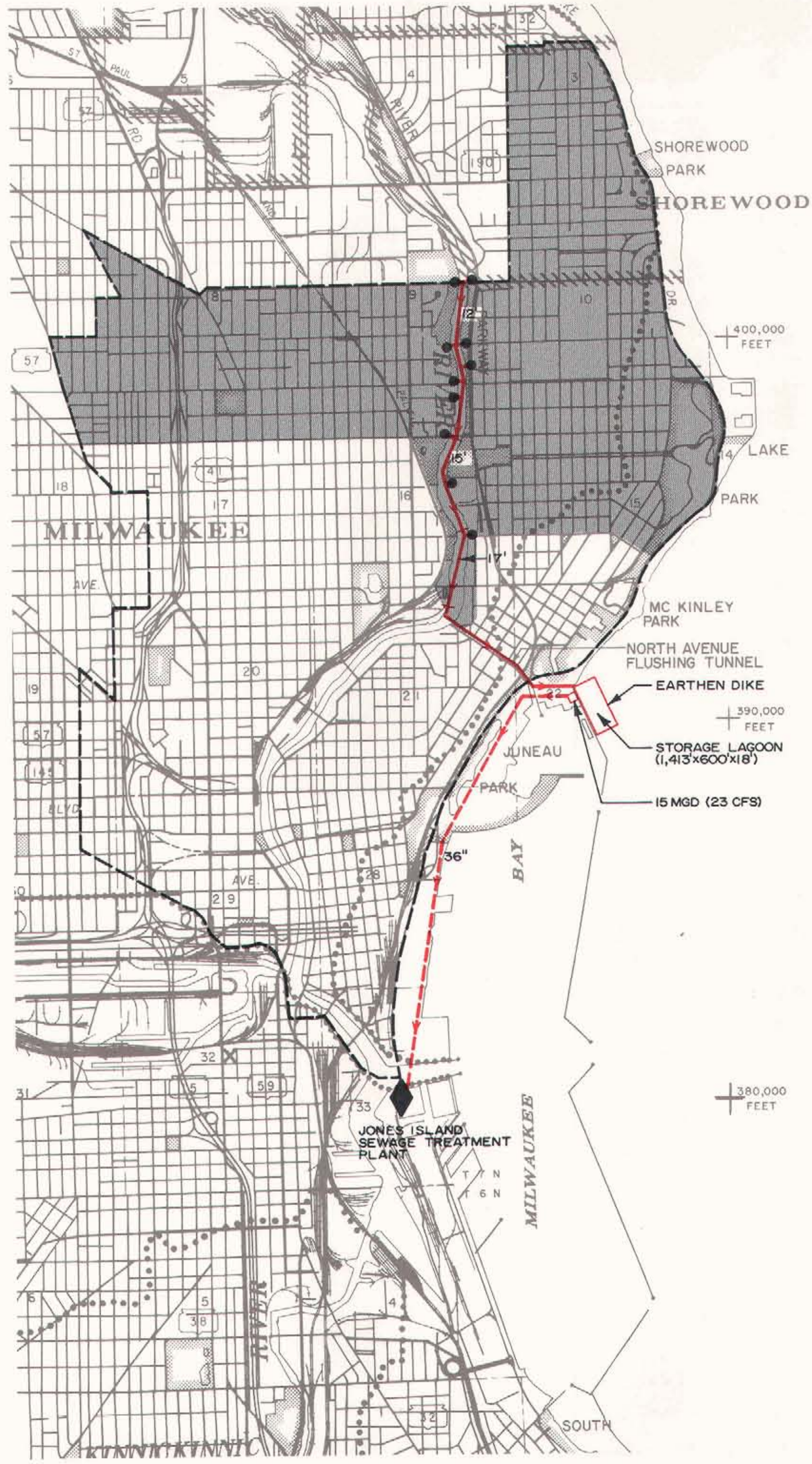
The combination lift and pumping station would serve the dual purpose of lifting the combined sewer overflows from the conveyance pipe into the storage lagoon and of pumping the stored sewage from the lagoon back through the conveyance pipe to the Jones Island sewage treatment plant. About 90 kilowatts of pumping capacity would be valved for use in evacuating flows from the lagoon to the Jones Island treatment plant at a maximum rate of 59 cfs.

This alternative for the 5,800-acre combined sewer service area would entail an estimated initial capital cost of $47.3 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $3.5 million, or $612 per acre served (see Table 41). The present worth of this alternative for 50 years at 6 percent interest is $55.9 million. These estimates include the cost of all required construction, operation, and maintenance, except for treatment facilities and land. No land acquisition costs would be entailed, since the conveyance pipes and the storage reservoir or lagoon would be located in the river bed and lake bottom.

Map 26

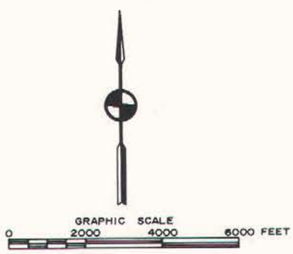
COMBINED SEWAGE STORAGE ALTERNATIVE 5A

DIKED STORAGE LAGOON IN LAKE MICHIGAN -- 2,100 ACRE COMBINED SEWER SERVICE AREA



LEGEND

- 5,800 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED
- 2,100 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED UPSTREAM OF THE NORTH AVENUE DAM
- COMBINED SEWER OUTFALL
- PROPOSED OVERFLOW CONVEYANCE CONDUIT TO DIKED STORAGE LAGOON
- PROPOSED OVERFLOW CONVEYANCE CONDUIT TO SEWAGE TREATMENT PLANT
- PROPOSED LIFT STATION



The fifth alternative combined sewer overflow pollution abatement plan element considered is based upon the use of an open storage reservoir or lagoon in Lake Michigan to temporarily store the combined sewer overflows, with eventual release for treatment to the Jones Island sewage treatment plant. This map illustrates how this alternative could be applied to the 2,100-acre combined sewer service area upstream from the North Avenue Dam. The storage lagoon would be created by a dike containing a seepage barrier to prevent the stored overflows from entering Lake Michigan prior to the treatment. This alternative was considered to have very poor aesthetic characteristics because of the visual impact of the lagoons in Lake Michigan and was, therefore, considered to have a very poor potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

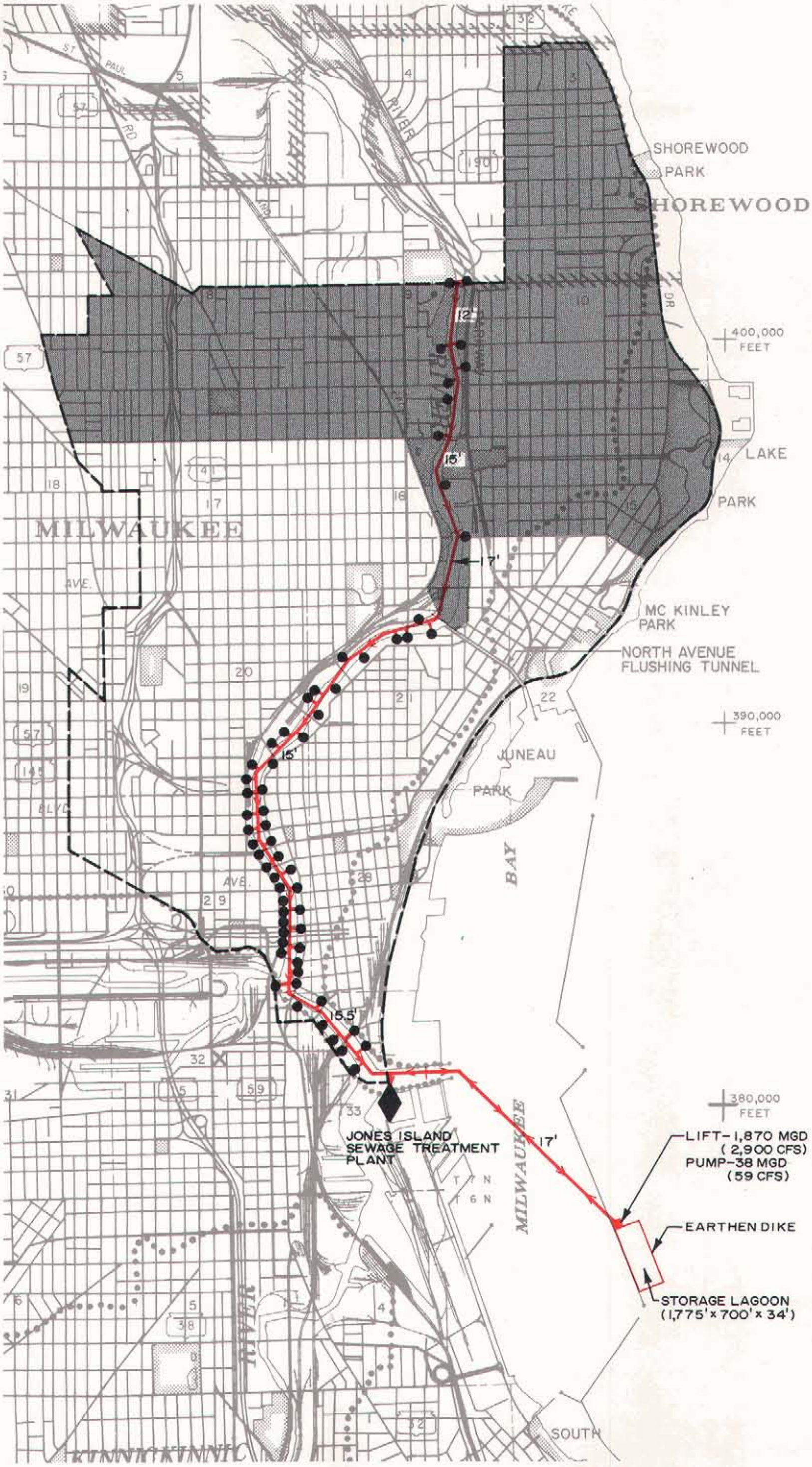
Map 27

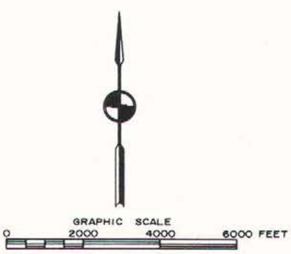
COMBINED SEWAGE STORAGE ALTERNATIVE 5B

DIKED STORAGE LAGOON IN LAKE MICHIGAN -- 5,800 ACRE COMBINED SEWER SERVICE AREA

LEGEND

- 5,800 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED
- 2,100 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED UPSTREAM OF THE NORTH AVENUE DAM
- COMBINED SEWER OUTFALL
- PROPOSED OVERFLOW CONVEYANCE CONDUIT TO DIKE STORAGE LAGOON
- PROPOSED LIFT AND PUMPING STATION





The application of the diked storage lagoon concept to the 5,800-acre combined sewer service area is shown on this map. While this alternative is technically feasible, it would have very poor aesthetic characteristics because of the visual impact of the lagoons in Lake Michigan and was, therefore, considered to have a very poor potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

If applied to the 2,100-acre combined sewer service area, this storage alternative would meet the water use objective for the Milwaukee River above the North Avenue Dam, assuming that pollution from the separate sanitary sewer overflow devices outside the combined sewer service area is controlled by the trunk and relief sewer construction program of the Milwaukee-Metropolitan Sewerage Commissions and by relief sewer construction programs in the local municipalities served by the Commissions. The water use objectives would not be met below the North Avenue Dam. If applied to the entire 5,800-acre combined sewer service area in the Milwaukee River watershed, this storage alternative would meet the water use objectives for the Milwaukee River both above and below the North Avenue Dam. As noted above, this alternative would also be applicable to the entire 17,200-acre Milwaukee combined sewer service area and would be capable of storing the overflows from the separate sanitary sewers. This alternative was considered to have a moderately high potential for disrupting the existing urban environment in the construction of the conveyance facilities below the North Avenue Dam, would have very poor aesthetic characteristics because of the visual impact of the lagoons in Lake Michigan, and was considered to have very poor potential for public acceptance.

Alternative 6—Buried Concrete Storage Tank in Maitland Field: The sixth storage alternative considered for the abatement of pollution from the combined sewer overflows was the provision of a reinforced concrete storage tank or reservoir buried under lands formerly used for the now abandoned Maitland Field airport. This storage alternative would be applicable to both the 2,100- and 5,800-acre combined sewer service areas in the Milwaukee River watershed and the entire 17,200-acre Milwaukee combined sewer service area, as well as to storing the separate sanitary sewer overflows, should that ever become necessary. Only its applicability to the 5,800-acre combined sewer service area in the Milwaukee River watershed was, however, examined in the initial screening process.

Under this alternative, overflows from the 62 existing combined sewer outfalls located along the Milwaukee River would be conveyed by gravity flow in reinforced concrete pipes buried in the river bed to a combination lift and pumping station and underground storage tank buried under Maitland Field (see Map 28). The conveyance pipes would be 12 to 17 feet in diameter and have capacities ranging from 750 to 2,900 cfs.

The combination lift and pumping station located at Maitland Field would have a capacity of 10,700 kilowatts to lift 2,900 cfs into the underground reservoir. About 90 kilowatts of pumping plant capacity would be valved for use in evacuating flows from the storage tank through a 48-inch force main to the Jones Island sewage treatment plant at a maximum rate of 59 cfs. The buried concrete reservoir would be 1,000 feet square and 42 feet deep and, with a capacity of 967 acre-feet, would be able to store two inches of runoff from the 5,800-acre combined sewer service area in the Milwaukee River watershed. The storage tank would be equipped with aeration facilities to provide agitation and sufficient oxygen to maintain aerobic conditions in the stored sewage during the maximum storage period of 11 days.

This alternative for the 5,800-acre combined sewer service area would entail an estimated initial capital cost of $78.3 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $5.5 million, or $946 per acre served (see Table 41). The present worth of this alternative for 50 years at 6 percent interest is $86.5 million. These cost estimates include the cost of all required construction, operation, and maintenance, except for treatment facilities and land. No land acquisition costs would be entailed, since the top of the tank would be covered with 5 feet of soil to permit continued use of Maitland Field for various public purposes.

As applied to the entire 5,800-acre combined sewer service area in the Milwaukee River watershed, this alternative would meet the state-established water quality objectives for the Milwaukee River, both above and below the North Avenue Dam. As noted above, this alternative would also be applicable to the entire 17,200-acre Milwaukee combined sewer service area. This alternative was considered to have a moderately high potential for disrupting the existing urban environment due to the construction of the conveyance facilities in the Lower Milwaukee River, would have no adverse aesthetic effect, and was considered to have an excellent potential for public acceptance.

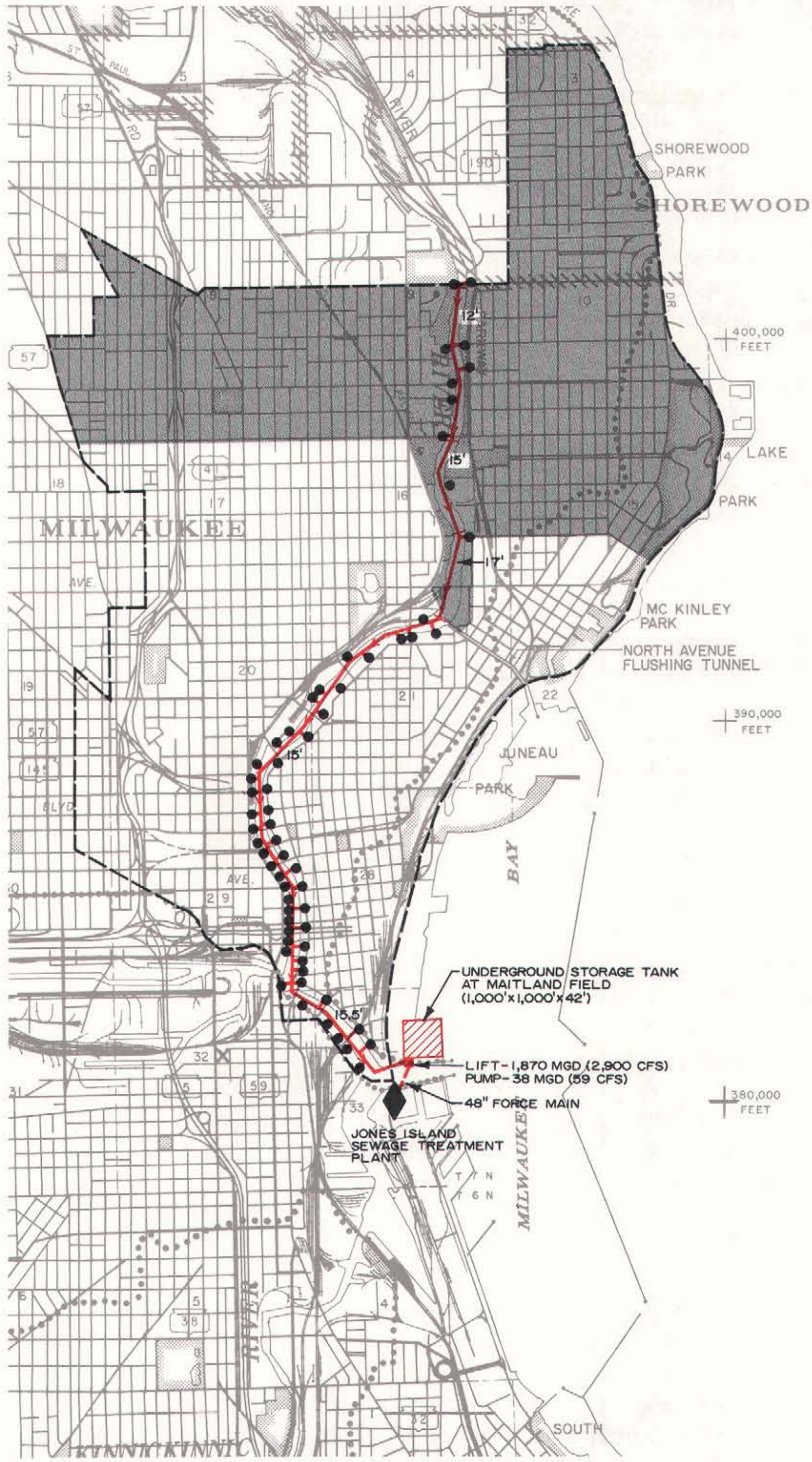
Map 28

COMBINED SEWAGE STORAGE ALTERNATIVE 6

BURIED CONCRETE STORAGE TANK UNDER MAITLAND FIELD--5,800 ACRE COMBINED SEWER SERVICE AREA

LEGEND

- 5,800 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED
- 2,100 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED UPSTREAM OF THE NORTH AVENUE DAM
- COMBINED SEWER OUTFALL
- PROPOSED OVERFLOW CONVEYANCE CONDUIT TO TEMPORARY STORAGE TANK
- PROPOSED OVERFLOW CONVEYANCE CONDUIT TO SEWAGE TREATMENT PLANT
- PROPOSED LIFT AND PUMPING STATION



GRAPHIC SCALE
0 2000 4000 6000 FEET

The sixth alternative combined sewer overflow pollution abatement plan element considered in the study is based upon the use of buried concrete storage tanks located under lands formerly used for the now abandoned Maitland Field Airport. This alternative as applied to the 5,800-acre combined sewer service area tributary to the Milwaukee River is shown on this map. The stored sewage would be released for treatment to the Jones Island sewage treatment plant. This alternative would have no adverse aesthetic effects and was considered to have an excellent potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

Alternative 7—Deep Tunnel Conveyance and Mined Storage Beneath the Milwaukee Harbor or Diked Surface Storage Reservoir: The seventh storage alternative considered for abatement of the pollution from the combined sewer overflows was the provision of a mined storage area located in the limestone bedrock beneath the Milwaukee Harbor near the existing Jones Island sewage treatment plant. This storage alternative would have no practical space limitations and would, therefore, be applicable to both the 2,100- and 5,800-acre combined sewer service areas in the Milwaukee River watershed and the entire 17,200-acre Milwaukee combined sewer service area, as well as to storing the overflows from the separate sanitary sewers, should this ever become necessary. Only its applicability to the 5,800-acre combined sewer service area was, however, examined in the initial screening process.

With respect to the 5,800-acre combined sewer service area in the Milwaukee River watershed, this alternative would intercept overflows from all 62 existing combined sewer outfalls located along the Milwaukee River by conveying the overflow sewage through vertical shafts into a deep tunnel intercepting sewer constructed in the Niagara dolomite limestone at an elevation from 250 to 350 feet below the land surface. The deep tunnel would convey the sewage overflows by gravity flow to a mined storage area located beneath the harbor near Jones Island (see Map 29). The conveyance tunnels would be 6 to 13 feet in diameter and have capacities ranging from 600 to 2,900 cfs. The mined storage area would consist of tunnels excavated through the limestone bedrock in a grid pattern and would have a combined storage capacity of 967 acre-feet, adequate to store two inches of runoff from the 5,800-acre combined sewer service area in the watershed.

The mined storage area would be equipped with aeration facilities to provide agitation and sufficient oxygen to maintain aerobic conditions in the stored sewage during the maximum storage period of 11 days. A lift station would be located in the mined storage area to lift the stored sewage to the Jones Island sewage treatment plant. The lift station would have a capacity of about 3,000 kilowatts to lift the stored sewage at a rate of 59 cfs.

A groundwater recharge system could be provided if exfiltration from the storage chambers resulting in groundwater pollution was found to be a problem. This groundwater recharge system would consist of a well system for artificial recharge of the aquifer surrounding the storage chambers to prevent any leakage of polluted water from the mined chambers into the aquifer. The cost of this recharge system is included in the cost estimates set forth in Table 41.

The injected water could be drawn in raw or untreated form from Lake Michigan and would not exceed the mineral content of the water occurring in the shallow limestone aquifer. The amount of recharge required would be relatively small, but the recharge facilities on which the cost estimates are based could provide up to 6 mgd. The injected water could also be provided from the City of Milwaukee public water supply system.

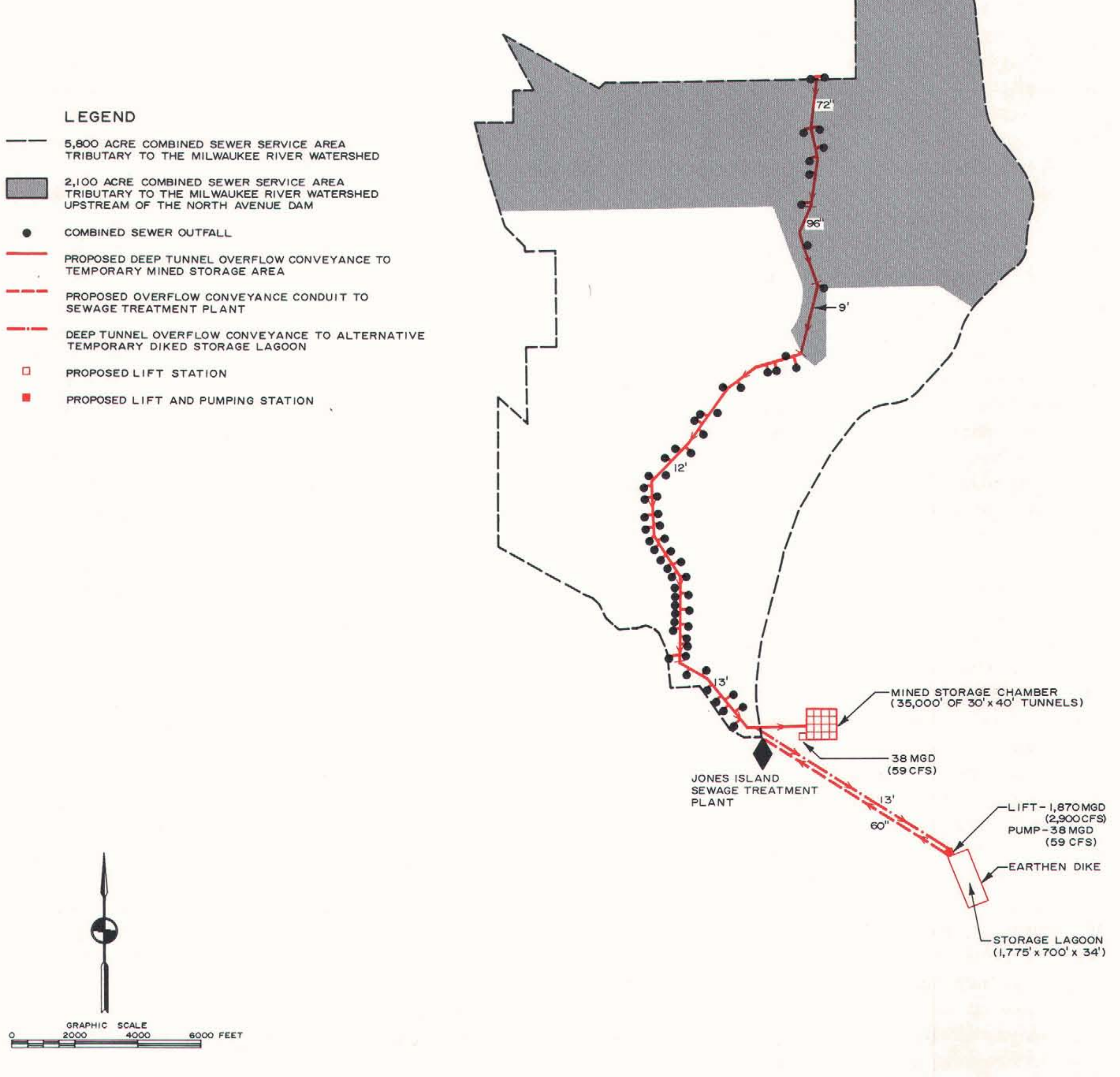
This storage alternative would entail an estimated initial capital cost of $54.7 million, inclusive of the cost of an aquifer protection system, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $3.8 million, or $651 per acre served. The present worth of this alternative for 50 years at 6 percent interest is $59.5 million (see Table 41). These cost estimates include the cost of all required construction, operation, and maintenance, except for treatment facilities. No land acquisition cost would be entailed, since the conveyance tunnels would be located beneath the river and since the mined storage areas would be located under Lake Michigan.

A variation of this storage alternative would convey the sewage overflows from the 62 existing combined sewer outfalls located along the Milwaukee River by the deep tunnels through the limestone bedrock to surface storage reservoirs located in Lake Michigan along the Milwaukee Harbor breakwater (see Map 29). These surface storage reservoirs would be similar to the diked storage lagoons discussed above under Alternative No. 5. Large two-way pumping facilities would be required as a part of this alternative plan element costing over $83 million, with the pumps capable of lifting 1,870 mgd into the surface reservoirs from the conveyance tunnels. This alternative would entail an estimated initial capital cost of $128.7 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $9.9 million, or $1,702 per acre served. The present worth of this alternative for 50 years at 6 percent interest is $155.6 million (see Table 41). These cost estimates include the cost of all required construc-

Map 29

COMBINED SEWAGE STORAGE ALTERNATIVES 7A AND 7B

DEEP TUNNEL CONVEYANCE AND MINED STORAGE UNDER THE MILWAUKEE HARBOR -- 5,800 ACRE COMBINED SEWER SERVICE AREA



The seventh alternative combined sewer overflow pollution abatement plan element considered in the study would intercept overflows from all combined sewer outfall points located along the Milwaukee River through the use of vertical shafts and a deep tunnel sewer constructed in the Niagara dolomite limestone about 300 feet below the land surface. This deep tunnel would convey the overflows to either a mined storage area located beneath the harbor near Jones Island or to surface storage reservoirs located in Lake Michigan along the Milwaukee Harbor breakwater. A ground water recharge system would be provided to prevent any leakage of stored sewage from the mined storage chambers into the ground water aquifer. This alternative would have no adverse aesthetic effects except if the Lake Michigan lagoons were used for storage instead of the mined storage area, and was, therefore, considered to have an excellent potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

tion, operation, and maintenance, except for treatment facilities. As in the mined storage alternative, no land acquisition costs would be entailed, since the conveyance tunnels would be located beneath the river and since the storage lagoons would be located in Lake Michigan.

If applied to the entire 5,800-acre combined sewer service area in the Milwaukee River watershed, this storage alternative would meet the water use objectives for the Milwaukee River both above and below the North Avenue Dam. As noted above, this alternative would also be applicable to the entire 17,200-acre Milwaukee combined sewer service area. This alternative was considered to have relatively low potential for disrupting the existing urban environment; would have no adverse aesthetic effects, except if the Lake Michigan lagoons were used for storage instead of the mined storage area; and was considered to have an excellent potential for public acceptance, except if the Lake Michigan lagoons were used for storage instead of the mined storage area.

Alternative 8—Open Storage Reservoirs along the Milwaukee River Banks: The eighth storage alternative considered for abatement of pollution from the combined sewer overflows was the provision of open storage reservoirs along the banks of the Milwaukee River and separated from the river by a concrete wall or an earthen dike. As such, the open reservoirs would act both as a storage tank and as a conveyance structure. A major deficiency of this storage alternative is that the flood carrying capacity of the Milwaukee River channel would be significantly reduced by the reservoirs with a concomitant increase in the risk of flood damage. A second major deficiency in the construction of such reservoirs would be the extreme disruption to existing urban development during the reservoir construction. These deficiencies were considered to be so serious that this alternative was not fully evaluated; and, therefore, no cost estimates were prepared.

Alternative 9—Storage under Piers and Waterfront Structures: The ninth storage alternative considered for abatement of the pollution from the combined sewer overflows was the provision of storage tanks under piers and other waterfront structures located along the lower reaches of the Milwaukee River. This alternative would intercept overflows from all 62 existing combined sewer outfalls located along the Milwaukee River and convey these overflows by means of a gravity flow reinforced concrete pipeline buried in the river bottom to the harbor area for storage under piers and waterfront structures, as indicated above. The required conveyance pipes for this alternative would be similar to those required under Alternative No. 6, the buried concrete storage tank located in Maitland Field. Preliminary investigation indicated that the volume of sewage storage required would be greater than the space available beneath the existing waterfront structures and piers. This deficiency was so serious that this alternative was not fully evaluated; and, therefore, no cost estimates were prepared.

Alternative 10—Conveyance of Sewage to North Avenue Dam for Release to the Milwaukee River: The tenth storage alternative considered for abatement of the pollution from the combined sewer overflows was the conveyance of such overflows to the North Avenue Dam and the subsequent discharge to the Milwaukee River below the Dam. This alternative would be applicable only to the 2,100-acre combined sewer service area located upstream from the North Avenue Dam. Overflows from the 10 existing combined sewer outfalls located upstream from the Dam would be conveyed by gravity flow in a 12- to 17-foot diameter concrete pipeline having a capacity ranging from 750 to 1,050 cfs and buried beneath the river bed. This pipeline would discharge to the Milwaukee River at a point below the North Avenue Dam (see Map 30). In effect, this alternative would involve no actual storage of the combined sewage overflows; however, it could subsequently be connected to an ultimate storage system.

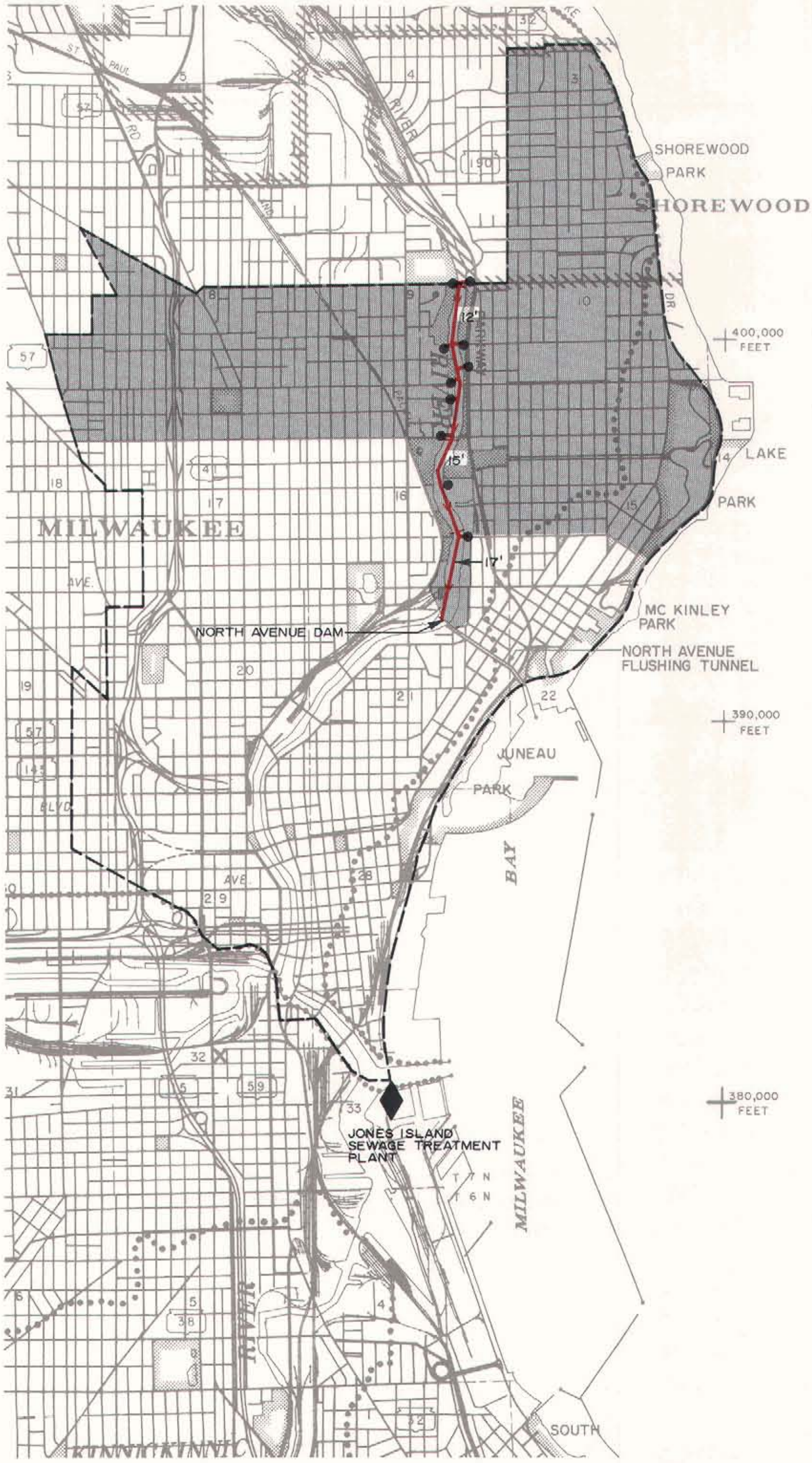
This alternative for the 2,100-acre combined sewer service area would entail an initial capital cost of $6.2 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $0.4 million, or $196 per acre served. The present worth of this alternative for 50 years at 6 percent interest is $6.5 million (see Table 41). These cost estimates include the cost of all required construction, operation, and maintenance, except for treatment facilities and land. No land acquisition cost would be entailed, since the pipeline would be located in the river bed.

This storage alternative would meet the water use objectives for the Milwaukee River above the North Avenue Dam assuming that pollution from the separate sanitary sewer overflows outside the combined sewer service area is controlled by the

Map 30

COMBINED SEWAGE STORAGE ALTERNATIVE 10

CONVEYANCE OF SEWAGE TO NORTH AVENUE DAM FOR RELEASE TO THE MILWAUKEE RIVER -- 2,100 ACRE COMBINED SEWER SERVICE AREA



LEGEND

- 5,800 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED
- 2,100 ACRE COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER WATERSHED UPSTREAM OF THE NORTH AVENUE DAM
- COMBINED SEWER OUTFALL
- PROPOSED OVERFLOW CONVEYANCE CONDUIT TO DISCHARGE POINT IN THE MILWAUKEE RIVER BELOW THE NORTH AVENUE DAM

GRAPHIC SCALE
0 2000 4000 6000 FEET

The tenth alternative combined sewer overflow pollution abatement plan element considered in the study would simply collect and convey the combined sewer overflows from the 10 outfall points located upstream from the North Avenue Dam for subsequent release to the Milwaukee River below the Dam. While this alternative would meet the water use objectives for the Milwaukee River above the dam, it would not contribute toward meeting the objectives for the river below the dam, nor would it contribute to the protection of the water quality of Lake Michigan.

Source: Harza Engineering Company and SEWRPC.

trunk and relief sewer construction program of the Milwaukee-Metropolitan Sewerage Commissions and by relief sewer construction programs in the local municipalities served by the Commissions. The water quality objectives would not be met below the North Avenue Dam.

Flow-Through or In-Flow Treatment Alternatives

A total of three different alternative plan elements were considered for abatement of the pollution from combined sewer overflows in the Milwaukee River watershed by providing flow-through or in-flow treatment of the combined sewer overflows. These three alternatives were: 1) the Allis-Chalmers rotating biological contactor, 2) the Rex Chainbelt screening/dissolved-air flotation system, and 3) instream treatment (see Table 42). The first two of the three alternatives involve the construction of small "flow-through" sewage treatment plants at each combined sewer outfall or at a common outfall of a number of existing outfalls connected for treatment purposes. These small treatment plants would reduce organic pollution from the combined sewer overflows by removing a portion of the settleable solids and by stabilizing the oxygen-demanding organic materials in the sewage. Experimental operation of small-scale prototypes of these facilities for several years has yielded mixed results. One of the systems, however—the Rex Chainbelt screening/dissolved-air flotation system—appears capable of providing the levels of treatment required. The characteristics, performance, and, where applicable, the costs of the two alternative flow-through treatment systems considered for the abatement of pollution from combined sewer overflows in the watershed are described below. In addition, a third alternative is described—namely, the provision of aeration equipment in the Lower Milwaukee River to provide instream treatment designed to maintain a dissolved oxygen level that would support a balanced aquatic community.

Alternative 11—Allis-Chalmers Rotating Biological Contactor: The first flow-through treatment alternative considered for the abatement of pollution from the combined sewer overflows in the Milwaukee River watershed was the installation of rotating biological contactor treatment facilities at all of the 62 combined sewer outfalls located along the river. The Allis-Chalmers Manufacturing Company of Milwaukee undertook a test and development program on this particular method of flow-through treatment in 1967, terminating the program in 1970. A demonstration facility was constructed at S. 8th and W. Montana Streets in Milwaukee, Wisconsin, near the outfall of a 30-inch diameter combined sewer which overflows to the Kinnickinnic River at that location. The service area of this combined sewer consisted of 30 acres of residential land use and five acres of light

Table 42

PRELIMINARY COST ESTIMATES--ALTERNATIVE COMBINED SEWER OVERFLOW FLOW-THROUGH AND IN-FLOW TREATMENT POLLUTION ABATEMENT PLAN ELEMENTS FOR THE LOWER MILWAUKEE RIVER WATERSHED

Alternative Plan Element		Combined Sewer Service Area Served (acres)	Capital Cost (Construction)							
Number Designation	Description		Structural	Aero Flotation Equipment and Installation	Instrumentation	Lift Pump Equipment and Minor Sewer Connections	Conveyance Pipes and Minor Sewer Connections	Land and Landscaping	River Aeration Equipment	Total
11	Allis-Chalmers Rotating Biological Contactor[a]	5,800	$ --	$ --	$ --	$ --	$ --	$ --	$ --	$ --
12	Rex Chainbelt Screening/ Dissolved-Air Flotation System	5,800	11,450,000	13,810,000	5,170,000	4,620,000	2,010,000	2,010,000	1,790,000	47,220,000
13	In-Stream Treatment[b]	5,800	--	--	--	--	--	--	--	--

Alternative Plan Element		Combined Sewer Service Area Served (acres)	Present Worth (1970-2020)			Equivalent Annual				
Number Designation	Description		Construction	Operation and Maintenance	Total	Construction	Operation and Maintenance	Total	Annual Cost per Acre	Capital Cost per Acre
11	Allis-Chalmers Rotating Biological Contactor[a]	5,800	$ --	$ --	$ --	$ --	$ --	$ --	$ --	$ --
12	Rex Chainbelt Screening/ Dissolved-Air Flotation System	5,800	57,670,000	12,100,000	69,770,000	3,660,000	770,000	4,430,000	764	8,141
13	In-Stream Treatment[b]	5,800	--	--	--	--	--	--	--	--

[a] Preliminary information from the Allis-Chalmers Manufacturing Company concerning the results of a demonstration project utilizing this flow through treatment system indicates that the demonstration program did not prove the process to be an effective alternative for abating pollution from combined sewer overflows. Consequently, no further evaluating of this alternative was made nor were cost estimates prepared.

[b] This alternative for treatment of combined sewer overflows was not considered applicable to the Milwaukee River, as procedures for treating such a large flow of water to the high standards required, particularly for removal of phosphorus, would be difficult or impossible to achieve operationally at an economic cost. Consequently, no further evaluation of this alternative was made nor were cost estimates prepared.

Source- Harza Engineering Company and SEWRPC.

industrial land use, with a total population equivalent of about 1,000 people. The objective of the demonstration was to determine the applicability of using power-driven rotating discs as the housing media for biological growths. The growths would provide biological treatment of the wastes in contact with the discs in a manner similar to conventional trickling filters. Although laboratory tests had indicated that, even with greatly shortened detention periods, the degree of treatment would be equivalent to conventional secondary sewage treatment methods, the results obtained during the demonstration project were disappointing.

The bio-discs afforded relatively effective treatment at the dry-weather flow (DWF) of about 35 gallons per minute. At multiples of 300 to 400 times DWF encountered during wet weather, however, the contact time provided with the discs was only a few minutes; and treatment was not effective. If the system were to be made effective, storage would be required to reduce the maximum flow to less than 30 times DWF.[4] Performance of the demonstration facility was intended to be measured in terms of suspended solids and biochemical oxygen demand removal for varying sewer discharge rates. During the demonstration it was observed that, with 60 to 90 minutes detention time, all ammonia was nitrified. Removal of phosphorus was not considered as an objective of the demonstration program; and, consequently, no data on phosphorus removal are available.

Although a final report has not been issued for the demonstration project, preliminary information now available from the Allis-Chalmers Manufacturing Company indicates that the demonstration program did not prove the process to be an effective alternative for abating pollution from combined sewer overflows. Consequently, no further evaluation of this alternative was made; nor were cost estimates prepared.

Alternative 12—Rex Chainbelt Screening/Dissolved-Air Flotation System: The second flow-through treatment alternative considered for abatement of the pollution from the combined sewer overflows in the Milwaukee River watershed was the installation of permanent screening/dissolved-air flotation treatment facilities at each of, or at combinations of, the 62 combined sewer outfalls located along the Milwaukee River.

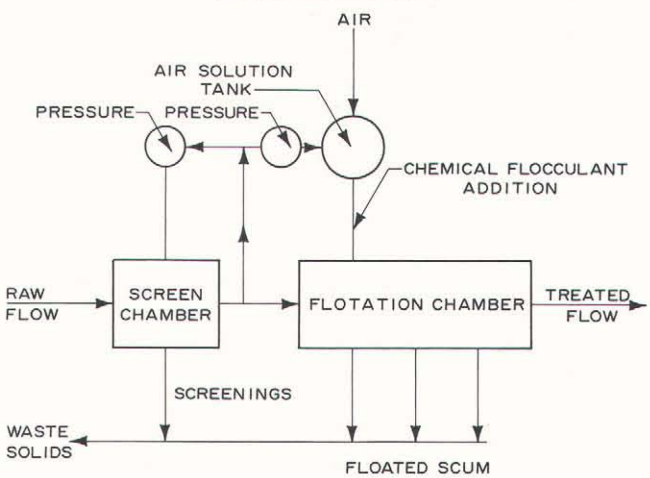
This flow-through treatment system, which has been developed on a demonstration basis by the Ecology Division of Rex Chainbelt, Inc., of Milwaukee, Wisconsin, basically consists of screen and flotation chambers operated in series (see Figure 17). The combined sewer overflow is

[4] *Communication to Harza Engineering Company from Mr. Paul Houriet, Allis-Chalmers Manufacturing Company, West Allis, Wisconsin, November 9, 1970.*

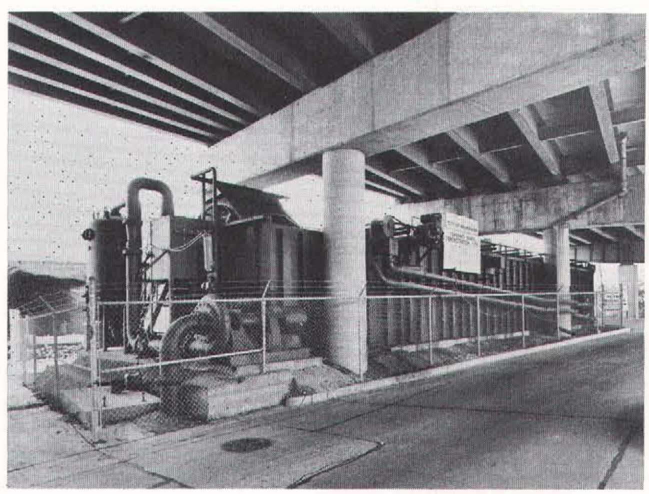
Figure 17

REX CHAINBELT SCREENING/DISSOLVED-AIR FLOTATION FLOW-THROUGH TREATMENT SYSTEM

FLOW DIAGRAM



ACTUAL INSTALLATION-HAWLEY ROAD OUTFALL



Source: Rex Chainbelt, Inc.

diverted into the screen chamber after passing through a bar rack designed to prevent large objects from entering the system. The screen consists of an open-ended screen drum rotating in the screen chamber. Solids that accumulate on the drum are flushed from the screen and removed from the system either through routing to a separate sanitary sewer or by removal to a land fill site. A portion of the screened water is pressurized and mixed with air in an air solution tank. The liquid becomes saturated with air; and, when the pressure is reduced, minute air bubbles are formed. The air-charged screened water is then mixed with the remaining screened water in the flotation chamber. As the screened water flows through the chamber, the air bubbles attach to particulate matter and float such matter to the surface for removal by mechanical skimmers. The floated scum is handled and disposed of as solid wastes with the screened solids. Chemical flocculating agents, such as ferric chloride, are added in the flotation chamber to remove nutrients; and, at the same time, chlorine is added to provide for disinfection before release of the treated combined sewage overflow to the receiving stream.

In 1967 Rex Chainbelt, Inc., was awarded a contract by the U. S. Environmental Protection Agency[5] to develop and demonstrate a feasible method of treating combined sewer overflows. After consideration of alternatives, a combination screening and air flotation process was selected as having the best potential. A demonstration facility was constructed at Hawley Road and Trenton Place in the City of Milwaukee near the outfall of an 8-foot, 6-inch by 5-foot combined sewer serving an area of about 500 acres which overflows to the Menomonee River at that location. The demonstration facility has a 5 mgd capacity and was designed to treat a portion of the combined sewer overflow. While the initial demonstration activities concentrated on performance with respect to the efficiency of the system in removing solids and in achieving chemical and biochemical oxygen demand reduction, subsequent applied research has shown that the addition of chemical flocculating agents can be utilized to effectively achieve nutrient removal. In this connection, it is important to note that the Hawley Road demonstration project is viewed as an ongoing project to be continued for an indeterminant period of time. In this way modifications to the basic concept and to the facility itself can be tested before inclusion in a larger scale, permanent operation. In particular, the Hawley Road facility can be utilized to test procedures designed to meet the effluent standards promulgated by the federal Lake Michigan Enforcement Conference and the State of Wisconsin.

[5]*Formerly the U. S. Department of the Interior, Federal Water Pollution Control Administration.*

The initial results of the Hawley Road demonstration facility, as operated through October 1969, were reported in summary form in a paper delivered at a symposium conducted by the U. S. Environmental Protection Agency, Water Quality Office, in Chicago in June 1970.[6] The performance of the facility up to that time is summarized in the data contained in Table 43. The Hawley Road facility handled 37 combined sewer overflows from its opening in May 1969 through October 1969. From the data initially presented, it appeared that removals of about 50 percent of the BOD and nearly 70 percent of the suspended solids could be achieved by the screening/dissolved-air flotation system. The data shown in Table 43 were discussed in the paper as follows:

> Two time periods are shown, spring storms and summer-fall storms. By observing the screen data in Table [43], it may be seen that during the spring storms removals

[6]*Donald G. Mason, Rex Chainbelt, Inc., Milwaukee, Wisconsin, The Use of Screening/Dissolved-Air Flotation for Treating Combined Sewer Overflows, presented at the Symposium on Storm and Combined Sewer Overflows, June 22-23, 1970, Chicago, Illinois.*

Table 43

CONTAMINANT REMOVALS IN PERCENT BY SCREENING AND FLOTATION AT THE HAWLEY ROAD DEMONSTRATION FACILITY, MILWAUKEE, WISCONSIN: MAY 1969-OCTOBER 1969

PARAMETER	REMOVAL SCREENING ONLY[a]		REMOVAL SCREENING & FLOTATION[a]	
	SPRING	SUMMER-FALL	WITHOUT CHEMICAL FLOCCULANTS (SPRING)	WITHOUT CHEMICAL FLOCCULANTS (SUMMER-FALL)
BIOCHEMICAL OXYGEN DEMAND............	23.4 ± 9.3	20.3 ± 6.5	48.4 ± 15.7	50.8 ± 12.5
CHEMICAL OXYGEN DEMAND............	33.9 ± 10.7	22.4 ± 5.0	52.9 ± 8.7	53.4 ± 8.6
SUSPENDED SOLIDS....	28.8 ± 10.5	24.9 ± 9.8	53.7 ± 11.7	68.3 ± 8.4
VOLATILE SUSPENDED SOLIDS............	28.2 ± 13.6	24.4 ± 13.2	51.0 ± 15.9	64.8 ± 10.0

[a]REMOVAL AS PERCENT AT 95 PERCENT CONFIDENCE LEVEL; SCREEN OPENINGS 297 MICRONS; SURFACE LOADING 2.5 GPM/SQ. FT.

SOURCE- "THE USE OF SCREENING/DISSOLVED-AIR FLOTATION FOR TREATING COMBINED SEWER OVERFLOWS," DONALD G. MASON, REX CHAINBELT, INC., MILWAUKEE, WISCONSIN, PRESENTED AT THE SYMPOSIUM ON STORM AND COMBINED SEWER OVERFLOWS, JUNE 22-23, 1970, CHICAGO, ILLINOIS.

ranged from 23-33 percent for all listed parameters. This was consistent with the preliminary data collected the previous year. During the summer-fall storms, however, COD removals decreased indicating a change in the characteristics of the overflow. It was determined that an increase in soluble organics had occurred which was the probable cause for the noted decrease in COD removal across the screen. The mechanical operation of the screen has been very satisfactory. The media utilized was type 304SS. No permanent media blinding has been experienced. No build-up of greases or fats has occurred. Some clogging problems have been experienced with the spray nozzles, but this was caused by a sealing problem around the screen, which allowed unscreened water to pass into the screened water chamber.

The overall removals, i.e., screening plus flotation are also shown in Table [43], removals are shown with and without the addition of chemical flocculants. The chemical flocculants when utilized were a cationic polyelectrolyte (Dow C-31) and a flocculant aid (Calgon A25). The polyelectrolyte dosage was 4 mg/l and the coagulant aid dosage was 8 mg/l. Contaminant removal without chemical addition was about 50 percent for all parameters as shown in Table [43]. Adding chemicals caused an increase in SS and VSS removals to around 70 percent. COD and BOD removals, however, did not increase significantly. This was probably a result of the increase in soluble organics associated with the summer-fall overflows. Chemical addition also provided a strengthening effect on the floated sludge blanket which is very desirable from the solids handling aspect. Mechanical operation of the flotation tank has been excellent. No mechanical problems have been experienced. Maintenance on the entire system is limited to periodic lubrication and requires less than six man hours per month.

Chlorination was tested for seven flows. It was observed that, in the spring and early summer when coliform densities were low, good disinfection was obtained. However, in late summer when coliform density increased, the effluent contained increased numbers of coliform organisms. Chlorine demand tests were run on some storms. The chlorine demand was generally in the range of 13 to 17 mg/l.[7]

The initial findings of the Hawley Road demonstration project were summarized in the paper as follows:

> Based on the data collected during the study and reported herein, it appears that the screening/dissolved-air flotation can be utilized as a successful alternate to sewer separation in some areas. Removals of BOD, COD, SS, and VSS in the range of 50-75 percent were recorded for the 30 overflows monitored to date. The solids removed from the overflows represented only about 1 percent (by volume) of the raw waste-water flow and had a concentration of 2 to 4 percent. The entire system is completely automated and requires a minimum of maintenance.
>
> Cost estimates indicate the complete installed system capital cost will be $12,000 per MGD capacity. This cost does not include land or sewer interconnection costs. Operating costs were estimated at 3.0 to 3.5¢/1000 gallons based on the use of flocculating chemicals to obtain the maximum removal efficiency. Operating costs without chemicals is estimated at less than 1.0¢/1000 gallons.[8]

Further operation of the Hawley Road demonstration facility after October 1969 indicated that, with the addition of ferric chloride and polymers, substantial removal of soluble phosphorus and nitrogen was possible (see Table 44). The ability of the screening/dissolved-air flotation system to achieve phosphate removals in excess of 85 percent became evident, this level of removal being reached under 19 of the 24 conditions studied. It should be noted that the performance variations shown in Table 44 may be attributed to the experimental nature of the facility. It is expected that improved, permanent installations could be designed and operated to consistently achieve high levels of phosphorus and nitrogen removal. Additional data presented in Table 45, which data were obtained during 1970 at the Hawley Road demonstration facility, show the effect of the overflow

---

[7] *Ibid.*, *Footnote 6.*

[8] *Ibid.*

rate on removal of suspended solids, volatile suspended solids, BOD, and COD. The performance of the system with respect to chlorination for disinfection is shown in Table 46.

The performance achieved on a demonstration basis at the Hawley Road facility tends to confirm published results[9] of a similar demonstration program conducted by the Rhodes Technology Corporation of Houston, Texas, in the City of Fort Smith, Arkansas (see Table 47). Data shown in this table indicate that the range of reduction in pollutional parameters during dry- and wet-weather flow conditions, with and without the use of chemical treatment as an adjunct to mechanical separation, compares favorably to results normally achieved in secondary sewage treatment facilities with respect to removal of suspended solids and BOD and, with chemical additives, exceeds the performance of such facilities with respect to nutrient removal.

Application of this alternative flow-through treatment process to the 5,800-acre combined sewer service area in the Milwaukee River water-

[9] *Rhodes Technology Corporation, Dissolved-Air Treatment of Combined Sewer Overflows, Houston, Texas, January 1970.*

Table 44

NITROGEN AND PHOSPHORUS REMOVALS IN PERCENT AT THE HAWLEY ROAD DEMONSTRATION FACILITY, MILWAUKEE, WISCONSIN, WITH UTILIZATION OF FERRIC CHLORIDE—1970

RUN NUMBER	INFLUENT NITROGEN (KJELDAHL) (MG/L)	REMOVAL EFFICIENCY		INFLUENT PHOSPHORUS (SOLUBLE) (MG/L)	REMOVAL EFFICIENCY	
		LOW SETTLING RATE[a] (PERCENT)	HIGH SETTLING RATE[b] (PERCENT)		LOW SETTLING RATE[a] (PERCENT)	HIGH SETTLING RATE[b] (PERCENT)
9	4.40	23	23	0.92	90	94
11	8.80	55	55	0.67	96	88
12	6.30	24	30	0.95	99	95
13	13.90	42	46	1.07	94	94
15	4.90	27	47	0.47	94	96
19	6.95	65	56	7.0	96	86
20	3.40	41	44	0.73	92	75
21	2.40	25	25	0.77	85	89
22	19.50	76	72	2.46	60	46
23	8.70	30	39	2.73	89	94
24	4.90	27	22	0.74	42	41
25A	6.40	38	39	1.78	97	97

[a] 2.5 GPM/SQ.FT.

[b] 3.75 GPM/SQ.FT.

SOURCE- REX CHAINBELT, INC., ECOLOGY DIVISION.

Table 45

COMPARISON OF THE EFFECT OF OVERFLOW RATE ON REMOVAL EFFICIENCIES AT THE HAWLEY ROAD DEMONSTRATION FACILITY, MILWAUKEE, WISCONSIN: 1970

RUN NUMBER	OVERFLOW RATE GPM/SQ.FT.	SUSPENDED SOLIDS REMOVAL (PERCENT)	VOLATILE SUSPENDED SOLIDS REMOVAL (PERCENT)	BOD REMOVAL (PERCENT)	COD REMOVAL (PERCENT)
701	4.75	27	35	33	40
701	3.56	38	47	36	33
704	4.16	33	5	55	58
704	3.09	77	90	69	58
705	3.53	79	79	69	72
705	2.65	79	80	65	74
706	3.83	66	64	54	72
706	2.87	81	73	75	76
707	3.56	50	62	58	43
707	2.67	68	72	61	52

SOURCE- REX CHAINBELT, INC., ECOLOGY DIVISION.

Table 46

SUMMARY OF DISINFECTION DATA AT THE HAWLEY ROAD DEMONSTRATION FACILITY: 1969 AND 1970

RUN NUMBER	CHLORINE DOSAGE MG/L	POINT OF ADDITION	DETENTION TIME (MIN.)	INFLUENT COLIFORM (PER ML.)	EFFLUENT COLIFORM (PER ML.)
695	10	PF	18	360,000	0
696	10	PF	18	5,700	0
697	10	PF	18	1,300	0
698	8	PF	18	7,800	0
699	10	PF	18	6,200	0.02
6910	10	PF	18	19,000	0
6911	10	PF	18	20,000	0.10
6912	10	PF	18	65,000	<50
6913	10	PF	18	38,000	<50
6919	10	EFF	10	310,000	600
6920	10	EFF	10	160,000	400
6921	10	EFF	10	5,500	0
6922	10	EFF	10	82,000	1,500
703	10	INF	21	220,000	<10
704	10	INF	21	12,200	< 1
705	10	INF	21	700	2
706	10	INF	21	340,000	38

PF=CHLORINE ADDED IN PRESSURIZED FLOW LINE.
EFF=CHLORINE ADDED TO EFFLUENT FROM FLOTATION BASIN.
INF=CHLORINE ADDED TO RAW WASTE PRIOR TO BAR SCREEN.

SOURCE- REX CHAINBELT, INC., ECOLOGY DIVISION.

Table 47

CONTAMINANT REMOVALS IN PERCENT AT A COMBINED SEWAGE DEMONSTRATION FACILITY IN FORT SMITH, ARKANSAS: 1969

POLLUTION PARAMETER	MAXIMUM REDUCTION OBSERVED (PERCENT)		
	DRY WEATHER		WET WEATHER
	(1)	(2)	(3)
SUSPENDED SOLIDS............	98 - 100	96 - 100	86 - 98
BIOCHEMICAL OXYGEN DEMAND....	81	76 - 100	79
TOTAL SOLIDS................	59	95 - 100	60
TOTAL PHOSPHORUS............	77 - 100	100	92
TOTAL NITROGEN..............	10 - 16	50	50

(1) ALUM ONLY OR ALUM PLUS COAGULANT AIDS. DATA JUDGED SUFFICIENT BY INVESTIGATORS FOR STATISTICAL ANALYSIS.

(2) FERRIC CHLORIDE, FERRIC CHLORIDE PLUS ALUM PLUS COAGULANT AIDS. DATA JUDGED INSUFFICIENT FOR STATISTICAL ANALYSIS.

(3) ALUM ONLY OR ALUM PLUS TRETOLITE FR-50.

SOURCE- DISSOLVED-AIR TREATMENT OF COMBINED SEWER OVERFLOWS, RHODES TECHNOLOGY, CORP., HOUSTON, TEXAS, JANUARY 1970.

shed would involve the construction of permanent screening/dissolved-air flotation treatment facilities at 42 locations along the Milwaukee River (see Map 31). Some of these facilities would serve only one combined sewer outfall, whereas others would serve a combination of outfalls connected by new intercepting sewers. In all cases the treatment facilities would be located underground for aesthetic reasons. This alternative would entail an estimated initial capital cost of $47.2 million, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $4.4 million, or $764 per acre served (see Table 42). The present worth of this alternative for 50 years at 6 percent interest is $69.8 million. These estimates include the cost of all required land, construction, operation, and maintenance, including conveyance and treatment facilities.

If applied to the entire 5,800-acre combined sewer service area in the Milwaukee River watershed, this flow-through treatment alternative would meet the water use objectives for the Milwaukee River both above and below the North Avenue Dam, assuming that the demonstrated performance of the Hawley Road facility can be slightly improved to consistently achieve 85 percent BOD and suspended solids removal at permanent facilities located along the entire Milwaukee River. This alternative would also be applicable to the entire 17,200-acre Milwaukee combined sewer service area. This alternative was considered to have a moderate potential for disrupting the existing urban development due to the need to construct the conveyance and treatment facilities along the Lower Milwaukee River; to have no adverse aesthetic effects, since all of the treatment facilities would be buried underground; and to have an excellent potential for public acceptance.

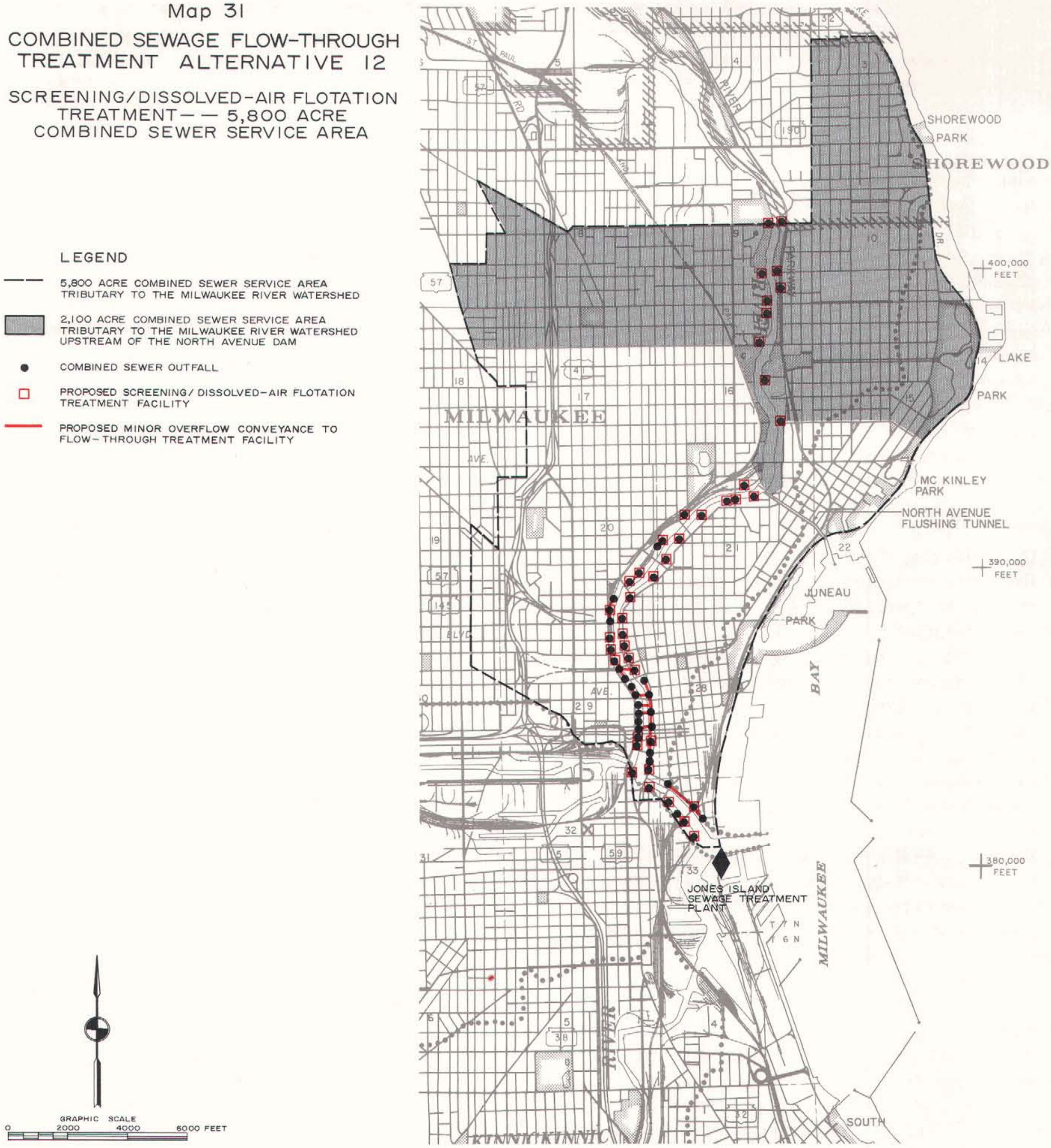
Alternative 13—Instream Treatment: Another alternative considered for abatement of the pollution from the combined sewer overflows in the combined sewer service area located along the Milwaukee River was the installation of aeration equipment in the Lower Milwaukee River to prevent the development of anaerobic conditions and to maintain a dissolved oxygen level that would support a balanced aquatic community. Overflows from the 62 existing combined sewer overflow points located along the Milwaukee River would, under this alternative, in effect be treated by the aeration which would be installed in the river bed below the North Avenue Dam. A prototype of such a facility was tested in the Passaic River in New Jersey, and the project was described as follows:

> The Water Resources Research Institute for New Jersey, at Rutgers University, started to study possibilities of instream aeration in 1965 and started full-scale tests in 1966. The equipment used consisted of a Yeomans Bros. 75 hp mechanical surface aerator and an air diffuser installation using rather coarse, bubble Link Belt diffusers (1/8 in nozzle) installed in manifolds laid on the bottom of the river. These types of equipment are commonly used in waste treatment plants. The diffuser aerator was installed in an excavated basin (in the river)....
>
> The test section of the Passaic River was between Pine Brook and Two Bridges. There are no tributaries or pollution sources of appreciable size in a 12-mile section of river, and the width is only 100 ft, so that a single aerator can act throughout the entire cross section. This river is an important source of water supply for Northern New Jersey, water being diverted directly from several reservoirs and at Little Falls. There is no large city in the upper Passaic basin above Little Falls, but the population had risen to 514,000 by 1966. In spite of generally prevalent secondary treatment of wastes, the dissolved oxygen concentration in summer is often below one mg/per L in the Pine Brook-Little Falls reach.
>
> The mechanical aerator produced a considerably higher transfer efficiency at low flow periods, amounting to 2.0 lb., 0_2 per hp-hr, when reduced to standard conditions (pure water, 20^oC water temperature, and zero dissolved oxygen). At higher river velocities, up to about a 50 percent increase was obtained. For Passaic River water, summer temperatures, and the raising of water of 4 mg/per L DO to 5.0 mg/per L, the corresponding figure for low flows would be about 0.73 lb. 0_2 per hp-hr.
>
> Cost estimates were made for several systems including different numbers and types of aerators. On the assumption of equal efficiency, 75 hp mechanical aerators were indicated as slightly more economical than a larger number of 50 hp aerators. A system

Map 31

COMBINED SEWAGE FLOW-THROUGH TREATMENT ALTERNATIVE 12

SCREENING/DISSOLVED-AIR FLOTATION TREATMENT— — 5,800 ACRE COMBINED SEWER SERVICE AREA



The application of flow-through treatment to combined sewer overflows represents an entirely different approach to resolving the sewer overflow problem then the storage alternatives presented earlier in this chapter. The above map illustrates how a flow-through treatment process could be applied in the 5,800-acre combined sewer service area tributary to the Milwaukee River. A total of 42 permanent flow-through sewage treatment facilities would be located to intercept the combined sewer overflows at 62 outfall locations along the river. Some of the flow-through treatment facilities would serve only one outfall, whereas others would serve a combination of outfalls connected by new conveyance facilities. In all cases, the flow-through treatment facilities would be located underground for aesthetic reasons. The particular flow-through treatment process utilized in this alternative is known as screening/dissolved-air flotation and has been developed by Rex Chainbelt, Inc. of Milwaukee.

Source: Harza Engineering Company and SEWRPC.

of nine 75 hp aerators, for example, would cost $391,000 to install; and total costs would amount to $102,000 annually.

On the assumption of a year-round schedule averaging 5-1/2 months of operation, the average cost of oxygen imparted to the water would be approximately $0.34 per lb. The Rutgers studies indicate that, for the Passaic River, to achieve a summer level of dissolved oxygen of 4.0 mg/per L by means of aerators would cost only about one-third as much as reaching the same objective by improving the many waste treatment plants. Recent cost studies of aerators in the Ruhr River in Germany indicate similar conclusion. In winter, in cold climates, the aerators would have to be removed for maintenance and to avoid heavy-icing.

The study conclusion was stated as follows:

In any event, it appears that the possibilities of instream aeration, forecast by such analysts as Clearly, Kneese, and Davis, have been solidly established by prototype field tests using commercial equipment. For rivers where secondary treatment of wastes will not be sufficient (and such conditions may be more numerous than is now realized), instream aeration is likely to offer the possibility of real savings in achieving standards of dissolved oxygen.

Some interesting questions are opened up by this potentiality since it is not clear how the necessary systems analyses will be made, and how surveillance will be carried out to ensure that the aerators are used as a supplement to treatment rather than as a substitute for it. It is also not clear who should pay for such aerators and at what level of government they should be planned and operated.[10]

This type of facility, while apparently capable of maintaining desired levels of dissolved oxygen in a river, would not solve the problems of excessive nutrient content or of excessive coliform concentrations present in the Milwaukee River during and following overflows of the combined sewers. The flow, which would have to be treated instream for control of coliform and phosphorus levels, would be at a very high rate and would constitute a very large volume annually. This alternative for treatment of combined sewer overflows cannot be considered applicable to the Milwaukee River, as procedures for treating such a large flow of water to the high standards required, particularly for removal of phosphorus, would be difficult or impossible to achieve operationally at an economic cost. Consequently, no further evaluation of this alternative was made; nor were cost estimates prepared.

Combined Sewer System Separation Alternatives (Alternatives 14 and 15): An alternative for the abatement of pollution from combined sewer overflows that has been suggested by certain federal and state agencies and by certain local officials is to "separate" the combined sewer system by constructing new sewers to convey the sanitary sewage to the existing sewage treatment plants, thus permitting the existing combined sewers to be used to convey only storm water runoff for discharge to the waterways of the area. The existing combined sewers would thus, in effect, be converted to "separate" storm water drainage sewers, while new sanitary sewers would be provided, discharging to existing intercepting sewers and through these sewers to the sewage treatment plants.

Costs for separation of street sewers in urban renewal areas of the City of Milwaukee have been reported by the public works agencies effecting such separation as set forth in Table 48. These costs reflect a long-term program of separation accomplished under ideal conditions created by the total or nearly total clearance of existing urban development in the service areas involved.

A study of such sewer separation was made in 1968 by the American Society of Civil Engineers (ASCE) under contract with the Federal Water Pollution Control Administration (FWPCA).[11] The objective of the study was to evaluate the feasibil-

[10] *See Water and Waste Engineering/Industrial, September 1970, Vol. 7 No. 9.*

[11] *U. S. Department of the Interior, Federal Water Pollution Control Administration, Combined Sewer Separation Using Pressure Sewers, Feasibility and Development of a New Method for Separating Wastewater from Combined Sewer Systems, Water Pollution Control Research Series ORD-4, October 1969, by the American Society of Civil Engineers. The Federal Water Pollution Control Administration has since been reorganized as part of the U. S. Environmental Protection Agency.*

Table 48

CONSTRUCTION COSTS FOR SEWERS IN SEWER SEPARATION PROJECTS IN COMBINED SEWER AREAS OF THE CITY OF MILWAUKEE[a]

AREA AND TYPE OF SEWER CONSTRUCTED	ACREAGE SEPARATED	TOTAL COST	COST PER ACRE
STORM SEWERS			
WASHINGTON PARK..........	315	$3,715,000	$11,800
SANITARY SEWERS			
LOWER THIRD WARD.........	29	255,000	8,800
JUNEAU VILLAGE...........	47	320,000	6,850
UWM-KENWOOD CAMPUS.......	35	180,000	5,150
N 28TH ST & W WELLS ST...	34	240,000	7,000
MARQUETTE UNIVERSITY.....	47	380,000	8,100
CIVIC CENTER.............	27	465,000	17,200
SUBTOTAL-SANITARY SEWERS	229	$1,840,000	--
TOTAL....................	544	$5,555,000	--

AVERAGE COST		ADJUSTMENT TO 1969 PRICES[b]	TOTAL WITH ENGINEERING AND OVERHEAD AT 10%
STORM SEWERS	$11,800	$13,000	$14,300
SANITARY SEWERS	8,040	8,850	9,730
ENTIRE PROGRAM	10,200	11,220	12,300

[a] THE COSTS PRESENTED IN THIS TABLE INCLUDE MAIN SEWERS IN THE STREETS BUT DO NOT INCLUDE SANITARY OR STORM BUILDING SEWERS NOR THE COST OF SEWER SEPARATION INSIDE BUILDINGS.

[b] THE REPORTED COSTS HAVE BEEN ADJUSTED BY APPROXIMATELY 10 PERCENT TO REFLECT HIGHER 1969 PRICES. THIS ADJUSTMENT WAS BASED ON THE ENGINEERING NEWS RECORD SEWER LINE COST INDEX.

SOURCE- *CITY ENGINEER, CITY OF MILWAUKEE AND HARZA ENGINEERING COMPANY.*

ity and costs of sewer separation using pressurized sewers, as conceived by Professor Gordon M. Fair of Harvard University. The costs of sewer separation utilizing the pressurized system were compared in the study with the costs of sewer separation utilizing conventional gravity flow systems. The use of a pressurized sanitary sewerage system would entail the incorporation of relatively small diameter pipes into the existing combined sewers for the conveyance of the sanitary sewage wastes under pressure to the existing intercepting sewers. As in more conventional (gravity flow) separation, the combined sewers would be retained as the conveyors of storm water. These two methods of separation—conventional or gravity flow and pressure—constitute pollution abatement Alternatives 14 and 15 for the lower Milwaukee River watershed.

The concept of the pressure sewer separation is described in the cited report as follows:

> Structurally, the proposed pressure systems would begin at a grinding and pumping unit within each building served by the system. Where possible, the unit would prepare the wastewaters for delivery to the system through small-diameter tubing inserted in the building sewer and connected to a conduit inserted in and attached to the interior of the existing combined sewer. The main trunks of the branching network of pressure conduits would discharge into the existing interceptor which thus would convey only wastewaters to treatment works. The existing building sewers and combined sewers would deliver to receiving water bodies only storm water runoff from rainfall and snowmelt, together with such ground water as entered the system from the soil.
>
> In the creation of the proposed separate wastewater system, construction activity and traffic disruption would be greatly reduced by using the pipe-within-a-pipe concept or, where necessary, by installing the relatively small-bore piping in shallow trenches exterior to the combined sewers. If total costs were less than for conventional separation, the scheme would constitute a viable alternative to conventional separation. By excluding seepage waters from pressurized reaches the hydraulic loads on interceptors and treatment works would be reduced accordingly. In addition, an inherent potential advantage of pressure sewerage is that the piping is free from the limitations of gravity systems which must constantly slope downward no matter what the surface topography.
>
> To minimize and, insofar as possible, prevent the clogging of tubing, conduits and auxiliary fittings, Professor Fair's concept included the grinding of sewage solids and pressurization in a single assembly at each building in which surges of peak flows would be attenuated by storage of incoming flows from the building served. Each residential building or structure with similar flows, therefore, would have a "storage-grinder-pump" unit.[12]

The feasibility and cost of separation of combined sewers by a pressurized sanitary sewer system were investigated during the ASCE project by

> ... designing pressurized sewer systems for three areas of reasonable size that are representative of many existing combined sewer systems as follows: (1) a 53-acre commer-

[12] *Ibid., Footnote 11.*

cial downtown area in Boston, Massachusetts; (2) a 157-acre mainly residential area in Milwaukee, Wisconsin; and (3) a 373-acre predominantly residential area in San Francisco, California. For purposes of comparison, conventional (gravity flow) separation of the test areas was studied by consultants in the cases of Boston and Milwaukee and by the Local Department of Public Works in the case of San Francisco.[13]

Pertinent data on the three areas studied and on the project features considered during costing are summarized in Table 49. The costs of the conventional gravity flow-separation alternatives were estimated in all three cases to be significantly cheaper to construct and operate than were the pressure systems.

It was estimated that the ratio of construction costs of the pressure system over a gravity system was about 1.5 to 1.0; and that annual operation and maintenance costs would be considerably higher for the pressure system, about 1.85 times as great at Milwaukee. Capital costs for the three pressure and gravity systems are given in Table 50. Annual costs for the pressure and gravity systems in Milwaukee are shown in Table 51. The annual cost is shown to be between 7.2 and 8.0 percent of the construction cost.

The following description of the sewer separation study for Milwaukee was summarized for the watershed study from a report jointly prepared by the ASCE staff and Greeley and Hansen, Consulting Engineers, Chicago, Illinois, in December 1968.[14]

The Milwaukee test area, located in the Milwaukee River watershed and as shown on Map 32, is just north of the central business district. The area comprises approximately 157 acres and is bounded generally on the north by the Milwaukee River and E. Kane Street; on the east, by the top of

[13] *Ibid., Footnote 11.*

[14] *ASCE Project Staff and Greeley and Hansen, Consulting Engineers, Chicago, Illinois, Combined Sewer Separation Project Report on Milwaukee Study Area, December 1968.*

Table 49

CHARACTERISTICS OF STUDY AREAS FOR HYPOTHETICAL APPLICATION OF ASCE COMBINED SEWER SEPARATION PROJECT

CHARACTERISTIC	SAN FRANCISCO CALIFORNIA	MILWAUKEE WISCONSIN	BOSTON MASSACHUSETTS
STUDY AREA DESIGNATION	LAGUNA STREET	PROSPECT AVENUE	SUMMER STREET
CONSULTANT MAKING EVALUATION	BROWN AND CALDWELL	GREELEY AND HANSEN	CAMP, DRESSER AND MC KEE
DESIGN YEAR	1993 (25 YEARS)	1993 (25 YEARS)	2020
EXTENT OF GROSS AREA	323 ACRES	157 ACRES	53 ACRES
TYPE OF DEVELOPMENT PRESENT	PREDOMINANTLY RESIDENTIAL	MAINLY RESIDENTIAL	HETEROGENEOUS COMMERCIAL
PROJECTED	RESIDENTIAL, INCLUDING HIGHRISE	PRIMARILY RESIDENTIAL WITH LARGE APARTMENT COMPLEXES	HIGH-RISE COMMERCIAL
LENGTH OF COMBINED SEWERS	66,000 FEET	33,000 FEET	13,000 FEET
TOPOGRAPHY	STEEPLY SLOPING (EL. 10 TO EL. 340)	GENTLY SLOPING (EL. 30 TO EL. 80)	GENTLY SLOPING (EL. 21 TO EL. 85)
POPULATION	21,800 (1960)	11,300 (1966) 14,000 (1993)	--
DWELLING UNITS	10,900 (1960)	3,500 (1966 EST.) 5,800 (1993)	--
ANNUAL (WINTER RATE) WATER USE METERED	2.97 CFS (1966)	1.15 CFS (1968)	1.54 CFS (1968)
FUTURE	4.78 CFS (1993)	1.76 CFS (1993)	3.41 CFS (2020)
NUMBER OF STRUCTURES	2,773 (1963)	--	--
NUMBER OF SERVICE CONNECTIONS	--	843 (1996)	600 (200 TO BE SEPARATED)(1968)
SPECIAL DIFFICULTIES	STEEP SLOPES	CLOSELY SPACED BUILDINGS	NARROW STREETS, SUBWAYS, CROWDED UTILITY PIPING, SURCHARGING AT HIGH TIDE.

SOURCE- FWPCA REPORT ORD-4, OCTOBER, 1969.

Table 50

ESTIMATES OF CAPITAL COSTS FOR HYPOTHETICAL APPLICATION OF ASCE COMBINED SEWER SEPARATION PROJECT

COST ESTIMATES	SAN FRANCISCO, CALIFORNIA		MILWAUKEE, WISCONSIN		BOSTON, MASSACHUSETTS	
ENGINEERING NEWS RECORD CONSTRUCTION COST INDEX..........	1320		1200 (IF MID-1968)		1250	
CAPITAL COSTS	PRESSURE (ALT. B)	GRAVITY	PRESSURE (M-1)	GRAVITY	PRESSURE (DES. I)[a]	GRAVITY[a]
PLUMBING SEPARATION AND CONNECTION TO STORAGE-GRINDER-PUMP UNITS........................	$ 4,416,000	$ --	$ --	$ --		
CONNECTION AS FAR AS PROPERTY LINES....................	--	5,413,000	--	--		
CONNECTION TO LATERALS...........	--	--	1,214,000	1,140,000		
STORAGE-GRINDER-PUMP UNITS (OR COMMINUTOR-PUMP EQUIVALENT)						
ALONE............................	--	--	1,417,000	--		
AND CONNECTION TO LATERALS.....	5,304,358	--	--	--		
CONNECTION, PROPERTY LINES TO LATERALS......................	--	1,003,075	--	--		
SUBTOTAL...........................	$ 9,720,000	$6,416,075	$2,631,000	$1,140,000	$4,000,000[a]	$2,000,000[a]
AREA COLLECTION SYSTEMS	$ 3,313,626	$2,374,848	$ 594,000	$1,055,000	$2,400,000	$2,700,000
TOTAL	$13,033,984	$8,790,923	$3,225,000	$2,195,000	$6,400,000	$4,700,000
UNIT COSTS						
PER GROSS ACRE	$ 40,350	$ 27,220	$ 20,600	$ 14,000	$ 128,000	$ 54,000
PER CONNECTION	$ 4,700	$ 3,170	$ 3,830	$ 2,610	$ 32,000	$ 23,500

[a]DETAILED CAPITAL COST DATA NOT AVAILABLE.

SOURCE- FWPCA REPORT ORD-4, 1969.

Table 51

COMPARISON OF ANNUAL COSTS FOR HYPOTHETICAL APPLICATION OF ASCE COMBINED SEWER SEPARATION PROJECT IN THE NORTH PROSPECT STUDY AREA, MILWAUKEE, WISCONSIN

PROJECT	ESTIMATED PROJECT CONSTRUCTION COST (1)	ESTIMATED ANNUAL COST (2)	ESTIMATED ANNUAL COST AS A PERCENTAGE: RELATIVE TO CONSTRUCTION COST OF GIVEN ALTERNATIVE[a] (3)	ESTIMATED ANNUAL COST AS A PERCENTAGE: RELATIVE TO GRAVITY SYSTEM CONSTRUCTION COST[b] (4)
GRAVITY SYSTEM				
M-GR				
ALL PUBLIC FUNDS[c]....	$2,195,000	$158,000	7.2	7.2
PUBLIC & PRIVATE....	2,195,000	174,800	8.0	8.0
PRESSURE SYSTEMS				
M-1 (PARALLEL LINES)				
ALL PUBLIC FUNDS[c]....	$3,225,000	$285,100	8.8	13.0
PUBLIC & PRIVATE....	3,225,000	323,100	10.1	14.7
M-2 (GRID SYSTEM)				
ALL PUBLIC FUNDS[c]....	$3,260,000	$285,500	8.7	13.0
PUBLIC & PRIVATE....	3,260,000	326,000	10.0	14.9

[a]COLUMN (2) ÷ COLUMN (1), IN PERCENT.

[b]COLUMN (2) ÷ $2,195,000, IN PERCENT.

[c]EXCEPT COST OF ELECTRIC ENERGY.

SOURCE- FWPCA REPORT ORD-4, OCTOBER, 1969.

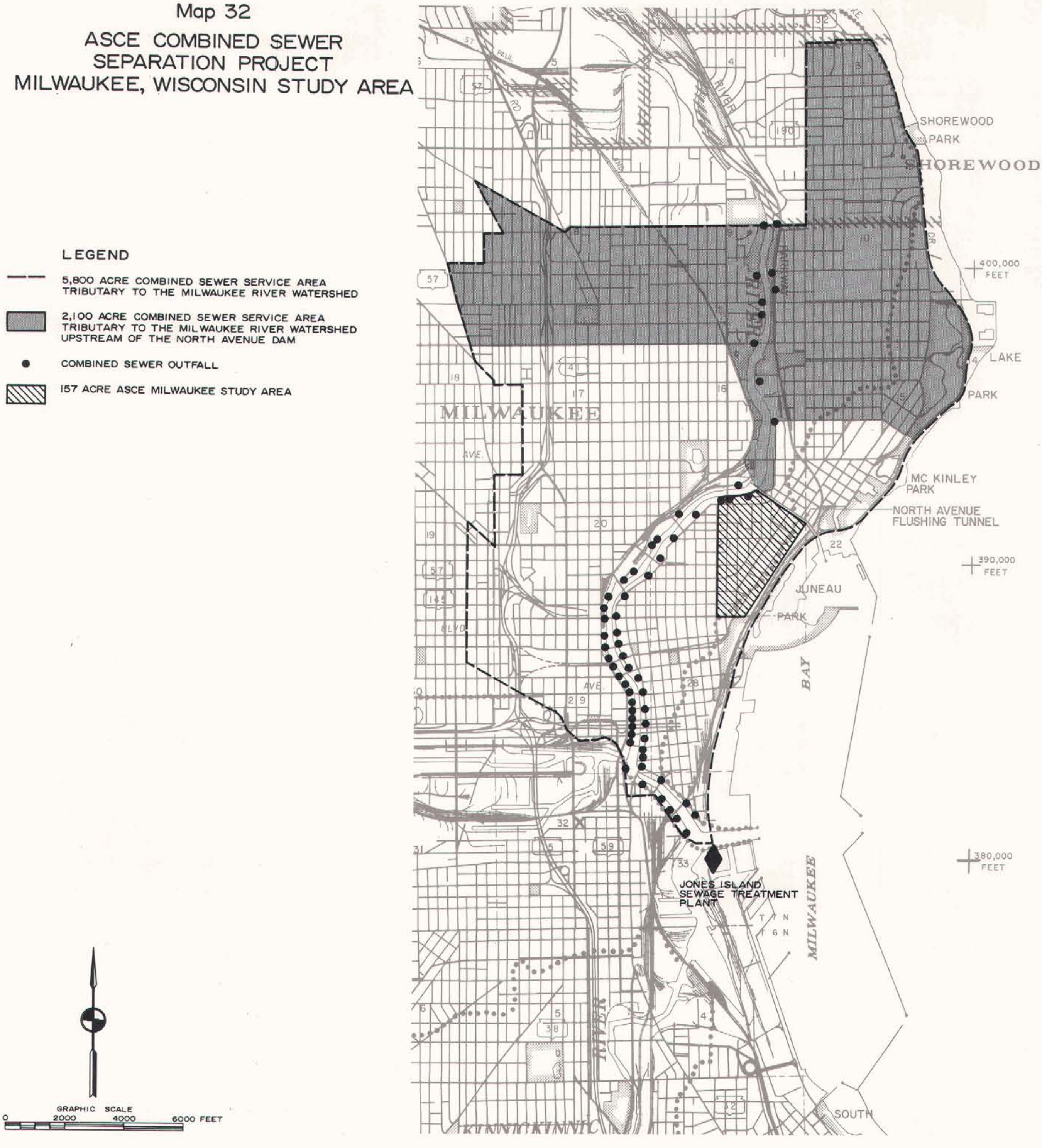
the bluff east of N. Prospect Avenue; on the south, by E. Juneau Avenue; and on the west, by N. Astor Street.

The study area is presently served by a combined sewer system. The dry-weather flow drains to the north and west to intercepting sewers near the Milwaukee River and in Brady Street. These sewers carry the sewage westerly and southerly for ultimate treatment at the Jones Island sewage treatment plant. During periods of heavy rainfall, a dilute mixture of sanitary sewage and storm water overflows into the Milwaukee River at outfall points.

The test area, called the N. Prospect Avenue study area, is mainly residential, although institutional and public buildings and small commercial establishments are scattered throughout. Prevailing land uses are summarized in Table 52. The test area is characterized by two different types of buildings (see Figure 18). Originally the area consisted of very densely located small residential structures. Most of the single-family residential buildings were constructed before the late 1930's, and many were built before 1900. They are generally of frame construction, with basements and foundation walls of limestone or concrete block. Although most of the buildings were originally intended for single-family homes, they are being used today as multi-family dwellings. The area along Prospect Avenue and part of Farwell Avenue has been, for the most part, rebuilt and consists of large apartment buildings and several institutional or public buildings. Several large homes remain, although they are mostly converted to other land uses.

Map 32

ASCE COMBINED SEWER SEPARATION PROJECT MILWAUKEE, WISCONSIN STUDY AREA



Separation of combined sewers has been generally assumed to be the answer to the resolution of the combined sewer overflow problem. This map shows a 157-acre area in the City of Milwaukee for which combined sewer separation study was conducted by the American Society of Civil Engineers to demonstrate the feasibility of separation and to determine the costs of such separation. The study explored three different methods of separation and concluded that the total cost of separation could be expected to range from a low of $14,000 per acre, or $2,600 per structure, to a high of $21,000 per acre, or $3,900 per structure.

Source: Harza Engineering Company and SEWRPC.

Table 52

PREVAILING LAND USES IN THE NORTH PROSPECT STUDY AREA, MILWAUKEE, WISCONSIN

DESCRIPTION	AREA OCCUPIED (ACRES)	NUMBER OF STRUCTURES	AVERAGE NUMBER OF STRUCTURES PER ACRE
SMALL RESIDENTIAL	69	606	8.8
RESIDENTIAL ABOVE COMMERCIAL	2	22	11.0
APARTMENTS	29	83	2.9
COMMERCIAL AND OFFICE BUILDINGS	19	93	4.9
INSTITUTIONAL	11	39	3.5
STREET RIGHT-OF-WAY	27	--	--
TOTAL	157	843	5.4

SOURCE- FWPCA REPORT ORD-4, OCTOBER, 1969.

Future development in the study area is expected to follow a controlled development plan, and the area is expected to remain primarily in residential use. Future residential redevelopment is expected to consist of large multi-family dwellings.

The old Milwaukee plumbing code, in effect until 1961, allowed all structures on the same lot to have one connection to the combined sewer. As revised in 1961, the code requires completely independent plumbing systems for all structures. This is particularly important considering that, of 843 structures located in the study area, 91 structures are located on the back of a lot, with each connected directly to the structure in front of it. In a few cases there are three or four buildings on the same sewer connection. Therefore, new sanitary and storm sewers would have to be constructed for these buildings.

House or building sewers in the test area are combined, except that 20 buildings, mainly apartments, are reported to have separate systems to the lot line. In 1961 the plumbing code was amended to require new buildings and buildings with essentially new plumbing to maintain separate sanitary and storm systems to the property line.

Roof drains (downspouts) are generally connected to the main building sewer beneath a concrete floor in the basement. Many of the basements are used as dwelling units. Footing drains, so far as could be ascertained in the separation study, are not used in the test area. The general approach to separation for all buildings except apartment houses would be to construct a new storm drain capable of delivering roof drainage to the existing combined sewer in a shallow trench around the outside of each structure. This would accomplish complete separation in the building except for basement floor drains. Basement floor drains would be ignored for separation purposes, as in nearly all cases the basements are used as living quarters; and it is believed that any original floor drains are not now operative. In order to use the existing building sewer from the house to the street, the new storm drain carrying the roof drainage would be carried around in front of the house and connected to the existing building sewer. Construction of a new connection is not required at the combined sewer, as the building sewer presently is connected to this main.

The method used to separate larger buildings would vary according to the particular building. Apartment buildings with four or more units per floor generally have unfinished basements or a crawl space. It is anticipated that a new storm sewer would be hung on the inside of the basement wall to pick up existing roof drains. All of the large apartment buildings in the area sampled for the field study have roof drains on the inside of the building and probably exposed in the basement. In small apartment buildings, the roof drains are not always inside the building. It is anticipated that a hole would be punched through the wall and the roof drain brought inside the basement and connected by a new storm main hung on the basement wall. An adjustment has been made in the cost estimate to include bringing an outside downspout into the basement for apartment houses.

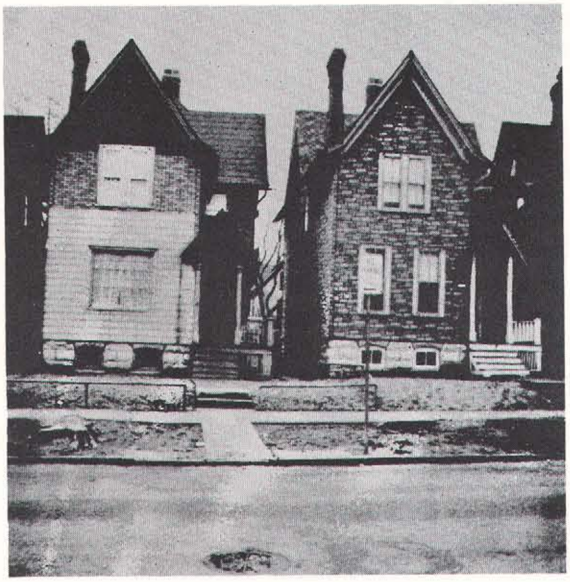
Commercial and institutional buildings generally have downspouts outside the structure. An estimate of the overall cost of separation indicates that it would generally be cheaper to construct an outside line than to construct and connect to a line hung on the inside wall.

Plumbing changes required to accomplish separation for the gravity collection system and for pressure separation are similar. The only real difference is the lack of a grinder-pump unit. When a gravity collection system is used, no plumbing changes are actually required in the building except when it is desirable to hang the roof-drain connecting main on the inside wall.

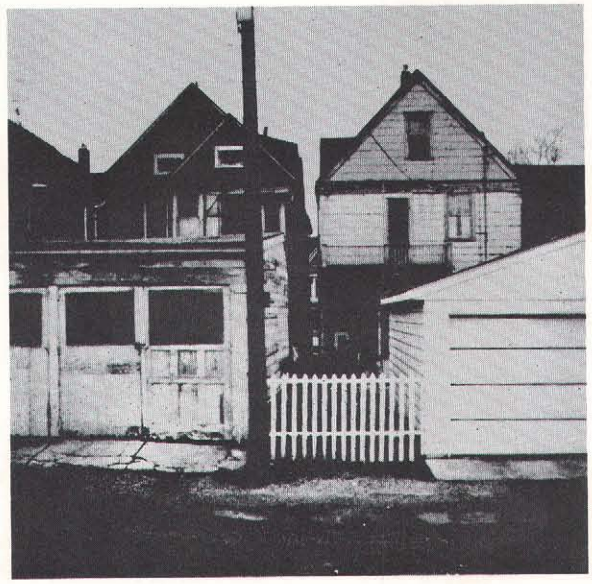
Layout and preliminary design of two pressure schemes for the Milwaukee study area collection system were compared with a conventional gravity sanitary sewer system. The pressure schemes were prepared by ASCE Project Staff and reviewed by the engineering firm of Greeley and Hansen.

Figure 18

TYPICAL CONDITIONS AFFECTING SEWER SEPARATION IN THE N. PROSPECT AVENUE STUDY AREA, MILWAUKEE, WISCONSIN



SIX FEET OF WORKING SPACE
BETWEEN STRUCTURES



THREE FEET OF WORKING SPACE
BETWEEN STRUCTURES

SIDEWALK BETWEEN TWO
STRUCTURES WITH EIGHT FEET
OF WORKING SPACE

TYPICAL COMMERCIAL AREA
NOTE: STONE FOUNDATION
FOR MIKE'S CAFE

Source: *ASCE Combined Sewer Separation Project, Milwaukee Study Area*, *December 1968.*

In the first scheme, Layout M-1 (see Table 53), pressure conduits would be placed in dual parallel shallow trenches, one on each side of the street. The second pressurized system, Layout M-2 (see Table 53), is a parallel grid-type configuration. It is anticipated that the new gravity collection system, M-Gr (see Table 53), would be constructed parallel to the existing combined sewers and in a slightly deeper cut. The average cut of the combined system in the test area is about 12 feet. For estimating purposes it was assumed that the new sanitary sewers would be at an average cut of 14 feet and generally at minimum slope. Separation of the sewers by the gravity system would cost about $14,000 per acre. The cheapest pressure system would cost about $21,000 per acre.

Annual cost comparisons for the Milwaukee study area (N. Prospect Avenue area) have been made and are shown in Table 51. Generally, the cost of work done in the public right-of-way is financed through the municipality; and it is anticipated that the construction cost of an area collection system would be amortized at 5 percent for 25 years by the municipality. In-house plumbing changes would probably be done by the property owner, and the cost of this work was assumed to be amortized at 7 percent for 25 years. Alternatively, it is possible that the total construction cost will be distributed to the taxpayers through general obligation or revenue bonds. In this case it was assumed that money could be borrowed at a minimum of 5 percent for 25 years construction.

The capital and annual costs for sewer separation by the gravity system were adjusted to a basis which would be comparable to other plan alternatives. The adjustments were:

1. Cost escalation from August 1968 to January 1969 of 6 percent.

2. Addition of 25 percent contingency plus 10 percent for engineering and overhead.

3. A discount rate of 6 percent.

4. Adjustment for a 50-year project life.

These adjustments resulted in a per acre construction cost of $16,300 (see Table 54) and an annual cost of $1,113 per acre.

Application of Separation Alternatives in the Watershed Study: Based upon the results of the foregoing pilot study of combined sewer separation, it was concluded for the purposes of the Milwaukee River watershed study that: 1) of the two alternative methods of separation—conventional or gravity flow and pressure—the conven-

Table 53

TOTAL SEPARATION COSTS FOR HYPOTHETICAL APPLICATIONS OF ASCE COMBINED SEWER SEPARATION PROJECT IN THE NORTH PROSPECT AVENUE STUDY AREA, MILWAUKEE, WISCONSIN

	PRESSURE SEWERS-PARALLEL LINES (PROJECT M-1)		PRESSURE SEWERS-GRID SYSTEMS (PROJECT M-2)		GRAVITY SEWERS (PROJECT M-GR)	
ITEM	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST
IN-HOUSE SEPARATION	$ 971,000		$ 971,000		$ 912,000	
COST PER STRUCTURE		$ 1,150		$ 1,150		$ 1,080
COST PER ACRE (GROSS ACRE)		6,180		6,180		5,820
GRINDER-PUMP	$1,134,000		$1,134,000		--	
COST PER STRUCTURE		$ 1,340		$ 1,340		--
COST PER ACRE		7,190		7,190		--
AREA COLLECTION	$ 475,000		$ 503,000		$ 843,000	
COST PER STRUCTURE		$ 565		$ 595		$ 1,000
COST PER ACRE		3,020		3,200		5,360
SUBTOTAL	$2,580,000	--	$2,608,000	--	$1,755,000	--
PLUS 25 ENGINEERING AND CONTINGENCIES	$ 645,000	--	$ 652,000	--	$ 440,000	--
TOTAL	$3,225,000		$3,260,000		$2,195,000	
COST PER STRUCTURE		$ 3,830		$ 3,887	0	$ 2,610
COST PER ACRE		20,600		20,800		14,000

SOURCE- FWPCA REPORT ORD-4, OCTOBER 1969.

Table 54

ADJUSTMENT OF CAPITAL COSTS FOR SEPARATION OF COMBINED SEWERS IN THE NORTH PROSPECT AVENUE STUDY AREA, MILWAUKEE, WISCONSIN

ITEM	COST IN ASCE STUDY[a]	ADJUSTED COST
IN-HOUSE SEPARATION	$ 912,000	$ 912,000
+ 6% ESCALATION AUGUST 1968 TO JANUARY 1969	-	55,000
AREA COLLECTION	843,000	843,000
+ 6% ESCALATION 1968 TO 1969	-	50,000
SUBTOTAL	$1,755,000	$1,860,000
ENGINEERING AND CONTINGENCIES		
AT 25%	$ 440,000	$ -
AT 37.5%	-	700,000
TOTAL	$2,195,000	$2,560,000
COST PER STRUCTURE	$ 2,610	$ 3,040
COST PER ACRE	14,000	16,300
COST IN-HOUSE AT 52% OF TOTAL (PER ACRE)	-	8,500
COST AREA COLLECTION AT 48% OF TOTAL (PER ACRE)	-	7,800

[a]COST AS REPORTED IN TABLE 9 OF "COMBINED SEWER SEPARATION PROJECT REPORT ON MILWAUKEE RIVER STUDY AREA," ASCE PROJECT STAFF AND GREELEY AND HANSEN CONSULTING ENGINEERS, CHICAGO, ILLINOIS, DECEMBER, 1968.

SOURCE- HARZA ENGINEERING COMPANY.

tional method would be preferable for application in the Milwaukee area because of its generally substantially lower costs, and 2) the cost of separating the Milwaukee combined sewer service area by conventional or gravity flow methods would range from about $18,000 to $20,000 per acre. The cost for total separation of combined sewers in the 5,800-acre combined sewer service area of the Milwaukee River watershed would, therefore, range from $104,200,000 to $116,000,000. This cost would include separation of sewers inside residences and other structures and construction of about 170 lineal miles of new lateral and main sewers which would carry the separated sanitary sewage to existing intercepting sewers.

The cost for total separation of combined sewers in the entire 17,200-acre Milwaukee combined sewer service area would range from $310 million to $344 million and would include separation of sewers inside residences and other structures and construction of about 500 lineal miles of new lateral and main sewers. No costs have been included in either of the foregoing cost estimates for the construction of new trunk or intercepting sewers or for treatment plant facilities, since the existing interceptors serve to convey the entire dry-weather flow from the combined sewered areas to the Jones Island sewage treatment plant.

It was assumed, therefore, that the separated sanitary sewage flow would not exceed the normal dry-weather flow. No costs are included in the above estimates for interest during construction. With respect to the 5,800-acre combined sewer service area in the Milwaukee River watershed, annual costs for this alternative would range from $6.8 million to $7.9 million, and with respect to the entire 17,200-acre Milwaukee combined sewer service area, $21.2 million to $23.5 million.

The unit cost of $18,000 to $20,000 per gross acre was selected for use in the screening process based upon the following considerations:

1. The cost for separation of sewers in the N. Prospect Avenue District of Milwaukee by conventional gravity conveyance was estimated for the 1968 ASCE Project as $14,000 for each occupied acre, with 52 percent being for in-house separation. This cost was adjusted, as shown in Table 54, to a 1969 price of $16,300 per acre, with an in-house separation cost of $8,500 per acre.

2. Actual costs of separation of street mains in areas where urban renewal projects were recently undertaken in Milwaukee have ranged from $5,000 to $17,000 per acre (see Table 48). When adjusted for cost escalation and engineering and overhead, these costs increase to $6,000 and $20,000 per acre respectively. The average cost for construction of sanitary sewers would increase from $8,040 per acre to $9,730 per acre (see Table 48). These costs prevailed under conditions where new buildings were being constructed and only partially reflect the costs that would be incurred where separation would be accomplished in old buildings.

3. Addition of the cost actually incurred in construction of street mains ($9,730) and the cost estimated for in-house separation ($8,500) indicates a cost of $18,230 per acre for sewer separation.

However, a cost of $18,000 per acre is probably conservatively low for one or more of the following reasons:

1. Separation of sewers in a high-rise commercial area could be much more expen-

sive, as indicated by the cost of $94,000 per acre based on the study in the Summer Street area of Boston.

2. Costs of separation estimated for a densely developed residential area in the Laguna Street District of San Francisco ($27,200 per acre) were nearly two times the costs estimated for the Milwaukee N. Prospect Avenue area.

3. The project must be large scale, with completion by 1977, if the federal requirements are to be met. Therefore, economies that might be possible with a piecemeal urban renewal separation program could not be attained.

Concluding Remarks—Preliminary Screening Process

The results of the preliminary screening process, as described above, indicated that, of the 15 alternatives considered for the abatement of pollution from combined sewer overflows, 13 could be applied practically, although with differing levels of effectiveness, to the lower Milwaukee River watershed. Of the 13 alternatives identified as feasible in the screening process, 11 were fully costed. The annual unit cost on a per acre served basis of the 11 costed alternatives differed by a wide margin, ranging from a low of $196 per acre for the Conveyance of Sewage to the North Avenue Dam Alternative (Number 10) to a high of $1,702 per acre for the Deep Tunnel Conveyance and Diked Surface Storage Reservoir Alternative (Number 7B). The range in annual unit costs of those alternatives applicable to the full 5,800-acre combined sewer service area within the watershed and, therefore, able to meet the water use objectives and effluent standards as adopted for the watershed study, however, was much narrower, ranging from $612 per acre for the Diked Storage Lagoon in Lake Michigan Alternative (Number 5B) to $1,702 per acre for the Deep Tunnel Conveyance and Diked Surface Storage Reservoir Alternative (Number 7B) (see Table 41).

More importantly, the screening process indicated that the need for phosphorus removal made it likely that only the storage alternatives and the screening/dissolved-air flotation flow-through treatment alternative could meet the controlling water use and effluent standards at a practical cost. Furthermore, the screening process revealed that, of the 10 basic storage alternatives considered, only two—Alternative 5B, Diked Storage Lagoon in Lake Michigan, and Alternative 7A, Deep Tunnel Conveyance and Mined Storage beneath the Milwaukee Harbor—merited further consideration as alternative plan elements for meeting the pollution problems generated in the entire combined sewer service area in Milwaukee County. All of the other eight storage alternatives considered were found either to be unable to provide sufficient storage volume to control sewage overflows from throughout the combined sewer service area, were very expensive, or were unacceptable with respect to their aesthetic characteristics, potential disruptive effect upon the existing environment, or potential public acceptance. The screening process also revealed that, of the flow-through alternatives considered, only one—Alternative 12, Screening/Dissolved-Air Flotation Flow-Through Treatment System—merited further consideration as an alternative plan element for meeting the water pollution problems generated throughout the combined sewer service area of Milwaukee County.

Combined sewer separation was found to be particularly unattractive alternative. Its effective application not only would require the reconstruction of sewerage and drainage systems throughout all of the 17,200-acre combined sewer service area within Milwaukee County but, for successful application, would have to include measures to reduce the inflow of clear water to the separated sewer system. Failure to reduce such clear water inflows would require the provision of additional conveyance and storage capacity in the separated sanitary system in order to avoid periodic surcharge and overflow of sanitary sewage to the streams and watercourses of the watershed. Sewer separation, moveover, would provide no potential for the control or relief of flooding due to surcharged storm sewers; and pollutants that originate in stormwater runoffs from streets and other open areas could not be controlled and treated as would be possible under the storage and flow-through alternatives. It is recognized, however, that, regardless of the alternative combined sewer overflow abatement plan element selected, incremental sewer separation may be appropriate for application in connection with major urban renewal efforts in order to reduce the amount of clear water entering the sanitary sewers and to reduce the potential for basement flooding.

A sewer separation program in the entire 5,800-acre combined sewer service area of the Milwaukee River watershed would cost, at a minimum,

$104.2 million, or about $18,000 per acre served. In addition to this relatively high cost, the massive reconstruction program required, which would affect over 170 miles of sewers and streets in the City of Milwaukee and the Village of Shorewood, would be extremely disruptive to the normal flow of life and commerce within the areas affected with immeasurable but large indirect and intangible costs. These effects and costs would be even greater if a sewer separation program were undertaken for the entire 17,200-acre combined sewer service area in Milwaukee County. Such a program would cost, at a minimum, $310 million, or about $18,000 per acre served, and would require a replacement of over 500 miles of sewers and public streets. Finally, after construction of the separate sewer systems, there would be no assurance that the water use objectives and supporting stream water quality and effluent standards could be met.

The results of the screening process thus indicated that three alternative stream water quality management plan elements for controlling the major sources of stream water pollution in the lower watershed should be explored in greater detail; namely, Alternative 5B, Diked Storage Lagoon in Lake Michigan; Alternative 7A, Deep Tunnel Conveyance and Mined Storage Beneath the Milwaukee Harbor; and Alternative 12, Screening/Dissolved-Air Flotation Flow-Through Treatment System. These three basic alternatives are accordingly described in greater detail in the following section of this chapter.

Detailed Consideration of Selected Alternatives

As noted above, the results of the preliminary screening process indicated that two combined sewer overflow storage alternatives—Alternative No. 5B, Diked Storage Lagoon in Lake Michigan, and Alternative No. 7A, Deep Tunnel Conveyance and Mined Storage Beneath the Milwaukee Harbor, and one flow-through treatment alternative—Alternative No. 12, Screening/Dissolved-Air Flotation—deserved further consideration in detail as alternative stream water quality plan elements for the Milwaukee River watershed. Only these three alternatives had the necessary flexibility to be adapted to solving the water pollution problems generated not only in the Milwaukee River watershed but throughout the entire 17,200-acre Milwaukee combined sewer service area and to solving any additional water pollution problems that might continue to be caused in the Milwaukee urbanized area by overflows from the separate sanitary sewerage system. All of the other alternatives considered either were very expensive; did not have the needed flexibility; were incapable of meeting the state-established water use objectives and effluent standards; or were unacceptable with respect to their aesthetic characteristics; potential disruptive effect upon the urban environment; or potential public acceptance.

In conducting the detailed analysis of the three alternatives subsequent to the screening process, several changes were made in the scope of the analysis and in the basic design criteria. The geographical scope of the analysis was expanded beyond the 5,800-acre combined sewer service area in the Milwaukee River watershed to include the entire 17,200-acre combined sewer service area in Milwaukee County. This change was made to recognize the setting of the lower watershed in the larger Milwaukee metropolitan area of which it is an integral part and to further recognize that any solution to the combined sewer overflow problem in the watershed must be applicable to, and be an integral part of, the solution to the combined sewer overflow problem in the entire metropolitan area.[15]

---

[15] *In the Prospectus for the Milwaukee River watershed study and in Chapter I, Volume 1, of this report, the geographic area to be considered in the analysis of the stream water quality problems of the watershed and in the preparation of a stream water pollution abatement and water quality management plan element was defined as that part of the total Milwaukee River watershed lying upstream from the North Avenue Dam. This definition was originally made on the basis that the North Avenue Dam clearly and sharply separate the river from its estuary and because water quality conditions in the estuary portion of the river below the dam are determined not only by the flow and water quality conditions of the Milwaukee River itself but also by the flow and water quality conditions of the Menomonee and Kinnickinnic Rivers, which are tributary to the estuary, and by the level and water quality conditions of Lake Michigan. It was and still is proposed to develop a separate water pollution abatement plan element for the estuary itself. It became apparent, however, during the course of the Milwaukee River watershed study that the magnitude and complexity of the combined sewer overflow problem would require study of the entire combined sewer service area within Milwaukee County in order to arrive at a sound solution for that portion of the problem upstream of the dam. Therefore, the Milwaukee River watershed study became the vehicle for examining and proposing solutions to the combined sewer overflow problem, not only within the approximately 2,100-acre combined sewer service area with overflows tributary to the Milwaukee River upstream from the North Avenue Dam but also the approximately 5,800-acre combined sewer service area with overflows tributary to the Milwaukee River and its estuary and the entire approximately 17,000-acre combined sewer service area in Milwaukee County.*

The scope of the analysis was further expanded to include the development of costs for a separate sewage treatment facility to treat the stored sewage as opposed to an alternative assumption that all stored sewage would be ultimately treated at the existing Jones Island sewage treatment plant. In the screening process described above, no treatment costs were considered with respect to the storage alternatives, since it was assumed that treatment costs would be common to all storage alternatives and would not, therefore, affect the selection of alternatives for further, more detailed consideration. Because the geographical scope of the analysis was expanded to include the entire 17,200-acre Milwaukee combined sewer service area, however, thus greatly expanding the volume of sewage to be stored and ultimately treated, and because it was recognized that it may be highly desirable to treat the very dilute stored sewage separately from the normal strength sewage so as not to upset the treatment processes at the Jones Island sewage treatment plant, it was decided to include separate treatment facilities and costs in the detailed consideration of the selected alternatives. In each case where storage of overflow was involved, the sewage treatment facility was designed to have a capacity of 50 mgd, with the pumping facilities at the storage reservoirs capable of delivering stored sewage at the rate of 77 cfs to the treatment facility. As in the screening process, it was assumed that pumping would be confined to a period of 18 hours of each 24-hour day in order to permit use of less costly off-peak electric power. The evacuation time, given the above design criteria and a four-inch runoff, would be 50 days.

Finally, the scope of the analysis was further expanded to include the development of designs and costs for the provision under each of the two storage alternatives of sufficient volume for the storage of four, as well as two, inches of runoff from the 17,200-acre tributary drainage area. In the preliminary screening process, the alternatives were designed and costed to intercept and provide storage for only two inches of runoff from the tributary drainage areas; in the detailed analysis, the alternatives were designed on the basis of either two inches or four inches of runoff. The rationale for selection of the two-inch runoff criterion was set forth earlier in this chapter. The two inch runoff design criterion would provide for control of overflow volumes resulting from runoff events with recurrence intervals up to and including three years; that is, the provision of two inches of runoff would reduce the frequency of combined sewer overflows from an average of 52 times per year at present to an average of about once every three years. Analysis of precipitation data for the Milwaukee area indicates that two inches of runoff would most likely be produced by a rainfall event having, irrespective of its duration, a total accumulation of approximately 2.6 inches and which would occur during the "summer" months of May through October. The four inch runoff design criterion was selected to provide an alternative with a much greater reduction in the frequency of combined sewer overflow inasmuch as four inches of storage would reduce the combined sewer overflows to an average of about once every 40 years. Four inches of runoff would be expected to result from a 4.6 inch rainfall event occurring during the May through October period. The two inch and four inch runoff design criteria, therefore, resulted in the development of designs and costs for alternatives offering a wide spectrum of effectiveness in reducing combined sewer overflows.

Although the scope of analysis was not expanded to include provision for the storage and treatment of sewage overflows from the separate sanitary sewerage system, it is important to note that each of the three alternatives considered in detail possesses the flexibility to be adapted to such use should it ever become necessary to do so. It was assumed for the purposes of the watershed study that the extensive program of trunk and relief sewer construction currently being conducted by the Milwaukee-Metropolitan Sewerage Commissions would, together with local relief sewer construction programs in municipalities served by the Commissions, abate all stream pollution resulting from the separate sanitary sewer overflows. An important factor in reducing separate sewer overflows is the reduction of clear water flows entering the separate sanitary sewers through infiltration and discharges from foundation drains and downspout connections. A determination as to whether or not the combined sewage storage and treatment alternatives will need to be made applicable to the overflows from the separate sewers will have to await completion of the sewer construction programs and the institution of controls over clear water inflows, and subsequent evaluation of the effectiveness of these programs in abating separate sewer overflows.

<u>Deep Tunnel Conveyance and Mined Storage Beneath the Milwaukee Harbor:</u> The basic concept of the deep tunnel and mined storage alternative was described earlier in this chapter in the discussion

relating to the preliminary screening process. The combined sewer overflows, equivalent in volume to either two inches or four inches of runoff, would be captured at points just upstream of the present combined sewer outfalls to the streams.[16] These polluted overflows, instead of entering the streams, would be dropped through vertical shafts into a network of concrete-lined tunnels which would be aligned generally under the streams. The tunnels, designed for flow under pressure in order to utilize the large head available, would conduct the overflow sewage to a central mined storage reservoir about 350 feet below the land surface. The mined storage reservoir, made up of large unlined chambers in the Niagaran geologic group below the ground water level, would consist of two sections—a settling chamber and the main storage reservoir.

Sewage would first flow into the settling chamber, which would be large enough to both contain the entire runoff during small storms and retain much of the solid loads generated during larger storm runoffs, which runoffs would then overflow into the main mined storage reservoir. The stored sewage would be aerated during the entire time of residence in the storage chambers. The partially treated sewage would then be pumped to a treatment facility on the land surface, utilizing off-peak power. This alternative, if designed to provide for storage of a four-inch runoff, would cost $210 million, including conveyance, storage, and treatment facilities, and contingencies, engineering and overhead, but exclusive of interest during construction. Such interest might total about $20 million. Annual costs would total $16.7 million for debt service and retirement and operation, maintenance, and power. Amortization of interest during construction would increase this amount to $18 million annually. If designed to provide for storage of a two-inch runoff, this alternative would cost about $165 million, exclusive of interest during construction. Such interest might total about $16 million. Annual costs would be $13.9 million for debt service and retirement and operation, maintenance, and power. Amortization of interest during construction would increase this amount to $14.9 million annually.

<u>*Control Structures and Vertical Shafts:*</u> The existing combined sewers would be intercepted near their outfalls to the streams (see Map 33). Control structures at that point would divert flows which exceed the existing intercepting sewer capacity into vertical shafts for delivery to the tunnel system. The existing intercepting sewers would continue to operate as at present, conveying dry-weather flow and a small portion of the storm flow to the existing treatment facilities.

If the alternative is designed either for the two-inch or the four-inch runoff, the existing control facilities would be modified, as necessary, to allow overflow to the streams for these infrequent occasions when the capacity of the deep tunnel storage system would be exceeded. Inlets to the vertical shafts would be gated to prevent inflow when the mined storage reservoir would be filled. Provision would be made for the installation of stoplogs for emergency use in case of failure of the gates.

Cost estimates for this portion of the total system were based on a total of 41 vertical shafts (see Map 33). The shafts, which are presently estimated to range in diameter from 5 to 12 feet, would be circular and concrete lined, with a vertical partition wall to provide a return passage for entrained air. A stilling basin would be provided at the base of each shaft for energy dissipation. The vertical shafts would be designed for 0.5 inch of runoff per hour, which generally exceeds the present maximum delivery capacity of the existing sewer systems. Field surveys and more detailed hydraulic analyses would be required to define more precisely the capacities of the existing individual sewers to be intercepted and, therefore, the capacities to be provided in the matching shafts, should this alternative be advanced to the preliminary engineering design phase.

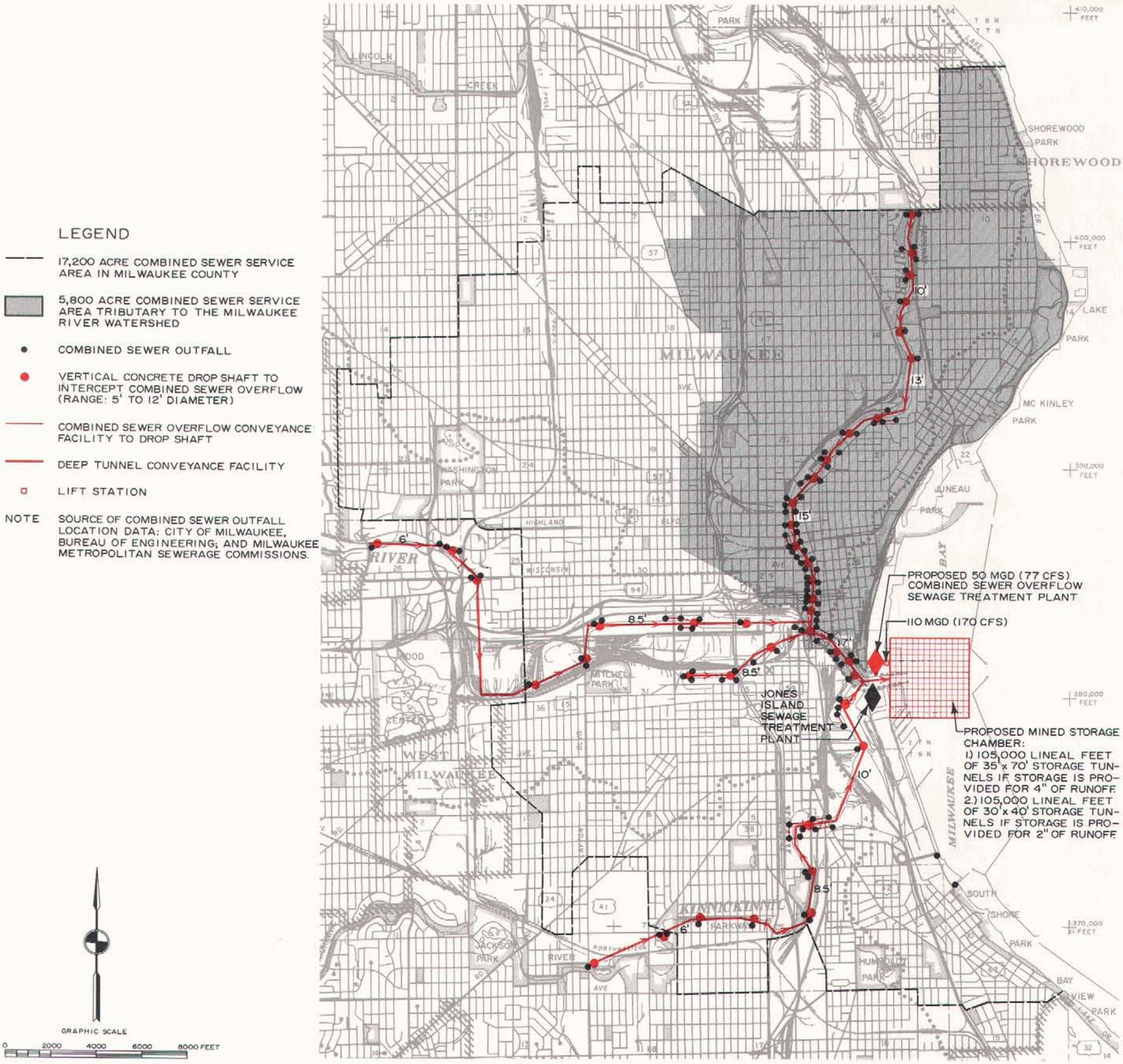
<u>*Conveyance Tunnels:*</u> A network of about 15 miles of circular concrete-lined tunnels, ranging in diameter from 6 to 17 feet, would convey the flow from the vertical shafts to the mined storage

---

[16] *It is important to note that all of the combined sewer overflow pollution abatement alternatives were designed to intercept, store, and treat combined sewer overflows from all 110 combined sewer outfalls discharging to the Milwaukee, Menomonee, and Kinnickinnic Rivers. There are an additional two known combined sewer outfalls discharging directly to Lake Michigan at isolated locations along the lake shoreline. Individual flow-through treatment or combination temporary storage flow-through treatment facilities would be constructed at these isolated outfall locations. The cost of constructing, operating, and maintaining these two flow-through or combination temporary storage flow-through treatment facilities has not been included in the cost estimates of the alternative combined sewer overflow pollution abatement plan elements for the 17,200-acre combined sewer service area.*

Map 33

EXPANDED COMBINED SEWAGE STORAGE ALTERNATIVE --
DEEP TUNNEL CONVEYANCE AND MINED STORAGE
BENEATH THE MILWAUKEE HARBOR



The application of the deep tunnel conveyance and mined storage combined sewer overflow pollution abatement alternative to the entire 17,200-acre combined sewer service area in Milwaukee County is shown on this map. Vertical shafts would be provided to drop the intercepted combined sewer overflows into deep concrete-lined tunnels located in the dolomite bedrock for conveyance to a mined storage area beneath the Milwaukee Harbor. The mined storage chambers would not be lined but the pressure in the surrounding aquifer would cause water to flow into, rather than out of, the storage chambers, making it impossible for the stored sewage to enter the aquifer from the storage chambers. Under this alternative the stored sewage would be treated at a proposed new sewage treatment plant to be located in the Maitland Field area north of and across the harbor entrance from Jones Island. With the exception of the treatment facility, all of the components of this system would be located underground.

Source: Harza Engineering Company and SEWRPC.

area (see Map 33). The tunnels would be designed to flow under pressure at velocities of up to 40 feet per second to gain economy by utilizing the great amount of head available. It is important to note that, as sized and costed, the conveyance tunnels could carry the peak rates of flow which can be delivered by the combined sewer outfalls, and, therefore, could serve the four- as well as the two-inch storage facilities. The tunnels would flow partially full during minor storms and would be designed to have adequate slope to maintain self-cleaning velocities under such gravity as well as under pressure flow.

The tunnels would be located in the bedrock below the Racine formation in the Niagaran group at an elevation of 250 to 350 feet below the surface. It is anticipated that locating the tunnels higher in the Racine formation could be expected to lead to high ground water inflows during construction. The alignment of tunnels would be dictated primarily by the location of existing combined sewer outfalls; and, therefore, the tunnels would be located generally under the streambeds. Design and cost estimates for conveyance tunnels were based on conventional drill-and-blast methods of excavation. However, recent experience of tunnel boring by tunneling machine or "mole" in Chicago, in similar formations, holds promise for substantially lower construction costs.

In determining the final sizing of the conveyance system, consideration should be given to potential future application to the abatement of separate sanitary sewer overflow, to the elimination of basement and underpass flooding, and to avoiding potential future combined, sanitary, and storm sewer capacity problems as the existing sewerage systems are expanded and improved. To provide the flexibility to meet such contingencies, a conveyance capacity considerably in excess of the existing combined sewer capacities would probably be appropriate.

Mined Storage Reservoir: The mined storage reservoir would provide capacity for temporary storage of combined sewer overflows prior to evacuation by pumping to the sewage treatment facility. Automatic controls would close the gates on the vertical shaft inlets should the mined storage reservoir be almost full. Thus, the flow in the mined storage reservoir would always be under atmospheric pressure, with a free water surface. Maintaining the mined storage reservoir at atmospheric pressure would assure that all ground water movement or seepage would be inward and would eliminate any potential for aquifer pollution, provided the piezometric surface is maintained above the reservoir chambers.

The storage reservoir would be constructed by mining methods. A grid configuration, adjusted, as necessary, to geologic conditions, would provide the greatest economies in mining and materials handling. The configuration would make available a large number of headings for continuous utilization of mining equipment and labor through the drill-blast-and-muck cycle. For cost estimation purposes, the intersecting galleries were spaced 185 feet apart and were assumed to be 35 feet wide by 70 feet high if designed to accommodate 4 inches of storage and 30 feet wide by 40 feet high if designed to accommodate 2 inches of storage. The composition and strength of the Niagara dolomite was judged to be such that lining would not be required. The cost estimates, however, include allowances for extensive rock bolting, provision of wire netting for protection of workers, and sealing of any large water-bearing crevices encountered.

The mined storage reservoir would be divided by overflow weirs into two separate sections—a settling chamber and a main reservoir. The settling chamber would receive the flow from the conveyance tunnels and would provide detention to allow settlement of all grit and a large portion of the settleable organic solids, a process comparable to the grit removal and primary treatment operations in a conventional sewage treatment plant. The floor of the settling chamber would be concrete lined, and the chamber would be provided with mechancial and hydraulic equipment for sludge handling. High-head sludge pumps located at one end of the settling chambers would pump the sludge and sediments to the treatment facilities on the surface.

For smaller overflows, up to about 600 acre-feet in volume, the entire runoff would be contained in the settling chamber. This sewage would be evacuated directly from the settling chamber to treatment facilities on the surface.

For larger overflows the partially treated sewage and storm water would spill from the settling chamber into the main storage area. A substantial portion of the settleable solids in the influent sewage would have been removed because of the reduced velocities of flow through the settling chamber. All sewage entering the main storage area would be held in storage and aerated until the settling chambers would be evacuated. Only then would the sewage from the main storage area be pumped to the treatment facilities. All pumping would be done during periods when off-peak power is available. The mined storage reservoir, including the settling chamber, would have a volume of 5,700 acre-feet, equivalent to a runoff of 4.0 inches over the combined sewer drainage area of 17,200 acres. The equivalent volume for two inches of runoff would be 2,850 acre-feet.

The settling chambers would be ventilated and lighted to the extent necessary to provide an atmosphere completely safe for inspection and maintenance of the chambers and the sediment removal facilities. The main storage area would be equipped with an independent aeration and ventilation system.

Pumping Station: The pumping station would contain four pump units capable of delivering 170 cfs (110 mgd) at maximum head. Sewage and storm water from the settling chamber would be conveyed by a conduit to a sewage treatment plant on the land surface. The pumping station would include appurtenant facilities for plant operation, ventilation, and access.

Treatment Facility: The cost estimates presented above include the cost of the construction and operation of treatment facilities to achieve the equivalent of primary, secondary, and advanced waste treatment and disinfection of the stored sewer overflows. Cost reductions might be achieved by combining or interconnecting the proposed treatment facility with the Jones Island and/or South Shore sewage treatment plants. In this respect, it should be noted that provision of a site on the land surface in the harbor area for a new sewage treatment facility would present certain potential land use conflicts and would have to compete with alternate public and private lakefront uses.

The required treatment capacity is a function of the volume and occurrence pattern of sewer overflows and the storage provided in the project for regulation of overflows. A normal treatment capacity of 50 mgd was selected after investigation of storage requirements based on runoff analyses. The treatment capacity of 50 mgd would be applicable to surface treatment facilities for secondary treatment for BOD and solids removal, chemical treatment for phosphate removal, and chlorination for disinfection. This facility most probably would be separate from the existing treatment plants, as the pollutants in the waste water would be of low concentrations and the large volumes of relatively weak sewage might upset the treatment processes of the Jones Island or South Shore sewage treatment plants, even if hydraulic capacity were available at these plants.

Primary treatment for removal of settleable solids would be provided in the underground settling chamber which would retain the entire runoff and, therefore, settleable solids from small storms and a significant portion of the settleable solids associated with flows from larger storms. Solids would be evacuated from sumps in the settling chamber by high-head sludge pumps located near the settling chamber. Mechanical equipment traveling along overhead rails would facilitate flow of the solids to the sumps. A special flushing system would be provided for final cleanup of the settling chambers after the supernatant is withdrawn. Facilities would be included in the settling chambers for addition of polymers to increase the efficiency of solids removal, particularly during large storms when the runoff exceeded the volume of the settling chamber. Solids evacuated from the settling chamber would be pumped either to the proposed new treatment facility or to the existing Jones Island sewage treatment plant for final disposal.

The secondary treatment facilities would consist of an aerated lagoon and final settling tanks. The influent to the secondary treatment facilities would be from the settling chamber or the main storage chamber. The influent would be passed through a screening chamber before entering the secondary treatment facilities. Solids collected from the final settling tanks could be returned to the influent or could be conveyed to the Jones Island sewage treatment facility for treatment and disposal.

After final settling, the sewage would pass through phosphate removal facilities. Removal would be accomplished by coagulation with lime, alum, ferric sulfate, or other appropriate chemical using rapid mix, flocculation, and settling facilities. Before being released to Lake Michigan, the effluent would be chlorinated to reduce the total and fecal coliform indexes to the required levels.

Should this alternative be advanced to the preliminary engineering design phase, a program of field measurement and laboratory testing of combined sewer overflow would be necessary to obtain more precise data on the quantity and quality of overflow to be handled in subsequent design phases because of uncertainties regarding: 1) the quality of the relatively dilute waste water from the overflows, 2) the biological reaction rates attendant to the treatment of such overflows, and 3) the potential influence of intermittent operations.

If the studies indicated that biological processes could not be successfully applied because of the dilute nature of the waste water and the intermittent loading of the system, consideration could be given to seeding the system with raw sanitary sewage, thus providing the bacteria and nutrients necessary for maintenance of satisfactory biological conditions. Since the Jones Island sewage treatment facility is located near the proposed storage area, it would be advantageous to coordinate the proposed treatment processes and facilities with that of the Jones Island facility for possible economies and operational advantages and, insofar as possible, to achieve continuous operation of the treatment facilities utilizing the proposed overflow treatment facilities, in times of dry weather, to supplement the Jones Island and South Shore treatment facilities. As indicated earlier, it may be possible to utilize surplus treatment capacity of the entire metropolitan system in lieu of providing the separate treatment costed herein, thereby reducing the overall costs of this alternative.

Geology, Ground Water, and Aquifer Protection: The information available indicates that the conveyance tunnels and the mined storage areas could be located in the lower formations of the Niagaran group (see Figure 19). These facilities would, thus, be located about 250 to 350 feet below the surface of Lake Michigan. The lithologic character of the bedrock underlying southeastern Wisconsin was described in Chapter IV of Volume 1 of this report.

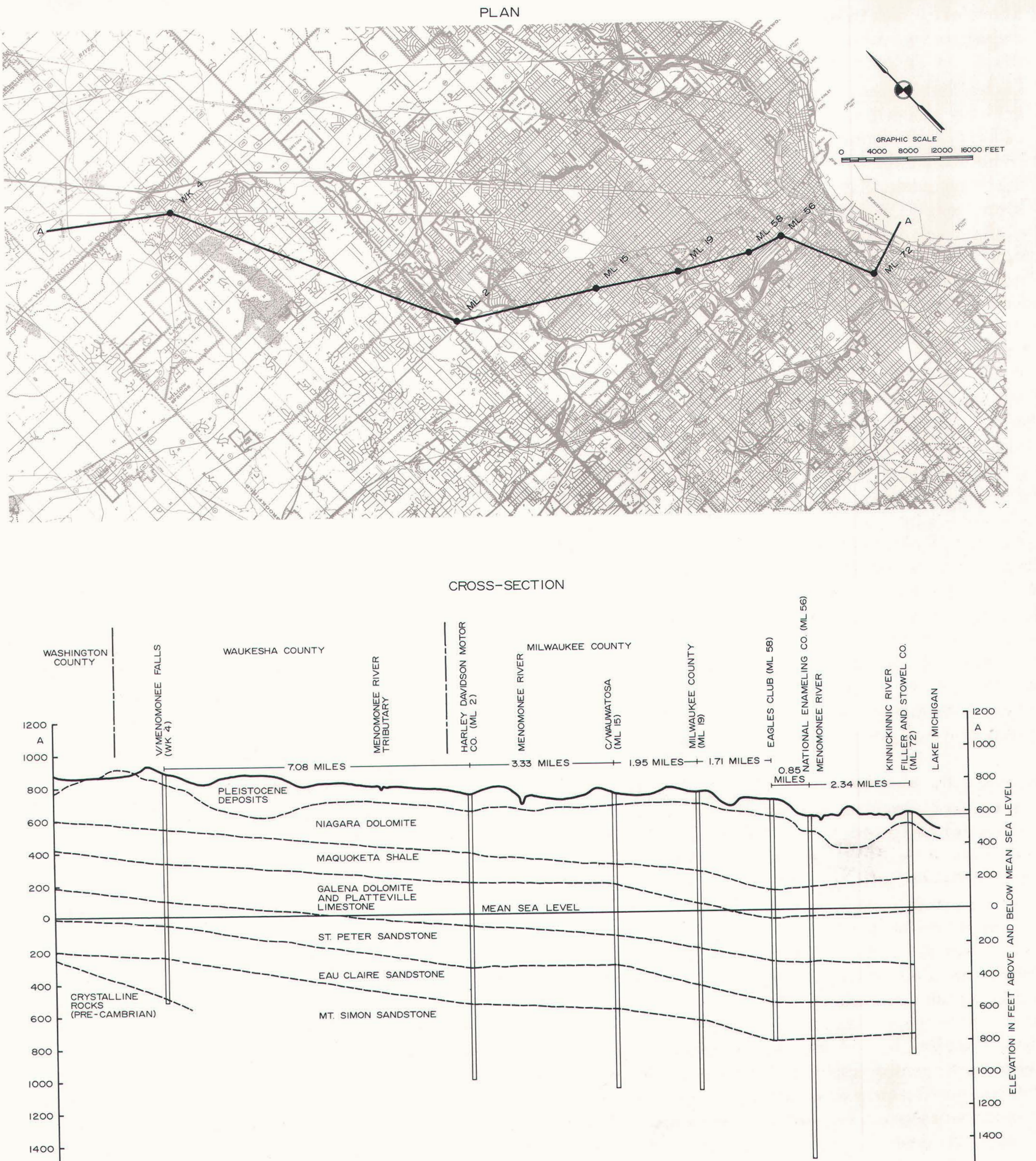
Ground water levels in the Niagaran aquifer should be at an elevation of 200 to 300 feet above the roof of the proposed storage chambers and conveyance tunnels. The conveyance tunnels would be lined to prevent leakage into or out of the surrounding aquifer. Whatever leakage might occur, however, would be into the tunnels, which would be under atmospheric pressure except for relatively short periods of peak flow. The storage chambers would not be lined, but the pressure in the surrounding aquifer would cause flow into, rather than out of, the storage chambers which would be under atmospheric pressure at all times. Thus, with a differential in water pressure levels between the chambers and the surrounding aquifer, it would be impossible for the combined sewer overflow to enter the aquifer from the storage chambers.

Although the piezometric surface in the Niagaran aquifer very likely would be maintained by natural recharge at elevations even higher than the pressure head which would develop in the conveyance tunnels for short intervals during peak rates of flow, costs for a well system for artificial recharge to prevent leakage of polluted water from the tunnels in the Niagaran group were included in the cost estimates. The amount of recharge required would be relatively small, but the cost estimates include enough facilities to recharge as much as 6 mgd into the aquifers surrounding the conveyance tunnels and storage chambers.

Ground water factors would be analyzed by electric-analog or digital-computer model during feasibility and design study stages following collection of subsurface information. A program of subsurface investigations would include core drilling and logging of geologic conditions found in the boreholes and well pumping tests and geophysical logging. The entire subsurface investigation program could be preceded by a seismic survey if additional definition of the top of rock would be required. Should subsequent subsurface investigation prove that it would be unreasonably costly or technically unfeasible to locate subsurface storage in the Niagaran group, the tunnels and storage area could be located about 700 feet below the surface in the Platteville and Galena formations. The technical feasibility of developing storage in this deeper formation has been established for the Chicago area through extensive studies. There is no reason to expect significantly different geologic conditions would be encountered in this deeper formation in the Milwaukee area.

Seepage into the Tunnels and Chambers: After the storage system becomes operational, ground water seepage would occur into the tunnels and chambers which would require evacuation. Significant ground water flow occurs in the Niagara dolomite only through crevices and solution cavi-

Figure 19
STRATIGRAPHIC CROSS-SECTION THROUGH MILWAUKEE AND EASTERN WAUKESHA COUNTIES



Source: U. S. Geological Survey.

ties. These flow passages would be sealed in the tunnels prior to installation of lines, and would be sealed in the chambers as encountered during construction if the flow produced was significant. Therefore, the inflow of ground water to the underground system should be relatively small.

System Operation and Performance: Although the primary function of the system would be the capture, conveyance, detention, and treatment of combined sewer overflows to prevent pollution of the Milwaukee River, the system would provide some local flood relief potential. The existing combined sewers would be partially relieved of surcharge conditions and thus would serve to reduce local basement and street flooding. The potential would exist, moreover, to reduce flows into the streams of the metropolitan area by as much as 8,600 cfs.

The full storage and pumping capacity of the system would be required only at rare intervals. Only about 10 storms annually could be expected to produce overflows larger than the volume of the settling chamber. In larger storms the overflow volume would exceed the capacity of the settling chamber and would spill to the main underground storage area. All overflows reaching the main underground storage area would be pumped to the surface after the storage in the settling basin was evacuated. It is anticipated that releases in excess of about 50 mgd would not be necessary under normal operating conditions, but pumping capacity would be available to pump at a rate of 110 mgd to permit evacuation of the design runoff.

The possibility exists that, if only two inches of storage are provided, for certain extreme events, the storage capacity of the system would not be sufficient to accommodate the runoff. In such extreme cases, it would be necessary to use the closure gates at the overflow control structures to stop inflow to and prevent pressurization of the mined storage area. Under such infrequent circumstances, estimated to occur on an average of only once in three years, the excess runoff would overflow to the streams. It is estimated that such rare overflow to the streams would contain only about 2 percent of the total present BOD load of the combined sewer overflows. If four inches of storage were provided, overflows from the combined sewer system would be virtually eliminated.

System Costs: The design criteria described in the foregoing discussion relative to the provision of four inches of storage were the basis for the preparation of project cost estimates. The proposed layout of the conveyance tunnels, storage chambers, and treatment facilities is shown on Map 33. The estimated total cost for construction of these major project components and appurtenant facilities is $210 million, exclusive of interest during construction (see Table 55). Such interim financing would total about $20 million, depending on sources and method of financing, and would raise the total project cost to about $230 million.

Annual costs for facilities and for operation, maintenance, and power, but exclusive of costs for interest during construction, would total about $16,740,000, as follows:

Facilities	$13,300,000
Operation, Maintenance, and Replacement	3,000,000
Power	440,000
Total	$16,740,000

Adding a charge for interest during construction would raise the total annual cost to about $18,010,000.

The annual costs for the facilities are based on construction costs for January 1969 and on an overall project life of 50 years with an interest rate of 6 percent. All project components were assumed to have a life of 50 years, except electrical and pump systems, which would require replacement after 25 years, and aeration sludge handling and aquifer recharge systems, which would be replaced at 20-year intervals.

If the system is designed to store and treat only two inches of runoff from the combined sewered area, the required facilities would cost about $165 million, exclusive of interest during construction, or about $45 million less than the facilities for storing four inches of runoff. Comparable annual costs would be about $13.9 million.

Although it is desirable that, in the future, virtually no overflows of combined sewers should occur, the incremental cost of $45 million for controlling an estimated additional 2 percent of the pollutants now entering the waterways from the combined sewers, as measured in terms of the average annual organic waste loading (BOD), can be considered to be very high. The present overflows of the combined sewers, at least in that

Table 55

COST ESTIMATES--DETAILED CONSIDERATION OF ALTERNATIVE COMBINED SEWER OVERFLOW POLLUTION ABATEMENT PLAN 17,000-ACRE COMBINED SEWER SERVICE AREA IN MILWAUKEE COUNTY

ALTERNATIVE PLAN ELEMENT	STORAGE DESIGN CRITERION (INCHES OF RUNOFF)	CAPITAL COST (CONSTRUCTION)											
		STRUCTURAL	SEWAGE TREATMENT FACILITIES	SLUDGE HANDLING	INSTRUMENTATION	LIFT PUMP EQUIPMENT AND MINOR SEWER CONNECTIONS	COLLECTION AND CONVEYANCE PIPES	LAND AND LANDSCAPING	TUNNEL AND RESERVOIR AERATION	RIVER AERATION	STORAGE	AQUIFER RECHARGE	TOTAL
DEEP TUNNEL CONVEYANCE AND MINED STORAGE BENEATH THE MILWAUKEE HARBOR	2	$ --	$25,000,000	$ 9,000,000	$ --	$ 7,600,000	$54,000,000	$ --	$ 6,800,000	$ --	$ 61,000,000	$ 1,600,000	$165,000,000
DEEP TUNNEL CONVEYANCE AND MINED STORAGE BENEATH THE MILWAUKEE HARBOR	4	--	25,000,000	9,000,000	--	7,600,000	54,000,000	--	7,800,000	--	105,000,000	1,600,000	210,000,000
REINFORCED CONCRETE PIPE CONVEYANCE IN THE STREAM-BEDS AND DIKED STORAGE LAGOONS IN LAKE MICHIGAN	2	--	25,000,000	8,000,000	--	43,000,000	81,300,000	--	3,400,000	--	28,300,000	--	189,000,000
REINFORCED CONCRETE PIPE CONVEYANCE IN THE STREAM-BEDS AND DIKED STORAGE LAGOONS IN LAKE MICHIGAN	4	--	25,000,000	8,000,000	--	43,000,000	81,300,000	--	6,900,000	--	56,600,000	--	220,800,000
SCREENING/DISSOLVED-AIR FLOTATION FLOW-THROUGH TREATMENT SYSTEM	--[a]	34,000,000	41,000,000	--	15,350,000	13,700,000	5,950,000	24,800,000	--	5,300,000	--	--	140,100,000

ALTERNATIVE PLAN ELEMENT	STORAGE DESIGN CRITERION (INCHES OF RUNOFF)	PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL			ANNUAL COST PER ACRE	CAPITAL COST PER ACRE
		CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL		
DEEP TUNNEL CONVEYANCE AND MINED STORAGE BENEATH THE MILWAUKEE HARBOR	2	$165,000,000	$54,000,000	$219,000,000	$10,450,000	$ 3,440,000	$13,890,000	$ 808	$ 9,593
DEEP TUNNEL CONVEYANCE AND MINED STORAGE BENEATH THE MILWAUKEE HARBOR	4	210,000,000	54,000,000	264,000,000	13,300,000	3,440,000	16,740,000	973	12,209
REINFORCED CONCRETE PIPE CONVEYANCE IN THE STREAM-BEDS AND DIKED STORAGE LAGOONS IN LAKE MICHIGAN	2	189,000,000	59,600,000	248,500,000	12,000,000	3,780,000	15,780,000	917	10,988
REINFORCED CONCRETE PIPE CONVEYANCE IN THE STREAM-BEDS AND DIKED STORAGE LAGOONS IN LAKE MICHIGAN	4	220,800,000	59,600,000	280,400,000	14,000,000	3,780,000	17,780,000	1,055	12,837
SCREENING/DISSOLVED-AIR FLOTATION FLOW-THROUGH TREATMENT SYSTEM	--	170,500,000	35,500,000	206,000,000	10,820,000	2,250,000	13,070,000	760	8,145

[a]NOT APPLICABLE.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

portion of the Milwaukee River watershed above the North Avenue Dam, were estimated in Chapter IX of Volume 1 of this report to total about 15 percent of the total pollutants produced by sewer overflows above the Dam in the watershed, also as measured in terms of the average annual BOD loading. A residual of 2 percent of this amount would be less than 1/2 of 1 percent of the total average annual waste loading contributed to the stream system above the Dam by all sewer overflows. The potential shock effect on fish and aquatic life of discharge of this residual pollution loading would be minimal, as overflows would occur only after about two inches of runoff were stored, thereby containing the first and most pollutant-laden flush of storm water runoff from rooftops, yards, pavements, and sewers. Moreover, during such a large runoff event, the streamflows would be high, and the stream water could be expected to have a relatively high dissolved oxygen content and large dilution potential. Finally, a proven need for larger storage facilities could be readily met at any time by extension of the mined storage chambers.

Diked Storage Lagoons in Lake Michigan: The basic concept of the diked storage lagoon in Lake Michigan alternative was described earlier in this chapter in the discussion relating to the preliminary screening process. The combined sewer overflows, equivalent in volume to either two inches or four inches of runoff, would be captured at the locations of the present combined sewer outfalls to the streams.[17] These polluted overflows, instead of entering the streams, would be diverted into a network of gravity flow reinforced concrete pipes buried in the stream beds. These concrete pipes would be precast and floated along the streams to their proper position before being sunk into prepared trenches located in the stream beds. The pipes would conduct the overflow sewage to two lagoons located east of the Milwaukee Harbor breakwater (see Map 34). Each lagoon would consist of two sections—a settling basin and a main storage reservoir.

Sewage would first flow into the settling basin, which would be large enough to both contain the entire runoff during small storms and retain much of the solids loads generated during larger storm runoffs, which runoffs would then overflow into the main storage reservoir from the settling basins. The stored sewage would be aerated during the entire time of residence in the lagoon. The partially treated sewage would then be pumped to a treatment facility on the land surface, utilizing off-peak power. This alternative, if designed to provide for storage of a four-inch runoff, would cost a total of $220.8 million, including conveyance, storage, and treatment facilities and contingencies, engineering, and overhead, but exclusive of interest during construction. Such interest might total about $20 million. Annual costs would total $17,780,000 for debt service and retirement and operation, maintenance, and power. Amortization of interest during construction would increase this to $19,050,000 annually. If designed to provide for storage of a two-inch runoff, this alternative would cost about $189 million, exclusive of interest during construction. Such interest might total about $18 million. Annual costs would total about $15,780,000 for debt service and retirement and operation, maintenance, and power. Amortization of interest during construction would increase this amount to $16,920,000 annually.

Control Structures and Conveyance System: The existing combined sewers would be intercepted near their outfalls to the streams (see Map 34). Control structures at that point would divert flows which exceed the existing intercepting sewer capacity into the conveyance system. The existing intercepting sewers would continue to operate as at present, conveying dry-weather flow and a small portion of the storm flow to the existing treatment facilities.

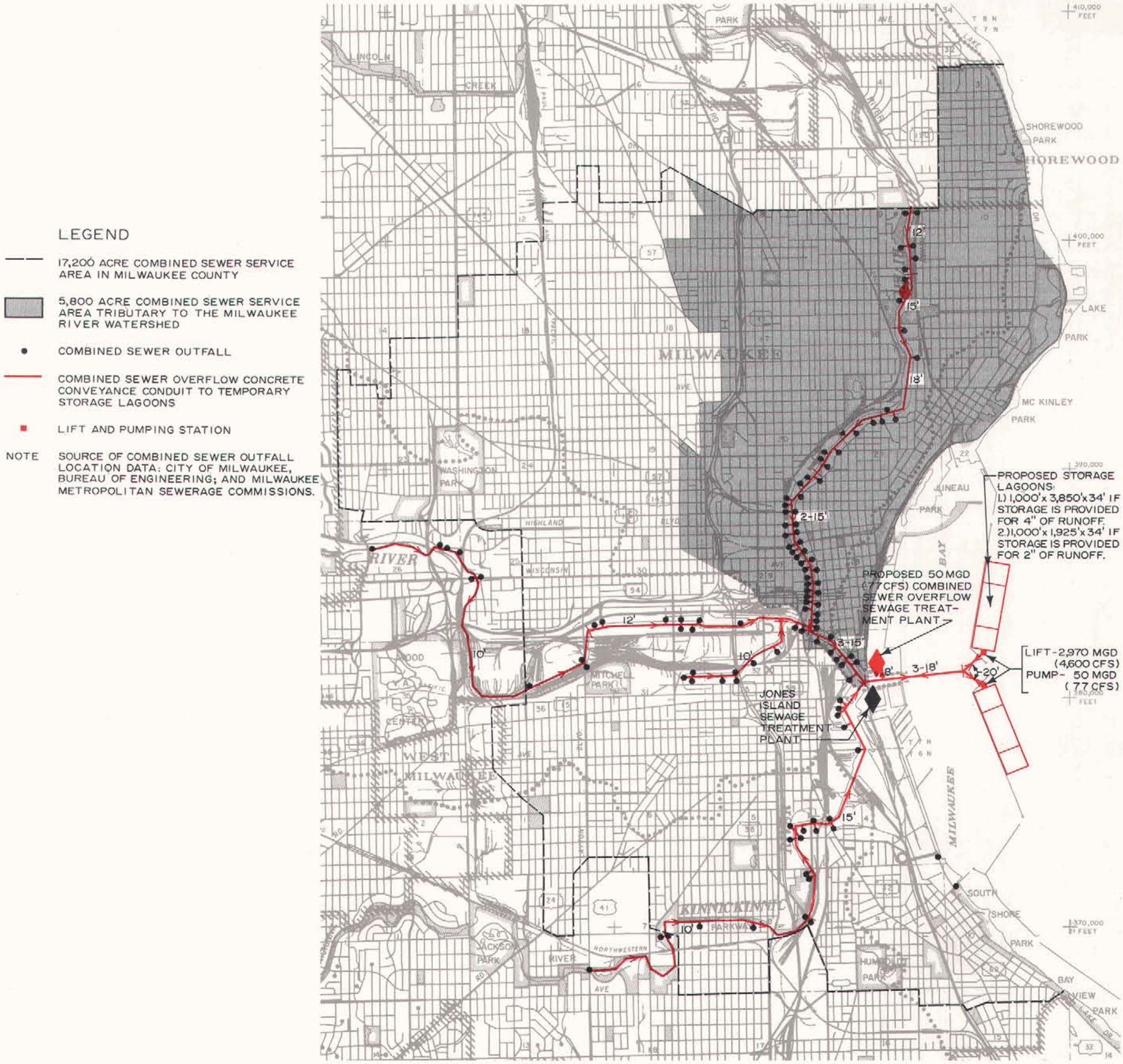
If the alternative is designed for the two-inch runoff, infrequent occasions would occur when the capacity of the lagoons in Lake Michigan would be exceeded. In such cases the flows would be conveyed through the conveyance system, through the lagoons, and spill directly to Lake Michigan. Such spills would not occur, except in extremely rare instances, if storage capacity is provided for the four-inch runoff.

The conveyance inlets to the concrete pipes would be designed for 0.5 inch of runoff per hour, which generally exceeds the present maximum delivery capacity of the existing combined sewer systems. Field surveys and more detailed hydraulic analyses would be required to define more precisely the capacities of the existing individual sewers to be intercepted and, therefore, the capacities to be provided in the matching conveyance inlets.

[17] *Ibid., Footnote 16.*

Map 34

EXPANDED COMBINED SEWAGE STORAGE ALTERNATIVE -- DIKED STORAGE LAGOONS IN LAKE MICHIGAN



The application of the diked storage lagoon alternative to the entire 17,200-acre combined sewer service area in Milwaukee County is shown on this map. Two open storage lagoons would be provided under this alternative, each of which would be located outside the harbor breakwater. The dikes forming the lagoons would be so constructed to prevent seepage from the lagoons into Lake Michigan. Treatment of the stored sewage would be provided at a new sewage treatment plant located in the Maitland Field area, north of and across the harbor entrance from Jones Island. Because of the aesthetic effects of the intrusion of these lagoons in Lake Michigan, this alternative was considered to have a poor potential for public acceptance.

Source: Harza Engineering Company and SEWRPC.

The conveyance network would extend a total of about 15 miles along the watercourses of the Milwaukee area. The conveyance conduits would be multi-barrelled, circular, concrete pipes ranging in diameter from 10 to 20 feet. The pipes would be designed to flow at a maximum velocity of 20 feet per second. The concrete conduits would flow partially full during minor storms but would have adequate slope to maintain self-cleaning velocities under such gravity flow conditions.

The alignment of the concrete pipes would be dictated primarily by the location of existing combined sewer outfalls; hence, the pipes would be located below the stream beds of the Milwaukee, Menomonee, and Kinnickinnic Rivers and in the harbor area. Designs and cost estimates for the concrete pipes are based on their being precast, floated along the streams, and sunk into a prepared trench in the stream bed. A liberal allowance was made in the unit cost estimates for the relocation of existing utilities which cross the rivers.

Lake Michigan Lagoons: The storage reservoir would provide capacity for the temporary storage of combined sewage overflows prior to evacuation by pumping to a sewage treatment facility. In all except the most extreme runoff events, the sewage stored in the lagoons would be below the lake level. Thus, any seepage of lake water through the dike would be inward and would eliminate any potential for lake pollution. In circumstances where more than two inches of runoff would occur, an automatic control device would open gates on outlets in the lagoon to permit direct spillage to Lake Michigan. If the lagoon storage system was designed to provide for a four-inch runoff, however, no such spillage to Lake Michigan would be necessary.

The storage reservoir lagoon would be formed by a rock and earthen dike constructed outside the existing Milwaukee Harbor breakwater. The core of the dike would be a slurry trench seepage barrier. Cost estimates were based on the construction of two independent lagoons with a combined storage capacity of 5,370 acre-feet. The remaining necessary 360 acre-feet of storage would be provided by the concrete pipe conduits. The dikes would be about 46 feet high and water would be lagooned to a depth of 34 feet. The dikes would have slopes of 3.5 horizontal to 1.0 vertical on the lake side and 2.5 to 1.0 on the lagoon side. Each of the lagoons would be about 1,000 feet wide and would extend a combined total of about 7,700 feet along the harbor breakwater, as shown on Map 34. No lining would be placed in the bed of the lagoon, as seepage would be minimal through the clay layers in the lake bottom.

The storage reservoir would be divided by overflow weirs into two separate sections—a settling basin and a main reservoir. The settling basin would receive the flow from the concrete pipe conveyance system and would provide detention to allow settlement of all grit and a large portion of the settleable organic solids, a process comparable to the grit removal and primary treatment operation in the conventional sewage treatment plant. The floor of the settling basin would be concrete lined, and the basin would be provided with mechanical and hydraulic equipment for sludge handling. Sludge pumps would pump the sludge and sediments to the treatment works on the land surface.

For smaller overflows, up to about 600 acre-feet in volume, the entire runoff would be contained in the settling basin. This sewage would be evacuated directly from the settling basins to treatment facilities. For larger overflows partially treated sewage and storm water would spill from the settling basin into the main storage areas. A substantial portion of the settleable solids in the influent sewage would have been removed because of the reduced velocities of flow through the settling basins. All sewage entering the main storage areas would be held in storage and aerated until the settling basins would be evacuated. Only then would the sewage from the main storage area be pumped to the treatment facilities. All pumping would normally be done during periods when off-peak power is available. The lagoon storage reservoir, including the settling basins and some conduit storage, would total a volume of 5,700 acre-feet, equivalent to a runoff of four inches over the combined sewer drainage area of 17,200 acres. The equivalent volume for two inches of runoff would be 2,850 acre-feet.

Pumping Station: Six pump units capable of delivering a total of 9,190 cfs (5,940 mgd) at maximum head would be housed in two pumping stations near the lagoons. The pumping plants would serve the dual purpose of lifting flow from the conveyance pipes serving the 17,200-acre combined sewer service area into the storage lagoons and of later pumping the stored waste waters back through the conveyance pipes from the lagoons to the treatment facilities. Only about 2 percent of the total pumping station capacity would be used to pump the stored sewer overflows directly to the sewage treatment plant.

Treatment Facility: The cost estimates presented above include treatment facilities to achieve the equivalent of primary, secondary, and advanced waste treatment and disinfection of the stored sewer overflows. The treatment facilities would be similar to those described above for the treatment of sewage stored under the deep tunnel and mined storage alternative. Cost reductions might be achieved by combining or interconnecting the proposed treatment facility with the Jones Island and/or South Shore sewage treatment plants.

Geology, Foundation, and Seepage Conditions: The storage lagoons would be located adjacent to the existing Milwaukee Harbor breakwater (see Map 34). In 1961 five borings were made by the U. S. Army Corps of Engineers on the north arm of the Milwaukee breakwater to depths ranging from 40 feet to 100 feet. Samples taken were subjected to graduation analyses, Atterburg limit tests, density measurements, shear tests, and permeability analyses. The logs of these borings show that there are interbedded layers of clay and clayey materials and coarser, more permeable, sandy materials.[18] From these borings it appears that seepage either into or out of the lake lagoons would be minimal due to the layers of clay underlying the lagoon sites. The strengths of the materials would be adequate to support a structure of the size proposed for the lagoon dike. There should, therefore, be no unusual foundation problems or costs encountered in constructing a lagoon at this site.

The full storage and pumping capacity of the system would be required only at rare intervals. Only about 10 storms annually would produce overflows larger than the volume of the settling basins. In larger storms, the overflow volume would exceed the capacity of the settling basins and would spill to the main lagoon storage area. All overflows reaching the main storage area would be pumped to the treatment facility after the storage in the settling basins was evacuated. It is anticipated that releases in excess of about 50 mgd would not be necessary under normal operating conditions, but pumping capacity would be available to pump at a much greater rate to permit rapid evacuation of the stored sewer overflows.

The possibility exists that, if only two inches of storage are provided, for certain extreme events, the storage capacity of the system would not be sufficient to accommodate the runoff. In such extreme cases, it would be necessary to use closure gates at overflow points in the lagoons to permit the spillage to Lake Michigan and to prevent surcharging of the lagoons. Under such rare circumstances, the spill would have been through the lagoons where solids removal and aeration would have been effected. It is estimated that such rare overflow to Lake Michigan would contain less than 2 percent of the total present BOD load of the combined sewer overflows. If four inches of storage are provided, overflow from the lagoons would be virtually eliminated.

System Costs: The design criteria described in the foregoing discussion relative to the provision of four inches of storage were used as a basis for the preparation of project cost estimates. The proposed layout of the conveyance pipes, storage lagoons, and treatment facilities is shown on Map 34. The estimated total cost for construction of these major project components and appurtenant facilities are $220.8 million, exclusive of interest during construction (see Table 55). Such interim financing would total about $20 million, depending upon sources and methods of financing, and would raise the total project cost to about $241 million. Annual costs for facilities and for operation, maintenance, and power, but exclusive of costs for interest during construction, would total about $17,780,000, as follows:

Facilities	$14,000,000
Operation, Maintenance, and Replacement	3,420,000
Power	360,000
Total	$17,780,000

Adding a charge for interest during construction would raise the total annual cost to about $19 million.

The annual cost for facilities are based on construction costs for January 1969 and on an overall project life of 50 years with an interest rate of 6 percent. All project components were assumed

[18] *Unpublished data obtained from the U. S. Army Corps of Engineers. Copies of the boring logs are on file at the SEWRPC offices.*

to have a life of 50 years, except electrical and pump systems, which would require replacement after 25 years, and aeration and sludge handling systems, which would be replaced at 20-year intervals.

If the system is designed to store and treat only two inches of runoff from the combined sewered area, the required facilities would cost about $189 million, exclusive of interest during construction, or about $31.8 million less than the facilities required for storing four inches of runoff. Comparable annual costs would be about $15.8 million. Although it is desirable that, in the future, virtually no overflows of combined sewers should occur, the incremental cost of $31.8 million for controlling an estimated additional 2 percent of the pollutants now entering the waterways from the combined sewers, as measured in terms of the average annual organic waste loading (BOD), can be considered to be very high. The present overflows of the combined sewers, at least in that portion of the Milwaukee River watershed above the North Avenue Dam, were estimated in Chapter IX of Volume 1 of this report to total about 15 percent of the total pollutants produced by sewer overflows above the Dam in the watershed, also as measured in terms of the average annual BOD loading. A residual of 2 percent of this amount would be less than 1/2 of 1 percent of the total average annual waste loading contributed to the stream system above the Dam by all sewer overflows. The potential shock effect on fish and aquatic life of discharge of this residual pollution loading would be minimal, as overflows would occur only after about two inches of runoff were stored, thereby containing the first and most pollutant-laden flush of storm water runoff from rooftops, yards, pavements, and sewers. Moreover, during such a large runoff event, the stream flows would be high, and the stream water could be expected to have a relatively high dissolved oxygen content and large dilution potential. Finally, a proven need for larger storage facilities could be readily met at any time by extension of the mined storage chambers.

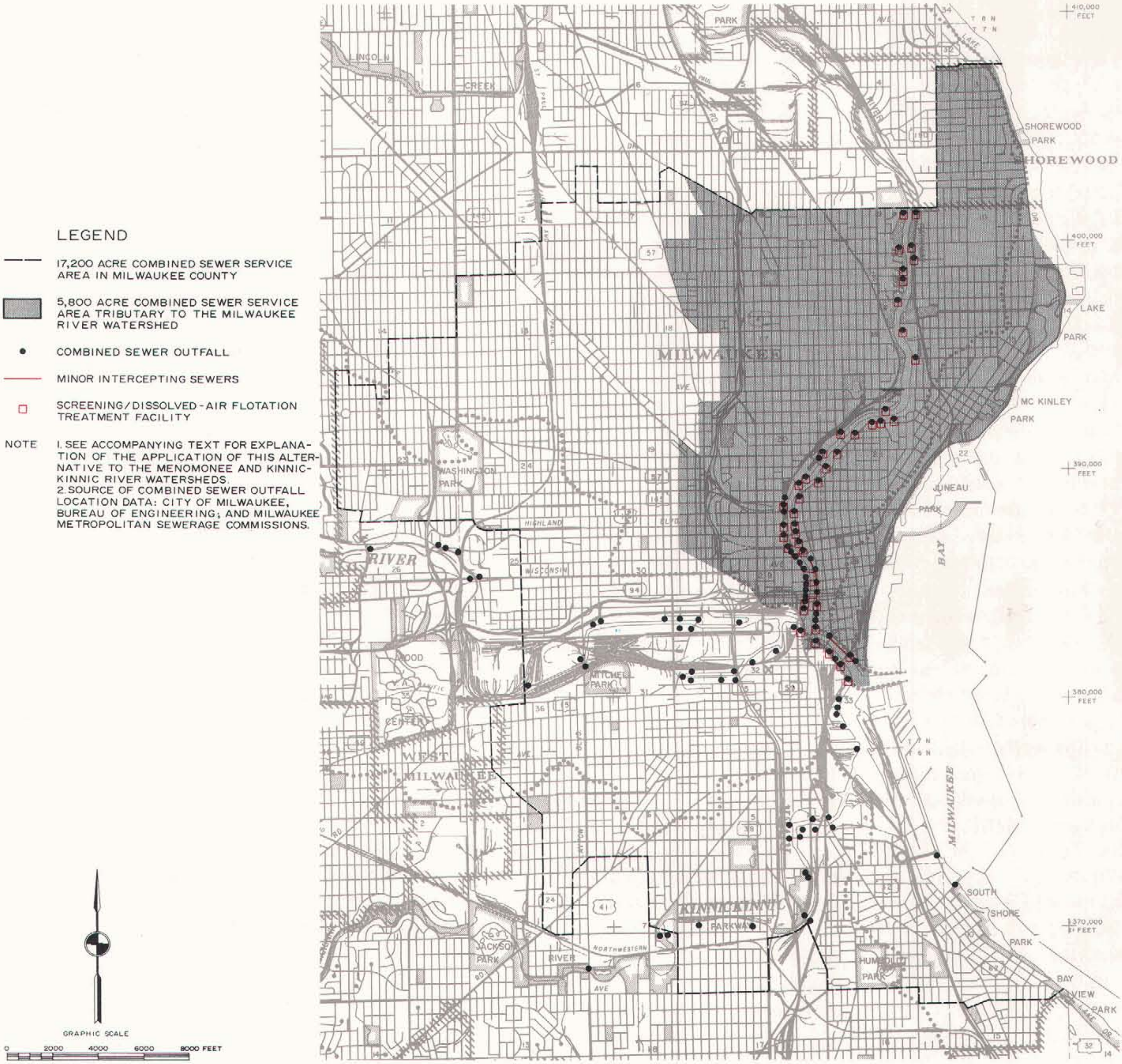
Screening/Dissolved-Air Flotation Treatment System Combined with Instream Aeration: The basic concept of the screening/dissolved-air flotation treatment system, which is a flow-through treatment system applied to overflows from combined sewer outfalls, was described earlier in this chapter in the discussion relating to the preliminary screening process. The combined sewer overflows would be treated at or near the location where they discharge from the combined sewer system outfalls to the receiving streams. Permanent screening/dissolved-air flotation treatment facilities would be installed to serve the 62 combined sewer outfalls in the Milwaukee River watershed, the 22 combined sewer outfalls in the Kinnickinnic River watershed, and the 26 combined sewer outfalls in the Menomonee River watershed (see Map 35).[19] Preliminary analyses completed under the watershed study indicated that a total of 42 such flow-through treatment facilities would be required to serve the 62 combined sewer outfalls in the Milwaukee River watershed. It was not feasible, however, to conduct similar analyses for the Kinnickinnic and Menomonee River watersheds within the context of the Milwaukee River watershed study. In order to estimate total costs for the application of this alternative to the entire 17,200-acre combined sewer service area in Milwaukee County, therefore, it was necessary to apply unit costs on a per acre basis developed for the 5,800-acre combined sewer service area in the Milwaukee River watershed to the entire combined sewer service area. Each of the permanent treatment facilities would be designed to provide the necessary degree of sewage treatment to meet both the state-established water use objectives and the sewage effluent standards promulgated by the federal Lake Michigan Enforcement Conference and the State of Wisconsin.

The flow-through treatment alternative would be designed to provide treatment meeting the recommended effluent standards of all combined sewer overflows resulting from rainfall-runoffs up to a rate of 0.5 cfs per acre, the criterion described previously in the chapter. It is important to note that this same runoff limitation exists for the conveyance facilities utilized in the two storage alternatives described above. Unlike the storage alternatives, however, the flow-through treatment alternative would not have the additional limitation on the total volume of runoff imposed by the capacity of the storage facilities. For example, the storage alternatives described above are limited in the alternatives presented to handling either a two-inch or four-inch total volume of runoff. Because the flow-through treatment alternative involves only minor retention periods,

[19] *Ibid.*, *Footnote 16.*

Map 35

EXPANDED COMBINED SEWAGE FLOW-THROUGH TREATMENT ALTERNATIVE -- SCREENING/DISSOLVED-AIR FLOTATION TREATMENT SYSTEM



The application of the screening/dissolved-air flotation flow-through treatment alternative to the entire 17,200-acre combined sewer service area in Milwaukee County is shown on this map. While specific sites for the location of such flow-through treatment facilities in the Kinnickinnic and Menomonee River watersheds were not selected as part of the Milwaukee River watershed study, it is anticipated that groups of nearby outfalls could be combined to minimize the number of individual flow-through treatment facilities that would be needed. All such treatment facilities would be located underground.

Source: Harza Engineering Company and SEWRPC.

no such limitation would apply. Since both alternatives, however, have the same limiting conveyance factor of 0.5 cfs per acre runoff rate, they are, in fact, directly comparable.

This alternative, as applied to the entire 17,200-acre combined sewer service area in Milwaukee County, would cost an estimated $140.1 million, including necessary conveyance facilities; treatment facilities; and contingencies, engineering, and overhead, but exclusive of interest during construction. Such interest may be expected to total about $13 million. Annual costs would total $13,070,000 for debt service and retirement and operation, maintenance, and power. Amortization of interest during construction would increase this amount to $13,915,000 annually.

Conveyance and Flow-Through Treatment Facilities: The major components of this alternative plan element are the flow-through treatment facilities located at or near individual or groups of individual combined sewer outfalls located in the 17,200-acre combined sewer service area of Milwaukee County and the intercepting sewers necessary to tie together groups of outfalls for treatment at a single flow-through facility. The cost estimates presented above include the necessary treatment capacity to achieve the equivalent of primary, secondary, and advanced waste treatment and disinfection of the total combined sewer overflow. This is true because the treatment facilities and all necessary conveyance facilities would generally be designed to handle the maximum possible overflow from the combined sewer outfalls.

Primary treatment for removal of settleable solids would be provided in the screening and flotation chambers. The rate of flow through the unit determines its capacity; and, therefore, each unit could be designed to handle the entire hydraulic capacity of the particular outfall or combination of outfalls it serves. In all cases the treatment facilities would consist of permanent installations located underground for joint land use and aesthetic reasons. The combined sewer overflows would discharge directly by gravity into the screen chamber and be carried through the entire treatment unit by gravity, with discharge back to the stream system directly from the unit utilizing pumping facilities. The pumping facilities would be designed to accommodate the total overflow to be treated, and, as such, would have a capacity equal to or exceeding 0.5 cfs per acre of tributary drainage area.

Appropriate facilities would be included in the flotation chamber for the addition of chemical flocculating agents, such as polymers, ferric chloride or ferric sulphate, or lime, to increase the efficiency of solids removal and to provide for appropriate nutrient removal. The amount of the chemical flocculating agents retained with the solids on the micro-strainers will have to be investigated, together with the characteristics of the agents, in order to evaluate the potential long-term effects, if any, upon the receiving environment.

Solids evacuated from each individual unit would be discharged to a nearby intercepting sanitary sewer for treatment at either the existing Jones Island or South Shore sewage treatment plant. Additional data on the feasibility of the disposal of the solids in the sewer system will be available when the Racine, Wisconsin, flow-through treatment plant is placed into operation in 1972. Solids handling and disposal at the existing sewage treatment plants is estimated to have a gross cost of about $52 per dry ton and a net cost of about $12 per ton when offset by the revenues received from the sale of Milorganite fertilizer manufactured from the solids. Such handling and disposal would probably be more expensive if an alternative method of pickup and land fill, incineration, or composting were to be considered, both because the high moisture content of the solids would add substantially to the tonnage to be trucked and because temporary storage facilities would be required at the treatment facility.

The required treatment capacity for each of the individual flow-through treatment plants is a function of the volume and occurrence pattern of runoff which causes the combined sewer overflows in each particular subdrainage area. The average rate of discharge of each of the 62 combined sewer outfalls in the Milwaukee River watershed was estimated, based upon investigation of the hydraulic capacities of the outfalls and of the size and runoff characteristics of the tributary drainage basins. It was estimated that a total treatment capacity of 5,580 mgd would be necessary to serve the entire 17,200-acre combined sewer service area in Milwaukee County, and a capacity of 1,870 mgd would be necessary to serve the 5,800-acre combined sewer service area in the Milwaukee River watershed. An extensive program of field survey and laboratory testing would be required in order to more precisely determine the quantity and quality of flow at each individual combined sewer outfall if this plan element were adopted and advanced to the preliminary engineering design stage. Attention would have to be directed in such a program to removing uncertainties regarding the differing rate and quality of flow of the relatively dilute waste water from the various subdrainage areas in order to design the individual treatment units. These variables would be of a scale seldom encountered in previous demonstration designs, since they relate to time of treatment, as well as total flows. No associated geological or ground water problems would be expected to occur with this type of flow-through sewage treatment unit, since all of the facilities are enclosed in an underground structure and since all effluent is discharged directly to receiving surface waters.

System Operation and Performance: The primary function of the flow-through treatment system of combined sewer overflows would be to very briefly detain and adequately treat such overflows before release to the receiving streams. In some cases it is expected that instream aeration would be necessary downstream from the treatment plant outfall in order to maintain instream oxygen levels above the recommended standard of five parts per million during peak rates of waste discharge. Unlike the storage alternatives, there would be no attendant potential benefits from the flow-through treatment alternative, such as potential flood relief or the potential treatment of separate sanitary sewer overflows from the other parts of the metropolitan area without the addition of units. Unlike the storage alternatives, however, the capacity of the flow-through treatment system is limited only by the permissible rate of flow through the treatment facilities and attendant conveyance pipes and not, as are the storage systems, by the volume of the storage reservoirs or chambers. The only conveyance systems necessary under this alternative would be the intercepting sewers necessary to connect certain outfalls for treatment of the combined sewer overflows at common, rather than at individual, facilities.

Based upon the data obtained from operation of the Hawley Road and Fort Smith demonstration facilities over the past few years regarding the removal efficiencies of various pollutants, it should be possible to design and operate the screening/dissolved-air flotation flow-through treatment facilities to meet the state-established water use objectives, as well as the effluent standards promulgated by the federal Lake Michigan Enforcement Conference and the State of Wisconsin, although instream aeration may be needed to provide additional oxygen to the stream downstream from some of the flow-through treatment facilities during peak rates of flow. It is expected that suspended solids and volatile suspended solids removals in the range of 80 to 95 percent could be consistently attained, with somewhat lower BOD and COD removals ranging from 75 to 95 percent. The demonstration projects have shown that the removal efficiencies of the screening/flotation facilities are much higher during the periods of first storm flushes as compared to the extended overflow periods, a factor important in reducing initial shock, as well as total pollution loadings, on the stream system.

An important advantage of the flow-through treatment system is that the system is amenable to full automation, thereby reducing operation and maintenance costs. By maintaining proper chemical dosages and flocculation, the removal efficiencies of the key pollutants can be maintained in the ranges of 85 to 95 percent. The demonstration projects have also shown that effective chlorination can be provided in the screening/dissolved air-flotation system without additional detention time.

System Costs: The total construction cost of the flow-through treatment facilities and attendant intercepting sewers required to treat a peak rate of runoff of 0.5 cfs per acre from the total 17,200-acre Milwaukee combined sewer service area, is estimated at $140.1 million, exclusive of interest during construction. Such interim financing would total about $13.0 million, depending upon sources and method of financing, and would raise the total project cost to about $153.1 million. If the flow-through treatment system performs fully, as expected, instream aeration would become unnecessary, thereby reducing the total cost by $5.3 million. The annual cost for facilities and for operation, maintenance, and power, but exclusive of costs for interest during construction, would total about $13.1 million and consists of: 1) land and facilities, $10.8 million; 2) operation, maintenance, and replacement, $1.6 million; 3) power, $0.4 million; and 4) solids handling, $0.3 million. Adding a charge for interest during construction would raise the estimated total annual cost to about $13.9 million. If instream aeration proves to be unnecessary because of high performance of the flow-through treatment facilities, the total annual cost could be reduced by $1.0 million.

The annual cost for the facilities is based upon construction costs for January 1969 and on an overall project life of 50 years with an interest rate of 6 percent. All project components were assumed to have a life of 50 years, except the electrical and mechanical systems which could require replacement after 20 years. Instream aeration equipment and solids handling equipment would also be replaced at 20-year intervals (see Table 55).

Concluding Remarks—Detailed Consideration of Alternatives: More detailed study and analysis of the three most feasible alternative stream water management plan elements selected from the preliminary screening process of the 15 alternatives considered—Alternative 5, Diked Storage Lagoons in Lake Michigan; Alternative 7, Deep Tunnel Conveyance and Mined Storage Beneath Milwaukee Harbor; and Alternative 12, Screening/Dissolved-Air Flotation Flow-Through Treatment, combined with instream aeration—revealed that each of the three alternatives was fully capable of providing a feasible solution to the water pollution problems caused by the overflow of the combined sewer system in Milwaukee County. The comparative capital investment and average annual costs for the three alternatives considered are shown in Table 55. On the basis of these costs, it is apparent that the combined screened/dissolved-air flotation flow-through and instream aeration treatment alternative would be the most attractive of the alternatives for abating the stream and lake pollution due to combined sewer overflows in the Milwaukee metropolitan area. Both of the storage alternatives would be more expensive, both in terms of total capital and total annual cost. In addition, the flow-through treatment-instream aeration alternative is readily adaptable to incremental implementation, thus permitting an evolutionary approach to the solution of the combined sewer overflow problem without the total commitment to a heavy initial capital investment required in the storage alternatives. From a qualitative aspect, the flow-through treatment alternative would be as attractive as the deep tunnel and mined storage alternative; and both the flow-through treatment and deep tunnel storage alternatives would be preferable to the Lake Michigan lagoon storage alternative in this respect. The lagoons would constitute a major and highly undesirable aesthetic intrusion into Lake Michigan and, as such, would have a low potential for public acceptance.

In further refining the deep tunnel storage and flow-through treatment alternatives toward the resolution of the combined sewer overflow problem in the Milwaukee River watershed, it became apparent that a combination of the deep tunnel storage system, in conjunction with the screening/dissolved-air flotation flow-through treatment system, could provide a more economical means of solving the combined sewer overflow problem than either alternative alone. A new alternative, which combined the conveyance and storage feature of the deep tunnel system with the flow-through treatment feature of the screening/dissolved-air flotation system, was, therefore, explored, with the object of optimizing the provision of storage as opposed to treatment capacity in order to achieve a least-cost alternative. Under the concept of a combined deep tunnel storage/flow-through treatment alternative, the combined sewer overflows would be dropped through vertical shafts into a network of concrete-lined tunnels aligned generally under the streams. The tunnels, which would be designed for flow under pressure in order to utilize the large head available, would conduct the overflow sewage to a central mined storage reservoir about 350 feet below the Milwaukee Harbor area. Thus, the conveyance system under this combination alternative would be identical to the conveyance system previously described under the deep tunnel storage alternative (see Map 33). Once the combined sewer overflow reached the mined storage area, however, the overflow would be treated utilizing the screening/dissolved air-flotation equipment, which equipment would be installed within the mined storage reservoir area. When the inflow rate exceeds the capacity of the treatment facilities, the excess flow would be routed to mined storage chambers for temporary detention and subsequent treatment. In addition, the system would have the capability to store the treated effluent so that the necessary pumping of the effluent back to the surface for disposal could be accomplished during off-peak power utilization hours, with attendant savings in operating costs. It is important to note, however, that this combination mined storage/flow-through treatment system would have the capability of treating and returning to the surface waters within seven days all of the combined sewer overflow resulting from a storm causing a total of two inches of runoff, as opposed to a 25-day evacuation period for the conventional mined storage alternative using a 50 mgd facility. In concept and operation, the treatment facilities would be the same as that described under the previous discussion relating to the flow-through treatment alternative, wherein the treatment facilities were located at each of, or combinations of, the combined sewer outfalls. Since the treatment process would be identical, the treatment performance could also be expected to be identical. Thus, the only difference between the combination alternative and the flow-through alternative previously described would be the installation of the facilities at one central location in a mined storage reservoir as opposed to numerous locations along the stream system.

An analysis was made to determine the most economical combination of storage and treatment facilities given the basic design criterion of a peak flow rate of 0.5 cfs per acre of tributary drainage area. The analysis indicated that the size of the mined storage reservoir could be reduced by approximately 5 percent over that indicated for the conventional mined storage reservoir alternative and that the capacity of the treatment facilities required to treat the combined sewer overflow entering the mined storage reservoir could be reduced from the over 5,000 mgd of total treatment capacity needed, if individual flow-through treatment facilities were constructed at numerous locations throughout the metropolitan area, to about 500 mgd. Substantial savings could, therefore, be achieved in reducing the needed treatment capacity, although very little would be saved in terms of reducing the cost of excavating the mined storage reservoirs.

It is important to note that the only factor limiting the capacity of this alternative would be the capacity of the conveyance tunnels and evacuation pumps designed to handle 0.5 cfs per acre of tributary drainage area. Storage capacity would not be a limiting factor as in the deep tunnel storage alternatives with conventional treatment facilities which were, as described above, designed to hold a maximum of two inches or four inches of runoff from the 17,200-acre area. The screening/dissolved-air flotation flow-through treatment operation in the mined storage reservoir would be the same as that described under the basic flow-through treatment alternative, with performance with respect to contaminant removals expected to attain the peak levels demonstrated in the Hawley Road facility and with the solids being returned to the existing sewage treatment plants in the Milwaukee area for final removal.

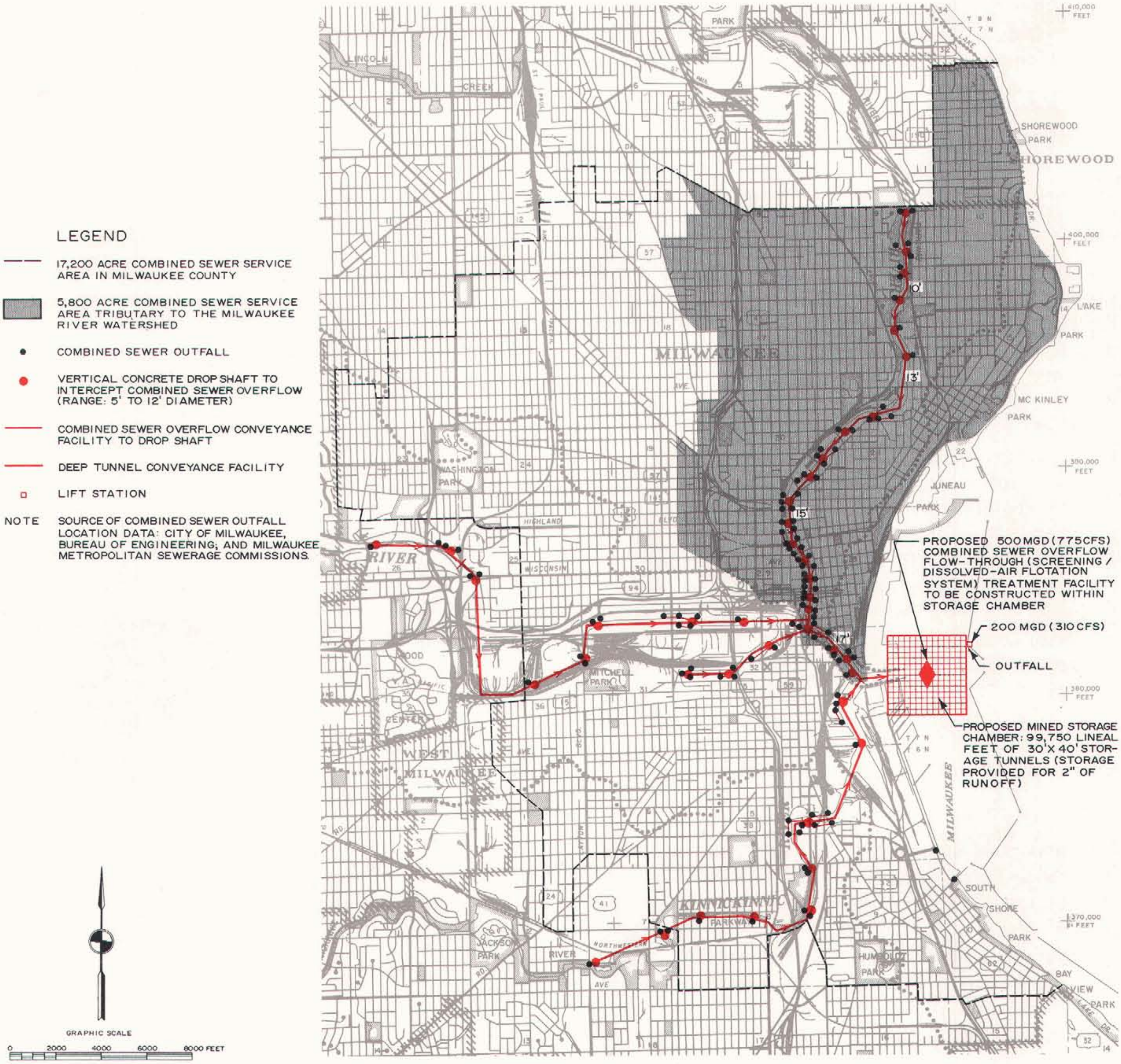
The proposed layout of the combination deep tunnel storage and flow-through treatment alternative is shown on Map 36, including the location of the combined sewer outfalls, the conveyance tunnels, the storage chambers, the screening/dissolved-air flotation equipment, and the discharge point of the treated effluent to the Milwaukee Harbor. The total construction cost of this combination alternative is estimated at $121.5 million, exclusive of interest during construction (see Table 56). Such interim financing could be expected to total about $12.0 million, depending upon sources and method of financing, and would raise the total project cost to about $133.5 million. Annual costs for facilities and for operation, maintenance, and power, but exclusive of costs of interest during construction, would total about $10.3 million, comprised as follows: 1) facilities, $8.8 million; 2) operation, maintenance, and replacement, $1.8 million; 3) power, $0.2 million; and 4) sludge handling, $0.3 million. Adding the charge for interest during construction would raise the total annual cost to about $11.1 million. The annual costs for these facilities are based upon construction costs for January 1969 and on an overall project life of 50 years with an interest rate of 6 percent. All project components were assumed to have a life of 50 years, except the electrical and mechanical systems and the sludge handling equipment, which would require replacement after 20 years.

The results of the foregoing analysis indicate that a combination of the deep tunnel storage concept and the Rex Chainbelt screening/dissolved-air flotation flow-through treatment concept would comprise the most economical method of controlling the pollution from the combined sewer overflows in the 17,200-acre combined sewer service area located in Milwaukee County. The total initial capital cost of the combination storage/flow-through treatment alternative is, as noted above, about $121.5 million, as compared to the total estimated initial capital cost of the deep tunnel conventional treatment alternative of $165.0 million and the total initial capital cost of the conventional flow-through treatment-at-numerous-locations alternative of $141.1 million. Similarly, the total estimated annual cost of the combination alternative would be $10.3 million, as opposed to the total estimated annual cost of $13.9 million and $13.1 million for the deep tunnel and flow-through treatment alternatives, respectively.

Based upon the foregoing analyses, it is recommended that the combination deep tunnel mined

Map 36

RECOMMENDED COMBINED SEWER OVERFLOW POLLUTION ABATEMENT PLAN ELEMENT--DEEP TUNNEL CONVEYANCE, MINED STORAGE, AND SCREENING/ DISSOLVED-AIR FLOTATION TREATMENT SYSTEM



This map illustrates the recommended combined sewer overflow pollution abatement plan element as applied to the entire 17,200-acre combined sewer service area in Milwaukee County. This recommended plan element combines the deep tunnel conveyance and mined storage concepts with the screening/dissolved-air flotation flow-through treatment concept in order to effect the most economical solution to the combined sewer overflow pollution problem in Milwaukee County. All combined sewer overflows would be intercepted by vertical shafts connected to a deep tunnel intercepting sewer, conveyed by this sewer to a mined storage chamber constructed in the bedrock underlying the harbor, and treated utilizing the flow-through treatment process with treatment facilities located in the storage chamber. The treated effluent would then be discharged to Lake Michigan.

Source: Harza Engineering Company and SEWRPC.

Table 56

COST ESTIMATES--RECOMMENDED COMBINED SEWER OVERFLOW POLLUTION ABATEMENT PLAN ELEMENT FOR THE 17,200-ACRE COMBINED SEWER SERVICE AREA IN MILWAUKEE COUNTY

Recommended Plan Element	Capital Cost (Construction)									
	Storage Design Criteria (Inches of Runoff)	Aero Flotation Treatment Facilities	Instrumentation and Controls	Conveyance Tunnels	Diversion and Drop Shaft System	Mined Storage	Tunnel and Reservoir Aeration	Lift Pump Equipment and Minor Sewer Connections	Aquifer Recharge	Total
Deep Tunnel Conveyance, Mined Storage, and Screening/Dissolved-Air Flotation Treatment System	2	$4,300,000	$ 300,000	$38,700,000	$15,300,000	$50,000,000	$ 7,200,000	$ 4,100,000	$ 1,600,000	$121,500,000

Recommended Plan Element	Present Worth (1970-2020)			Equivalent Annual			Annual Cost per Acre	Capital Cost per Acre
	Construction	Operation and Maintenance	Total	Construction	Operation and Maintenance	Total		
Deep Tunnel Conveyance, Mined Storage, and Screening/Dissolved-Air Flotation Treatment System	$139,000,000	$23,000,000	$162,000,000	$ 8,800,000	$ 1,460,000	$10,260,000	$ 597	$7,064

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

storage/flow-through treatment alternative be included in the recommended comprehensive watershed plan as the major water pollution abatement plan element for the lower Milwaukee River watershed. In making this recommendation, it is recognized that the next best alternative for the resolution of the combined sewer overflow problem is the use of screening/dissolved-air flotation flow-through treatment facilities at individual locations throughout the 17,200-acre combined sewer service area in Milwaukee County. It is further recognized that this second best alternative has a major advantage, in that it is readily adaptable to incremental implementation, thus permitting an evolutionary approach to the solution of the combined sewer overflow problem without a total commitment to a heavy initial capital investment required to construct the storage features of the combined storage/flow-through treatment alternative.

It is further recommended that, upon plan adoption and certification, a preliminary engineering study be undertaken to determine with greater precision and detail the configuration of the recommended system as required to serve the entire 17,200-acre combined sewer service area in Milwaukee County. It is estimated that this detailed engineering study would cost $1.2 million. Such a detailed engineering feasibility study, which is estimated to take 12 months to complete, must utilize the same water use objectives and effluent standards used herein, while refining design parameters relating to the volume and strength of sewage to be treated. It is anticipated that the study would include subsurface exploration, including geophysical logging and geohydrologic testing. In addition, such a study would include analyses of subsurface data collection; the collection and analysis of data for sewer capacity, hydrologic and hydraulic loadings, and water quality characteristics of combined sewer overflows; a review of applicable sewage treatment methods; the preparation of sewer layouts and cost estimates; and the preparation of a construction schedule. Such a feasibility study also should explore the potential for applying the recommended combination of the mined storage/flow-through treatment alternative in an incremental manner to a portion of the total combined sewer service area, such as the Milwaukee River watershed, as opposed to the desirability of constructing the entire system all at one time. Finally, the engineering feasibility study should continue to monitor the results of all ongoing demonstration studies with respect to the flow-through treatment system to determine if further modifications can be made to reduce costs of providing the necessary facilities to solve the combined sewer overflow pollution problem in the lower Milwaukee River watershed.

Industrial Waste Sources

It was concluded in Chapter IX of Volume 1 of this report that industrial waste discharges represent a relatively minor contribution to the existing surface water quality problems of the lower Milwaukee River watershed. Twenty-six industrial waste discharges were found to exist within the lower Milwaukee River watershed. Of this total, 13 discharge only cooling waters to the stream system through municipal storm sewer systems.

None of these 13 cooling water sources is considered to be a significant source of thermal pollution and, hence, none require corrective pollution abatement action. Eight of the remaining 13 waste sources discharge wash waters and, hence, should be connected to the sanitary sewerage system. These eight sources are: Automatic Auto Wash; City of Milwaukee, Fifth District Police Station; City of Milwaukee, Bureau of Electric Service; Modern Car Wash, Inc.; Pure Oil Capitol Court Auto Wash; Pure Oil Car Wash; Wisco 99 Car Wash; and Wisconsin Gas Company, North Service Center. The remaining five industrial waste sources discharge inorganic wastes which require improved treatment at the site before discharge to the municipal storm sewer system. These five sources are: Delta Oil Products Corp., Ricketson Color Division; Outboard Marine Corp., Evinrude Motors Division; Interstate Drop Forge Company; Paul J. Schmidt Trucking; and Sealtest Foods, Division of Dairy Products, Kraftco Corporation. The locations of all 26 of the industrial waste sources in the lower Milwaukee River watershed are shown on Map 37.

ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENTS—UPPER WATERSHED

As noted in the introductory section of this chapter, any water pollution abatement effort must, in the upper Milwaukee River watershed, be directed primarily, although not solely, at controlling the waste contribution from two major sources: existing municipal sewage treatment plants discharging partially treated wastes to the stream system of the upper watershed and agriculture runoff. Industrial waste discharges, while having a significant local effect upon stream water quality, are not an important source of pollution in terms of the watershed as a whole.

Twelve municipal sewage treatment plants presently discharge wastes to the stream system. These plants serve the Cities of Cedarburg and West Bend; the Villages of Adell, Campbellsport, Fredonia, Grafton, Jackson, Kewaskum, Random Lake, Saukville, and Thiensville; and the Newburg Sanitary District[20] and currently (1967) contribute about 54 percent of the pollution loading on the stream system above the Milwaukee County line, as such loading is measured by nutrient contribution. Agricultural runoff contributes about 33 percent of the pollution loading above the Milwaukee County line, while industrial waste sources, urban runoff, and miscellaneous sources together contribute the remaining 13 percent.

Although it is important to reduce the pollution loading on the stream system from all sources if significant progress is to be made toward achieving a higher level of stream water quality, primary attention must be directed, at least initially, at the major sources of pollution. The alternative plan elements described herein, therefore, deal primarily with controlling the pollutional effects of the 12 municipal sewage treatment plants in the upper Milwaukee River watershed. Not only do these 12 plants together account for over one-half of the pollutional loading on the stream system, as noted above, but they also represent a relatively small number of point sources of pollution which can be treated in an efficient and economical manner. Moreover, these 12 sources are publicly owned and operated and should, therefore, be more amenable to effective plan implementation. In contrast, agricultural runoff, the next most important source of pollutants, not only contributes only about one-half as much pollution in terms of nutrient input as the municipal sewage treatment plant sources do, but does so in a highly diffused fashion from many privately owned farms and is, therefore, not only very difficult to treat efficiently but is also far less amenable to effective plan implementation. Moreover, the relative contribution of nutrient input from agricultural sources is expected to decrease from 33 percent in 1967 to 20 percent in 1990, as urbanization proceeds within the watershed.

The following paragraphs describe first the recommendations with respect to industrial waste sources; second, the recommendations dealing with controlling the nutrient input from agricultural runoff; and third, the alternative plan elements for controlling the pollutional effects of the 12 municipal sewage treatment plants in the upper Milwaukee River watershed.

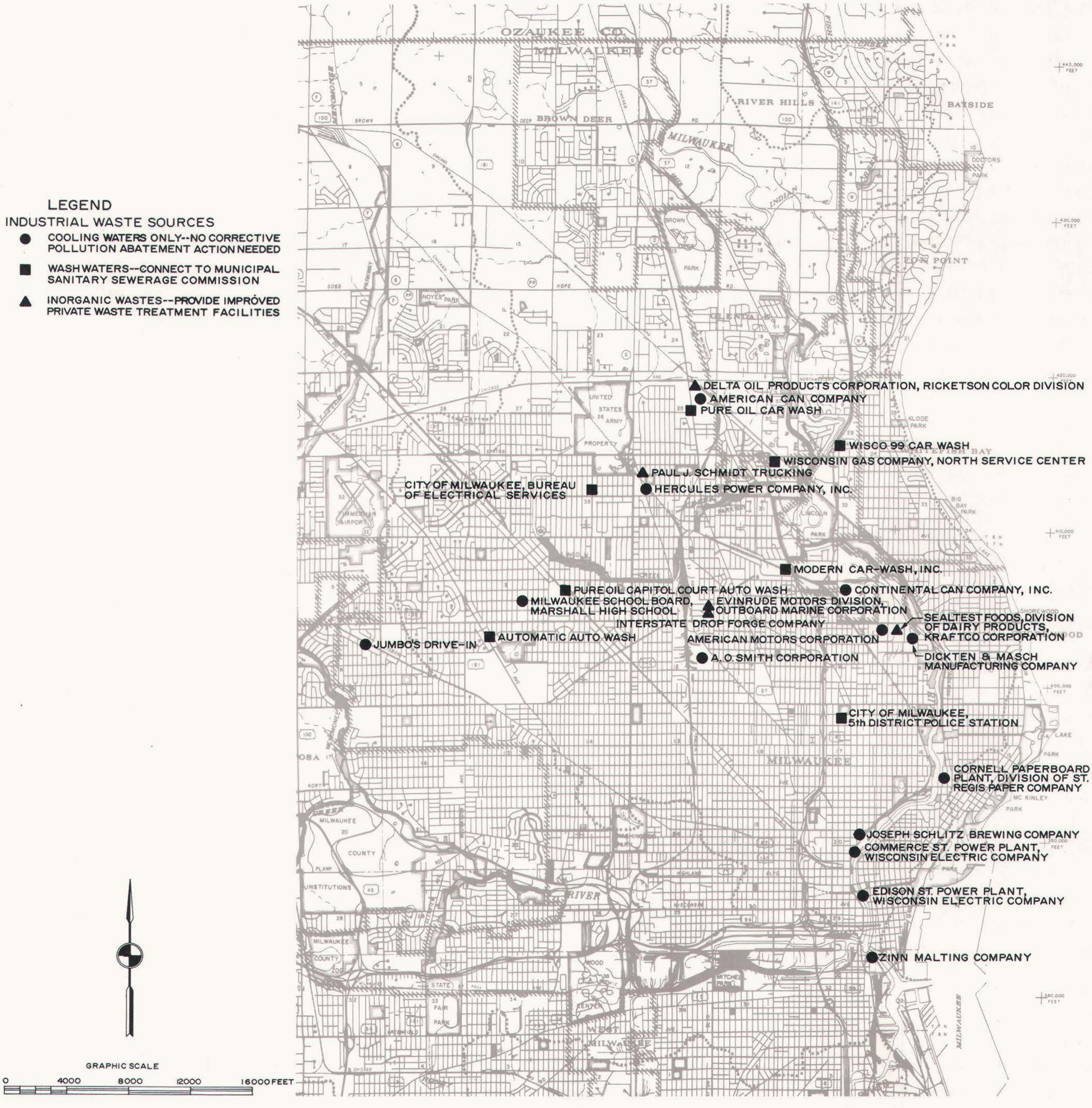
Industrial Waste Sources

As noted above, industrial waste sources constitute a relatively minor contribution to surface water pollution within the upper Milwaukee River

[20] *A total of 14 municipal sewage treatment plants were inventoried in the upper Milwaukee River watershed in 1967. As of January 1, 1971, however, two of these plants--the Lac du Cours and Ville du Parc subdivision plants--had been abandoned and their service areas connected to the Milwaukee metropolitan sewerage system.*

MAP 37

STREAM WATER QUALITY MANAGEMENT RECOMMENDATIONS FOR INDUSTRIAL WASTE SOURCES IN THE MILWAUKEE RIVER WATERSHED DOWNSTREAM FROM THE MILWAUKEE COUNTY LINE



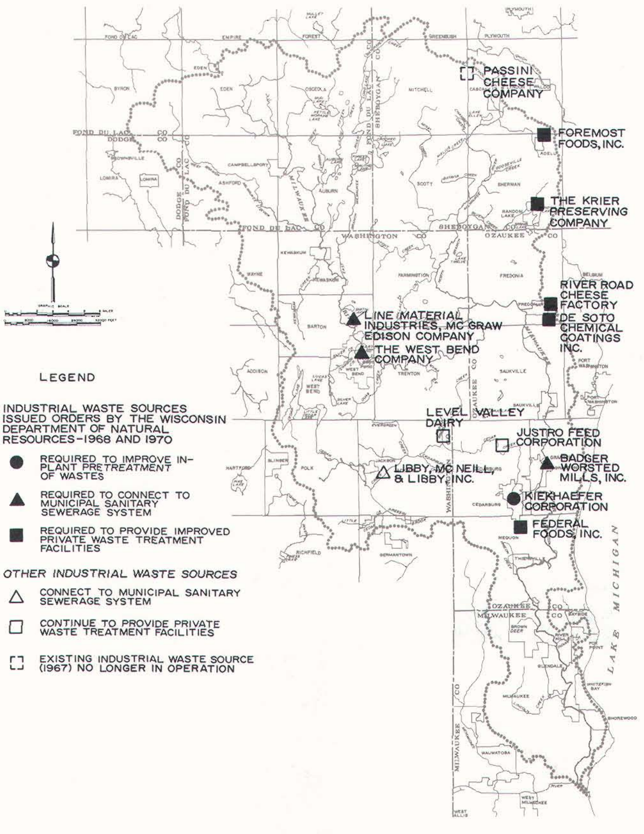
Industrial waste discharges represent a relatively minor contribution to the water pollution of the Lower Milwaukee River watershed. The above map identifies 13 cooling water sources which are not considered to be significant sources of thermal pollution and need no corrective pollution abatement action. Eight waste sources are identified on the map as requiring connection to the municipal sanitary sewerage system. Five additional waste sources are identified which require improved treatment of wastes at the source before discharge to the municipal storm sewer system.

Source: Wisconsin Department of Natural Resources and SEWRPC.

watershed. Thirteen major industrial waste discharges were found to exist in 1967 within the upper watershed (see Table 52, Volume 1, of this report). Orders have been issued by the Wisconsin Department of Natural Resources directing nine of the 13 firms involved to improve inplant pretreatment of wastes (one source); to connect to centralized municipal sanitary sewerage systems (three sources); or to provide improved industrial waste treatment facilities (five sources) (see Map 38). It is assumed that these orders will be complied with fully, thus reducing even further the pollutional effect of industrial waste sources in the upper Milwaukee River watershed.

Map 38

STREAM WATER QUALITY MANAGEMENT RECOMMENDATIONS FOR INDUSTRIAL WASTE SOURCES IN THE MILWAUKEE RIVER WATERSHED UPSTREAM FROM THE MILWAUKEE COUNTY LINE



Industrial waste discharge also represent a relatively minor contribution to the water pollution problems of the Upper Milwaukee River watershed. The above map identifies all twelve such sources remaining and indicates the corrective actions needed. In some cases the industries involved have already taken steps to meet the pollution abatement recommendations.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Of the remaining four industrial waste discharges in the upper watershed, one—the Passini Cheese Co., Inc.—has gone out of business and, therefore, no longer constitutes a waste source. One additional firm—the Libby, McNeill, & Libby canning plant—is cooperating with the Village of Jackson in the establishment of a new Jackson sewage treatment plant to serve both the Village and the plant. The remaining two firms—the Justro Feed Corporation located in the Town of Cedarburg, Ozaukee County, and the Level Valley Dairy, located in the Town of Jackson, Washington County—are located outside the existing or proposed sanitary sewer service areas of municipal sewerage systems within the watershed and cannot, therefore, be connected to such systems. These two latter firms should continue to provide a level of industrial waste treatment adequate to meet the established water quality objectives and standards. It should be noted that the standards promulgated by the federal Lake Michigan Enforcement Conference encourage the discharge of industrial waste to municipal sanitary sewerage systems following any needed preliminary treatment.

Agricultural Runoff Control

The control of stream water pollution in the upper Milwaukee River watershed from agricultural runoff can best be accomplished through the institution of good soil and water conservation measures and practices. A discussion is presented later in this chapter dealing with the control of pollution from agricultural runoff in connection with lake water quality management; and that discussion, while directed specifically at those land areas of the watershed which drain directly to the lakes concerned and, therefore, only indirectly to the stream system, is equally applicable to those land areas in the upper Milwaukee River watershed which drain directly to the stream system. The lake water quality management plan elements propose to control pollution from agricultural runoff by applying appropriate agricultural land management practices to about 8,200 acres of land, or about 3 percent of the total area of the watershed in agricultural use and about 2 percent of the total area of the watershed. Local technical study committees, formed by the U. S. Soil Conservation Service to assess the need for the institution of agricultural land management practices, have estimated that such practices are needed on an additional 65,000 acres of agricultural land in the Milwaukee River watershed, or about an additional 24 percent of the total area of the watershed in agricultural use and about an additional 15 percent of the total area of the watershed.[21] At an estimated average cost of $120 per acre, the institution of such practices would entail a total estimated cost of $9.8 million.

It is recommended that agricultural landowners in the watershed voluntarily apply such management practices to their lands in order to control soil erosion, reduce the nutrient input to the stream system, and improve the yields from their land. To the extent that such practices are carried out in the watershed, the pollution loading contributed by agricultural runoff to the stream system will be reduced.

Sewage Treatment Processes

Sewage treatment may be defined as any process to which sewage is subjected in order to remove or so alter its objectionable constituents as to render it less offensive and dangerous and less damaging to the receiving environment. Sewage treatment may be classified as primary, secondary, tertiary, and advanced.

Primary sewage treatment may be defined as physical treatment of raw sewage in which the coarser floating and settleable solids are removed by screening and sedimentation. Primary treatment normally provides 50 to 60 percent reduction of the influent suspended matter and 25 to 35 percent reduction of the influent biochemical oxygen-demanding organic matter (BOD). It removes little or no colloidal and dissolved matter.

Secondary sewage treatment may be defined as biological treatment of the effluent from primary treatment, in which additional oxygen-demanding organic matter is removed by trickling filters or activated sludge tanks and additional sedimentation. Secondary treatment normally provides up to 90 percent overall removal of the suspended matter and 75 to 95 percent overall removal of BOD. Secondary treatment facilities can be designed and operated to also remove 30 to 50 percent of the nitrogenous oxygen demand (NOD) and 30 to 40 percent of the phosphorus content of the influent sewage.

Tertiary sewage treatment may be defined as physical and biological treatment of the effluent from secondary treatment, in which additional oxygen-demanding matter is removed by use of shallow detention ponds to provide additional biochemical treatment and settling of solids or filtration using sand or mechanical filters. Tertiary treatment normally provides up to 99 percent removal of the suspended matter and 95 to 97 percent of the BOD. Although not specifically designed as a nitrogen-removal process, tertiary treatment involving aeration and modified activated sludge processes can reduce the NOD content by up to 95 percent by converting ammonia compounds to nitrates.

Advanced treatment may be defined as additional physical and chemical treatment to provide removal of additional constituents, particularly phosphorus and nitrogen compounds, by such means as chemical coagulation, sedimentation, charcoal filtration, and aeration. Although advanced treatment is traditionally conceived of as following secondary treatment or as combined with tertiary treatment, it can be performed following primary treatment or as an integral part of secondary treatment. Advanced treatment may remove up to 90 percent of the nitrogen and 90 percent or more of the phosphorus in the influent sewage. The expression "advanced treatment" ordinarily is understood to encompass tertiary treatment, but the expression "tertiary treatment" does not include advanced treatment.

An auxiliary treatment which may be used in combination with all the treatment methods is disinfection by chlorination or other chemical treatment. The combinations of the various unit operations usually provided to effect the various levels of treatment are shown in Figure 20.

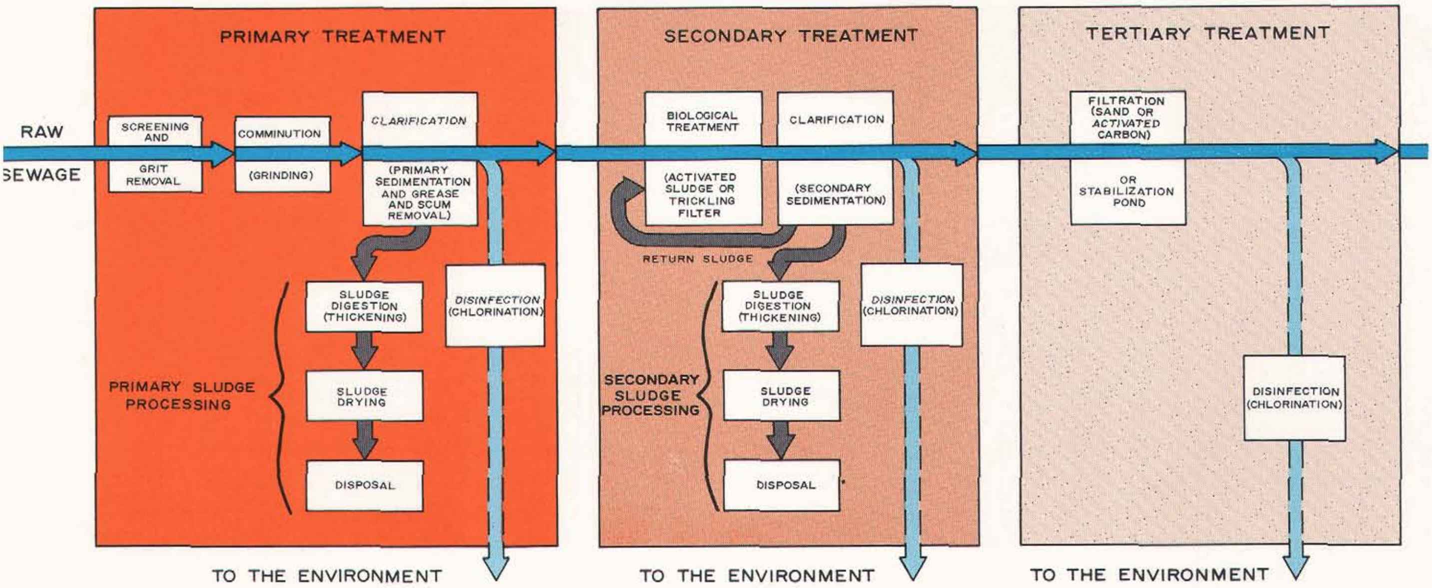
Existing Treatment Levels and State Orders

All of the 12 municipal sewage treatment plants presently operating in the upper Milwaukee River watershed are designed to provide secondary treatment. Even at present, however, this level of treatment is not sufficient to meet the established stream water use objectives and standards in several reaches of the Upper Milwaukee River and its major tributaries. This is due to at least three factors: insufficient BOD removal due to poor operation; lack of post-chlorination; and lack of nutrient removal. Anticipated population growth and urbanization in the watershed, with continued reliance on secondary treatment alone, may be expected to be accompanied by further deterioration of water quality conditions throughout the upper watershed. Future waste discharges from

[21] *Unpublished inventory data collected by the U. S. Soil Conservation Service under the Small Watershed Program in Wisconsin, 1965-1966.*

Figure 20

SEWAGE TREATMENT PROCESSES



The above diagram schematically illustrates the sequential *steps in the sewage treatment process. Sewage treatment may* be defined as any physical, biological, or chemical process to which sewage is subjected in order to remove or alter its objectionable constituents and thus render it less damaging to the receiving environment. Four degrees or levels of treatment are shown in this diagram, with each level providing a better quality of effluent that is eventually discharged into receiving waters. Only three of these levels of treatment are presently in common use, and most sewage treatment plants now operating in the Southeastern Wisconsin Region provide only secondary treatment.

In the first, or primary, level of treatment, metal screens remove large objects, such as sticks and rags, from the raw sewage. The sewage then passes into a grit chamber where coarse suspended materials, such as sand and gravel, settle to the bottom. From the grit chamber the sewage flows through a comminutor, which grinds any remaining large suspended solids, and then into a sedimentation tank where the velocity of flow is reduced so that the suspended particles sink to the bottom, forming a sludge blanket. Floating solids, oils, and greases are removed through skimming. Up to this point the primary treatment process is essentially physical (mechanical) in nature. The sludge is pumped to a heated tank where it is reduced by anaerobic bacteria --that is, bacteria which can exist without free oxygen--to a stable residue. The sludge digestion process is essentially biological in nature. By itself, this primary treatment removes only about 30 percent of oxygen-demanding organic matter in the raw sewage, the matter removed representing the coarser suspended solids in the sewage. Primary treatment removes little or none of the colloidal and dissolved matter in the sewage.

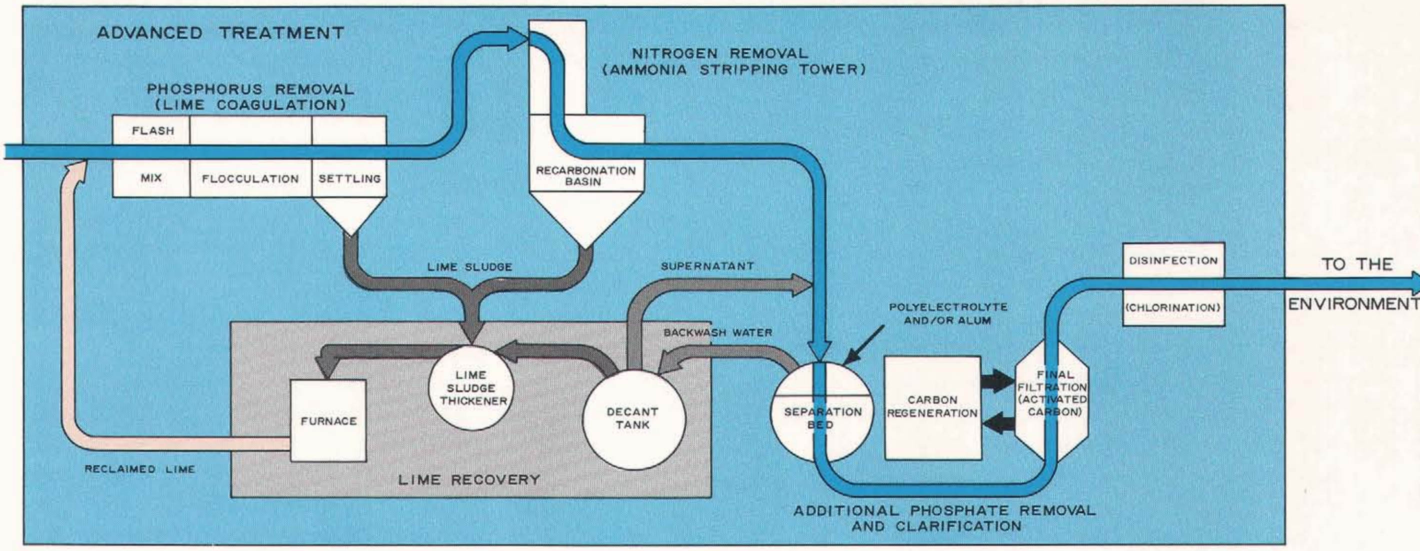
In secondary treatment most of the remaining oxygen-demanding organic matter is consumed by bacteria in the presence of oxygen. The effluent from the primary treatment facilities is further treated by such means as trickling filters or activated sludge tanks and additional sedimentation. The secondary treatment process is both physical and biological in nature. Secondary treatment removes up to 90 percent of the suspended matter and from 75 to 95 percent of the oxygen-demanding organic matter present in the raw sewage. In tertiary treatment additional solids and oxygen-demanding material are removed through detention of the secondary effluent in oxidation or stabilization ponds and through filtration by either sand or mechanical filters. Tertiary treatment, which may be either physical or biological or both in nature, removes up to 99 percent of the suspended matter and from 95 to 97 percent of oxygen-demanding organic matter present in the raw sewage.

Source: SEWRPC.

sewage treatment plants serving the Cities of Cedarburg and West Bend; the Villages of Campbellsport, Fredonia, Grafton, Jackson, Kewaskum, Saukville, and Thiensville; and the Newburg Sanitary District may be expected to render portions of Cedar Creek downstream from Cedarburg and the Milwaukee River from Campbellsport to the Milwaukee County line severely polluted, with water quality levels unable to meet the state-established water use objectives and standards. Future waste discharges from the two remaining plants—namely, the Village of Adell sewage treatment plant and the Village of Random Lake sewage treatment plant—are not expected to adversely affect stream water quality conditions. The Adell plant discharges to a seepage pond with no flow directly entering the stream system. The Random Lake plant discharges effluent to Silver Creek (Sheboygan County), which is dry during critical low-flow periods. Such discharge is not, however, expected to significantly affect water quality in the North Branch of the Milwaukee River.

All of the 12 communities operating municipal sewage treatment plants in the upper watershed have been issued orders by the Wisconsin Department of Natural Resources to provide improved secondary treatment in order to achieve higher levels of BOD removal and to provide post-chlorination facilities for the disinfection of the treated effluent.[22] In addition, those plants serving

[22] *Secondary treatment, with respect to municipal sewage treatment plants in daily service, has been defined by the Wisconsin Department of Natural Resources as sewage treatment which provides 90 percent removal of five-day*



Secondary and tertiary treatment processes remove and stabilize the oxygen-demanding organic waste materials in sewage but do not normally remove at best more than about 40 percent of the total phosphorus and 40 percent of the total nitrogen in the raw sewage, materials that are essentially good fertilizers. In advanced waste treatment, the effluent from either the secondary treatment or tertiary treatment facilities is further treated by essentially chemical processes to achieve the removal of the dissolved phosphorus and nitrogen compounds in the sewage that cause undesirable algae and weed growths in the receiving waters. The particular method of advanced waste treatment shown in the above diagram is only one of several possible methods. The method shown includes chemical coagulation, sedimentation, charcoal filtration, and aeration. Advanced waste treatment may be expected to remove up to 90 percent of the nitrogen and 95 percent of the phosphorus in the raw sewage. An auxiliary chemical treatment which should be used in combination with all four sewage treatment processes is disinfection by chlorination.

biochemical oxygen demand and total suspended solids determined as a monthly average of samples analyzed daily, with the monthly average five-day biochemical oxygen demand and total suspended solids concentration in the treatment plant effluent not to exceed 35 mg/l. (See letter from Mr. Thomas G. Frangos, Administrator, Division of Environmental Protection, to Mr. Kurt W. Bauer, Executive Director, SEWRPC, dated March 31, 1971.)

a population or population equivalent of 2,500 or more persons have been ordered to remove at least 85 percent of the influent phosphorus.[23] These water pollution abatement orders have been issued by the Wisconsin Department of Natural Resources pursuant to Chapter 144 of the Wisconsin Statutes and are in accord with the recommendations of the federal Lake Michigan Enforcement Conference. It is important to note that the Lake Michigan Enforcement Conference recommendations call for removal of 80 percent of total influent phosphorus on a basin-wide basis. In order to avoid diseconomics of scale, the Wisconsin orders call for 85 percent removal of phosphorus at the larger sewage treatment

---

[23]An initial set of pollution abatement orders was issued by the Wisconsin Department of Natural Resources on June 12, 1968, to the 12 communities in the upper Milwaukee River watershed operating sewage treatment facilities. In this initial set of orders, all 12 communities were ordered to remove 80 percent of the total phosphorus in the influent sewage. Subsequently, on February 27, 1970, the Department issued amended orders to all 12 communities. These amended orders provided for 85 percent phosphorus removal at the Cities of Cedarburg and West Bend and the Villages of Grafton and Thiensville. In addition, the Department endorsed the Village of Kewaskum's plans to remove 80 percent of the total phosphorus. The remaining seven communities were not given specific phosphorus removal orders in accordance with a revised state policy of not specifying the level of phosphorus removal for sewage treatment plants serving communities having a population or population equivalent of less than 2,500 people. For planning purposes in the Milwaukee River watershed study, it was assumed that, in addition to the five above-named communities, three additional communities--the Villages of Campbellsport, Jackson, and Saukville--would be ordered to meet the 85 percent removal requirement by 1990, since the respective populations or population equivalents of these two communities are expected to reach the threshold level of 2,500 people by the design year of the plan.

plants, with no specific requirement for phosphorus removal at the smaller sewage treatment plants but with an overall view toward reaching the desired goal of 80 percent removal of the phosphorus content of waste discharges on a basin-wide basis. As of January 1, 1971, all of the 12 communities now under such orders have begun compliance efforts to construct such facilities as may be necessary.

If, however, the state-established water use objectives and standards are to be met in all stream reaches of the watershed, it will be necessary to provide an even higher degree of treatment for selected waste discharges in the watershed. This higher degree of treatment could be in the form of tertiary and advanced waste treatment to effect higher levels of biochemical oxygen-demand (BOD) removal, nitrogenous oxygen-demand (NOD) removal, and nutrient removal from the sewered wastes before discharge to the stream system; in the form of instream treatment, such as aeration or low-flow augmentation, to provide a higher dilution of the wastes and chemical treatment of the stream to suppress excessive algae and other aquatic plant growth; or in the form of a combination of advanced waste treatment and instream treatment.

The effects on water quality of discharging various amounts of BOD and NOD to a stream can be predicted with a fair degree of certainty. The effects of discharging various amounts of nutrients which contribute to algae and other aquatic plant growth in streams cannot be accurately predicted at present, however, due to the limitations of existing knowledge about the interactions among nutrients, growth of aquatic life, and the stream environment. It is reasonable to expect, however, that discharge of large amounts of phosphorus and nitrogen to surface waters in the effluent from sewage treatment plants will cause excessive growths of algae and aquatic weeds, which will, in turn, severely interfere with the maintenance of a healthy fishery in, and the recreational and aesthetic enjoyment of, the Milwaukee River and its major tributaries. Excessive daily fluctuations in the dissolved oxygen content of the stream, sufficient to render the stream unsuitable for fish life, may be expected to occur. Such fluctuations already occur in the upper watershed in certain stream reaches and are particularly severe in reaches extending downstream from the existing sewage treatment plants and in the small impoundments along the river.

Assuming that the orders issued by the Wisconsin Department of Natural Resources are complied with, the total amount of phosphorus discharged to the upper reaches of the Milwaukee River system from municipal sewage treatment plants may be expected to be reduced from 60,000 pounds annually at present to about 47,800 pounds annually by 1990, a 20 percent reduction, representing, however, an overall removal of 80 percent of the phosphorus contained in the influent sewage. Such contribution from municipal sewage treatment plants would approximate 47 percent of the estimated total annual phosphorus load of 101,000 pounds at the Milwaukee County line (see Table 57).[24] For analytical and planning purposes, it has been assumed that the municipal sewage treatment plants in the upper watershed which are now required, or which by 1990 would be required by state orders to remove 85 percent of the phosphorus, can and eventually will be operated to reach a level of 90 percent phosphorus removal. This would result in a further phosphorus reduction of about 11,500 pounds, reducing the total annual phosphorus input from municipal sewage treatment plant effluents to 36,300 pounds, or approximately 40 percent of the estimated 1990 total annual phosphorus loading of 89,700 pounds at the Milwaukee County line and

[24] *In Table 62, page 236, of Volume 1 of this report, it is indicated that the average annual phosphorus contribution from sewage treatment plant effluent was estimated to reach 34,000 pounds by 1990. This estimate was based upon the assumption that all of the 12 plants would be required to provide 85 percent removal of influent phosphorus and that the total population to be served within the upper watershed, originally estimated at 65,000 persons, would be located within the existing and committed sewer service areas of the 12 existing sewage treatment plants. The revised estimate of 47,800 pounds set forth in the text above reflects changes in these basic assumptions which were required by findings growing out of the plan preparation process. The population to be served by sewage treatment plants discharging wastes to the river system was increased from 65,000 to 77,000 persons due primarily to the addition of the resident population in the Tri-Lakes and Cascade areas, which are not now served by public sewerage facilities. In addition, it was recognized that the amended state pollution abatement orders issued in February 1970 no longer require 85 percent phosphorus removal at sewage treatment plants serving a population or population equivalent of less than 2,500 persons. Therefore, the revised phosphorus contribution estimate included an assumption of only 45 percent phosphorus removal at the smaller sewage treatment plants. These two factors combined to cause an increase in the amount of phosphorus estimated to be contributed to the stream system in 1990 by sewage treatment plants.*

Table 57

COMPARISON OF INITIAL AND REVISED ESTIMATES OF PHOSPHORUS CONTRIBUTIONS FROM MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENT IN THE MILWAUKEE RIVER WATERSHED--1990

RIVER REACH	INITIAL PHOSPHORUS CONTRIBUTION[a] (LBS. PER YEAR)	REVISED PHOSPHORUS CONTRIBUTION[b] (LBS. PER YEAR)
MAIN STEM (ABOVE WEST BEND)	4,000	4,800
MAIN STEM (AT NORTH BRANCH)	17,000	27,600
MAIN STEM (AT MILWAUKEE COUNTY LINE)	34,000	47,800
MAIN STEM (AT NORTH AVENUE DAM)	34,000	47,800
NORTH BRANCH	1,000	4,700
CEDAR CREEK	8,000	10,200

[a] AS REPORTED IN TABLE 62 OF VOLUME 1 OF THIS REPORT. THIS PHOSPHORUS BUDGET ASSUMED 85 PERCENT REMOVAL EFFICIENCY AT ALL EXISTING SEWAGE TREATMENT PLANTS.

[b] AS DEVELOPED FOR THE COMPREHENSIVE WATERSHED PLAN. SEE FOOTNOTE 24, PAGE 266 OF THIS VOLUME.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

33 percent of such loading at the North Avenue Dam. This amount of phosphorus also represents about 60 percent of the present discharge (1967) of 60,000 pounds to the river system by municipal sewage treatment plants.

Ninety percent reduction of the influent phosphorus at the municipal sewage treatment plants is a reasonable maximum removal, since this level of removal can be achieved with relatively minor modifications to the existing and proposed sewage treatment facilities which are now being planned and constructed to meet the existing state orders for phosphorus removal, which orders presently require 85 percent removal. Incremental annual costs for removal of the additional 5 percent of phosphorus are estimated to range from 6 to 9 percent, primarily due to increased requirements for chemical flocculents and sludge disposal. Removal of more than 90 percent of phosphorus, however, under the present state of the technology involved, would require construction of additional facilities at considerable cost and was not, therefore, considered to be economically feasible. Because of the effects of urban and rural storm water runoff and septic tank effluent seepage, it may not be possible to continuously maintain, through control of the waste contribution from the municipal sewage treatment plants alone, phosphorus levels at all points in the stream below the approximate threshold level for algal blooms of 0.10 mg/l. High levels of phosphorus removal at sewage treatment plants, however, should serve to minimize nuisance growths of algae and other aquatic plants. By removing nearly 90 percent of the phosphorus from the treated municipal wastes, the amount present in the streams can be greatly reduced and a significant improvement in water quality conditions effected.

Alternative Plan Elements Investigated

Five basic alternative stream water quality management plan elements were investigated with respect to the upper watershed: 1) advanced waste treatment with 85 percent phosphorus removal at selected sewage treatment plants, as required by present state pollution abatement orders; 2) tertiary and advanced waste treatment with 80 percent NOD, 95 percent BOD, and 90 percent phosphorus removal at selected sewage treatment plants; 3) effluent disposal by land irrigation; 4) instream aeration; and 5) low-flow augmentation. In addition to these five basic alternative stream water quality management plan elements considered, several variations of the advanced waste treatment alternatives were explored. These variations deal only with the location and arrangement of the advanced waste treatment facilities in the West Bend-Kewaskum-Jackson-Tri-Lakes, Cedarburg-Grafton, and Thiensville areas of the watershed.

The sizes of the facilities needed to accommodate the hydraulic and biological loading for each of the alternatives considered were based upon the forecast future (1990) population levels as derived from the land use plan base element (see Chapter III of this volume), upon per capita waste flow contributions developed in the study for this purpose, and upon generally accepted engineering design criteria.

Per capita sewage flow rates for plan design were determined from the relationship shown in Figure 36 in Chapter IX of Volume 1 of this report. The average flow rates used varied from 120 gallons per capita per day (gpcd) for Newburg, the smallest urban community with a sewage treatment plant in the upper watershed, to 200 gpcd for West Bend, the largest community with a sewage treatment plant in the upper watershed. These per capita sewage flow rates were used to size the required sewage treatment plants and estimate their costs. Trunk sewers were sized to carry a peak hourly flow of two times the average sewage flow rate. The selection of this ratio of peak hourly flow to average flow was based on one of several recommendations contained in American Society of Civil Engineers Manual of Engineering Practice No. 37, Design and Construction of Sanitary and Storm Sewers (3rd

Printing 1963). The values selected for the average daily and peak hourly design flows compare favorably with the minimum average trunk sewer design flow requirement of 100 gpcd and a minimum peak hourly design requirement of 250 gpcd recommended in the 1968 edition of Recommended Standards for Sewage Works, Great Lakes-Upper Mississippi River Board of State Sanitary Engineers (Ten States Standards).

In addition to the per capita flow rates, the following salient engineering design criteria were used in determining the size and cost of necessary trunk sewer facilities: all sewers were designed to flow full, if slope permitted, using the Manning Formula with an "n" value of 0.013; the minimum design velocity was set at 2.0 feet per second; and the minimum depth of cover to the top of the sewer was set at 7.0 feet.

Ground surface elevations along the proposed trunk sewer alignments were obtained from U. S. Geological Survey 7.5 and 15 minute quadrangle topographic maps (scale of 1:24000 and 1:62500, with 10- and 20-foot contour intervals, respectively) or, where available, from large-scale (1" = 100' and 1" = 200', with 2-foot contour intervals) topographic maps prepared to National Map Accuracy Standards. Only generalized soil and geologic investigations were carried out along the proposed trunk sewer alignments, since the designs were of a preliminary nature intended to be used only as a basis for the selection between alternative plan proposals.

Construction and maintenance costs were developed for each of the alternative plans utilizing appropriate 1969 unit prices. The cost of each alternative so developed did not include the costs of the construction or the expansion of the community sewerage systems to serve future areas of urban development or land costs, unless otherwise noted. If per capita water consumption and sewage flow should, contrary to the forecasts, decrease in the future rather than increase, the associated costs for each alternative plan would also decrease somewhat; but the relative desirability of one alternative versus another could be expected to remain the same.

Alternative 1—Advanced Waste Treatment (85 Percent Phosphorus Removal—State Orders)

The first alternative stream water quality management plan element considered for the upper Milwaukee River watershed would essentially provide for waste treatment levels as currently required by the Wisconsin Department of Natural Resources. The Department has issued orders to existing urban communities in the upper watershed area operating municipal sewage treatment plants, which orders provide for: secondary treatment; advanced treatment (85 percent phosphorus removal) at all sewage treatment facilities serving populations or population equivalents of 2,500 or more people; and post-chlorination for effluent disinfection. Under this alternative, secondary treatment and post-chlorination for effluent disinfection would be provided at the following facilities: Adell, Fredonia, and Newburg. Secondary treatment, tertiary treatment, and post-chlorination for effluent disinfection would be provided at the Random Lake sewage treatment facility. Secondary treatment, advanced treatment (85 percent phosphorus removal), and post-chlorination would be provided at the following facilities: Campbellsport, Cedarburg, Grafton, Jackson, Kewaskum, Saukville, Thiensville, and West Bend.

For analysis and planning purposes, it was assumed that a sewage treatment facility would be constructed to serve the Village of Cascade and the nearby Lake Ellen area. In addition, it was assumed that a sewage treatment facility would be constructed to serve the Tri-Lakes area, a tributary drainage area that includes the developed urban areas around Big Cedar, Little Cedar, and Silver Lakes in the West Bend area of the watershed. Neither the Cascade-Lake Ellen area nor the Tri-Lakes area now have any public sanitary sewerage service, but in both cases the existing population densities and the need to protect stream and lake water quality warrant the provision of public sanitary sewerage service. In the case of the Tri-Lakes area, it was further assumed that, because the population threshold of 2,500 would be surpassed, treatment at this new plant would consist of secondary treatment, advanced treatment (85 percent phosphorus removal), and post-chlorination, while the Cascade plant would provide secondary treatment and post-chlorination.

An analysis was made to determine if the state-established water use objectives and supporting standards for the Milwaukee River and its major tributaries would be met under anticipated 1990 land use development conditions if all treatment plants were upgraded or, in the two instances cited above, newly constructed in accordance with the outstanding state pollution abatement orders.

The various criteria used in this analysis with respect to the levels of treatment are presented in Table 58. The stream water quality simulation model, as described in Chapter XII of Volume 1 of this report, was operated for the following specified conditions: 1) natural flow condition to equal the lowest seven-day flow during the period 1960-1969; 2) effluent flow to equal the projected 1990 flows; and 3) the low point of the oxygen profile, exclusive of effects of the processes of plant photosynthesis and respiration, to equal or exceed 5 mg/l.[25]

Operation of the stream water quality simulation model indicated that, even if the foregoing treatment levels at the 14 sewage treatment plants are achieved, substandard dissolved oxygen (DO) concentrations may be expected to occur in four reaches; namely, two reaches along the main stem of the Upper Milwaukee River, one reach located on the North Branch of the Milwaukee River below Cascade, and one reach on Cedar Creek below Cedarburg. Substandard DO concentrations would occur on the main stem of the Milwaukee River about two miles below the Campbellsport sewage treatment plant, where the DO could be expected to sag to 4.8 mg/l, and in the entire reach on the main stem downstream from the West Bend sewage treatment plant to the Newburg Weir, where the DO could be expected to sag to a low value of about 2.6 mg/l, with the stream becoming anerobic in the Newburg impoundment. The analysis revealed that the DO concentrations could be expected to be well in excess of 5.0 mg/l in the Milwaukee River from the Newburg Weir to the Milwaukee County line. On the North Branch of the Milwaukee River, the DO content could be expected to sag to 4.0 mg/l at a point about one mile below the proposed Cascade sewage treatment plant. Along Cedar Creek the DO could be expected to sag to anerobic conditions in the Hamilton Pond.

Thus, operation of the stream water quality simulation model indicated that the state-established stream water quality standards would not be met under 1990 land use development conditions even if all of the outstanding orders with respect to pollution abatement are complied with fully. The water quality in Cedar Creek, the North Branch of the Milwaukee River, and the main stem of the Milwaukee River above Newburg could be expected to be unsuitable for the preservation of fish and other aquatic life. In addition, excessive algae and other aquatic plant growths could be expected to continue to flourish in some reaches and could be expected to interfere with recreational and aesthetic uses of the stream.

Four alternative subsystem plan elements were considered in the watershed study for the provision of advanced waste treatment (85 percent phosphorus removal—state orders) in the upper Milwaukee River watershed. These four subsystem alternatives provide essentially the same levels of waste treatment throughout the upper watershed but differ with respect to the system configuration. Alternative 1A envisions the provision of such advanced waste treatment at nine sewage treatment plants, the provision of tertiary treatment at one sewage treatment plant, and the provision of secondary treatment only at four sewage treatment plants in the upper watershed. Alternative 1B envisions the provision of advanced waste treatment at five sewage treatment plants, the provision of tertiary treatment at one sewage treatment plant, and the provision of secondary treatment only at four sewage treatment plants in

[25] *The assumption explicit in this criterion is that respiration by aquatic vegetation will not reduce the DO level below 5.0 mg/l for more than eight hours in a 24-hour period and that the DO in the stream would not go below 4.0 mg/l at any time.*

Table 58

CRITERIA USED IN APPLICATION OF STREAM WATER QUALITY MODEL TO DETERMINE IF WATER USE OBJECTIVES AND STANDARDS WOULD BE MET UPON COMPLIANCE WITH OUTSTANDING STATE POLLUTION ABATEMENT ORDERS

TREATMENT LEVELS AT SEWAGE TREATMENT PLANTS[a]			
PLANT	BOD REMOVAL (PERCENT)	AMMONIA NITROGEN CONVERTED (PERCENT)	PHOSPHORUS REMOVAL (PERCENT)
ADELL	90	30	45
CAMPBELLSPORT	92	30	85
CASCADE	90	30	45
CEDARBURG	92	30	85
FREDONIA	90	30	45
GRAFTON	92	30	85
JACKSON	90	30	85
KEWASKUM	92	30	85
NEWBURG	90	30	45
RANDOM LAKE	90	30	45
SAUKVILLE	92	30	85
THIENSVILLE	92	30	85
TRI-LAKES	92	30	85
WEST BEND	92	30	85

OTHER CRITERIA	
NATURAL FLOW CONDITION	LOWEST SEVEN-DAY FLOW PERIOD 1960-1969
EFFLUENT FLOW	PROJECTED 1990 FLOWS
DISSOLVED OXYGEN	LOW POINT OF OXYGEN PROFILE, EXCLUSIVE OF EFFECTS OF THE PROCESSES OF PLANT PHOTOSYNTHESIS AND RESPIRATION, TO EQUAL OR EXCEED 5 MG/L.

[a] ALL TREATMENT PLANT EFFLUENT WOULD HAVE 3 MG/L D.O.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

the upper watershed, combining the treatment plants at Cedarburg, Grafton, Jackson, Kewaskum, Tri-Lakes, and West Bend. Alternative 1C envisions the provision of advanced waste treatment at seven sewage treatment plants, the provision of tertiary treatment at one sewage treatment plant, and the provision of secondary treatment only at four sewage treatment plants in the upper watershed, combining the West Bend and Tri-Lakes plants and the Grafton and Cedarburg plants. Finally, Alternative 1D envisions the provision of advanced waste treatment at two sewage treatment plants, the provision of tertiary treatment at one sewage treatment plant, and the provision of secondary treatment only at four sewage treatment plants in the upper watershed, conveying the sewage from the Cedarburg, Grafton, Jackson, Kewaskum, Thiensville, Tri-Lakes, and West Bend areas to the Metropolitan Sewerage District of Milwaukee County for ultimate treatment. Each of these subsystem alternative plan elements is described below. Although the alternative subsystem configurations presented do not represent all of the possible potential combinations of alternative configurations, those presented do represent the most reasonable alternatives in terms of engineering and economic feasibility and potential for implementation.

Alternative 1A: The first alternative subsystem plan element considered under Alternative 1 would essentially carry out the existing orders issued by the Wisconsin Department of Natural Resources to the various communities in the upper watershed. In addition, this alternative provides for newly established sewage treatment facilities in the Cascade-Lake Ellen and Tri-Lakes areas of the watershed. Secondary treatment and post-chlorination for disinfection would, under this subsystem alternative, be provided at the following facilities: Adell, Cascade, Fredonia, and Newburg (see Map 39). The Adell treatment facility is proposed to continue to discharge partially treated wastes to a seepage pond. The Cascade treatment facility, which would be a new facility, would also be proposed to treat sewage from the Lake Ellen area, as described in a later section of this chapter. Secondary treatment, tertiary treatment, and post-chlorination for disinfection would be provided at the Random Lake sewage treatment facility, which facility would also be proposed to treat additional wastes generated in the unincorporated lake development along the north and east shores of Random Lake, as described in a later section of this chapter. Secondary treatment, advanced treatment (85 percent phosphorus removal), and post-chlorination for disinfection would be provided at the following facilities: Campbellsport, Cedarburg, Grafton, Jackson, Kewaskum, Saukville, Thiensville, Tri-Lakes, and West Bend.[26]

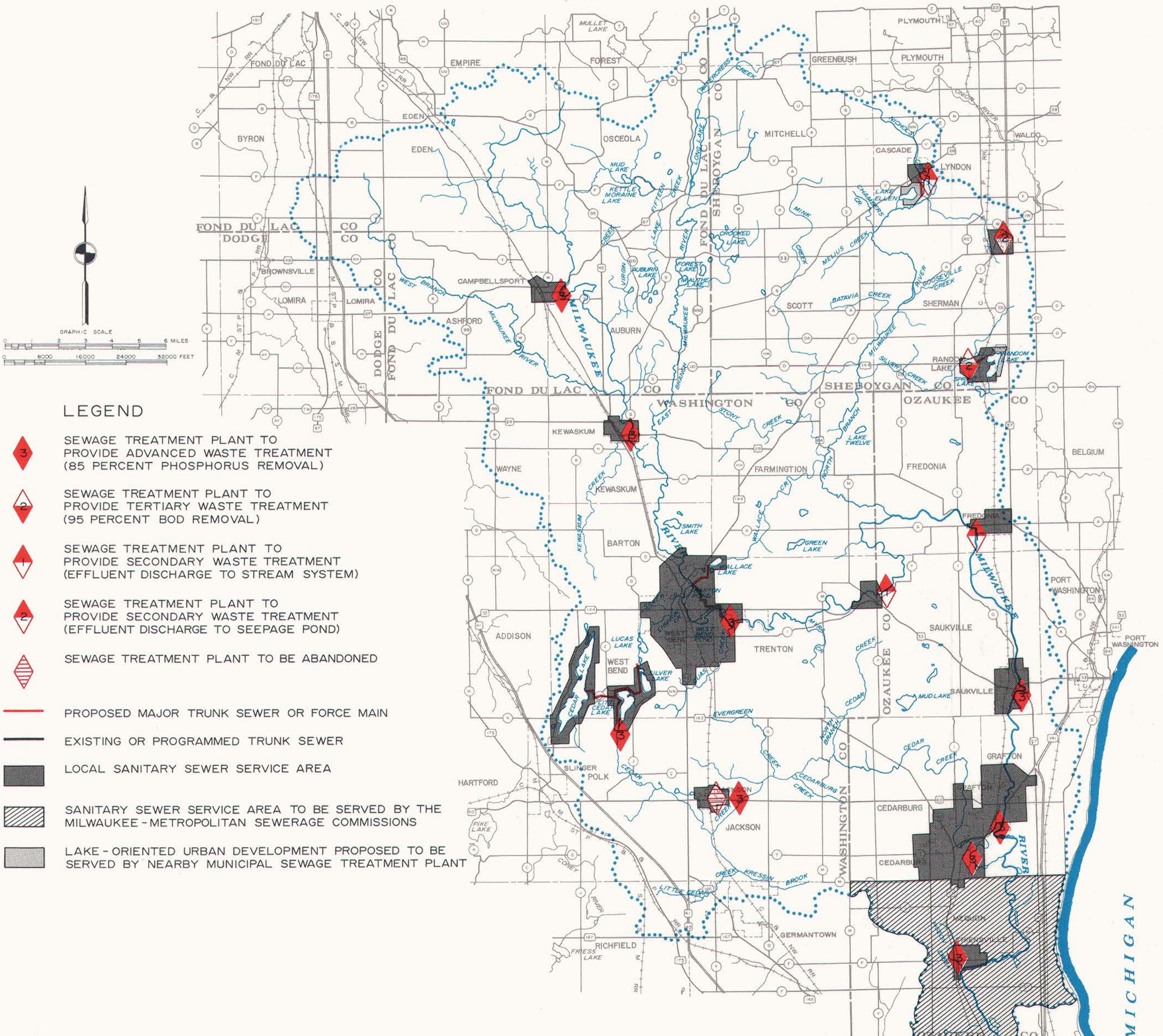
The facilities needed for this alternative subsystem plan element would include the expansion of all existing sewage treatment facilities to serve the forecast increased population levels and the construction of the new sewage treatment plants serving the Cascade-Lake Ellen and Tri-Lakes areas of the watershed. Implementation of this alternative subsystem plan element for the upper watershed would entail on estimated initial capital cost of $7,287,800, with the total annual cost, including operation and maintenance, over a 50-year period estimated to be $1,582,100, or about $27 per capita per year. The per capita cost has, for analysis purposes, been based upon an estimated 1980 population of 57,580 to be served by the facilities. The present worth of this subsystem alternative plan element for 50 years at 6 percent interest is $24,944,300. These estimates include the costs of all required plant improvements and additions, including secondary treatment at all 14 plants; tertiary treatment at the Random Lake plant; advanced treatment (85 percent phosphorus removal) at the Campbellsport, Cedarburg, Grafton, Jackson, Kewaskum, Saukville, Thiensville, Tri-Lakes, and West Bend plants; and effluent disinfection through post-chlorination at all 14 plants. The detailed cost estimates for each major element comprising this subsystem alternative are summarized in Table 59.

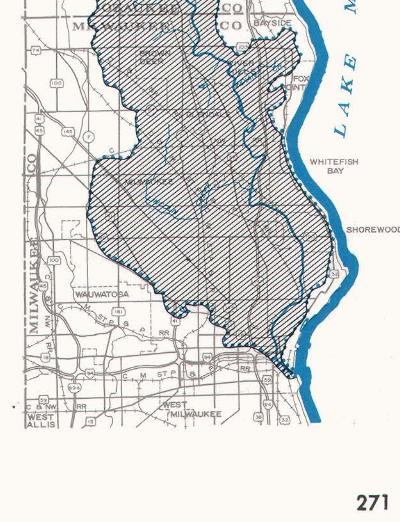
Alternative 1B: The second alternative subsystem plan element considered under Alternative 1 differs from the first subsystem alternative only in the number of sewage treatment plants provided. Under this second subsystem alternative, secondary treatment and post-chlorination for disinfection would be provided at the following facilities: Adell, Cascade, Fredonia, and Newburg (see Map 40). The Adell treatment facility is proposed to continue to discharge partially treated wastes to a seepage pond. The Cascade treatment facility, which would be a new facility, would also be

[26] *The West Bend treatment facility is proposed in this and all subsequent stream water quality management plan alternatives to treat sewage from the Wallace Lake area northeast of the City of West Bend.*

Map 39

UPPER MILWAUKEE RIVER WATERSHED
ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT IA
1990





The first alternative stream water quality management plan element considered for the upper watershed would carry out the existing orders issued by the Wisconsin Department of Natural Resources to the various communities in the watershed. In addition, new sewage treatment facilities would be provided in the Cascade-Lake Ellen area and Big Cedar-Little Cedar-Silver Lakes area of the watershed. Water quality analyses based upon the assumption that this alternative water quality management plan would be implemented indicated that the state-established water use objectives and standards would not be fully reached throughout the watershed. Substandard dissolved oxygen concentrations would be expected to occur below the Campbellsport sewage treatment plant, below the West Bend sewage treatment plant all the way to the Newburg Impoundment, below the Cascade sewage treatment plant, and below the Cedarburg sewage treatment plant in the Hamilton Pond. Thus, a course of action that would simply comply with the outstanding state pollution abatement orders, while beneficial to stream water quality, would not achieve the adopted water use objectives and standards.

Source: Harza Engineering Company and SEWRPC.

Table 59

DETAILED COST ESTIMATES ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT IA

PLAN SUBELEMENT	ESTIMATED COST						
	CAPITAL (CONSTRUCTION)	PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
		CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
CAMPBELLSPORT (0.40 MGD)......	$ 315,700	$ 414,700	$ 689,000	$ 1,103,700	$ 26,200	$ 43,700	$ 69,900
KEWASKUM (0.74 MGD)...........	465,000	617,000	904,000	1,521,000	39,100	57,300	96,400
WEST BEND (5.14 MGD)..........	1,204,000	1,837,000	4,470,000	6,307,000	116,200	283,800	400,000
TRI-LAKES (0.96 MGD)..........	796,000	981,500	1,220,000	2,201,500	62,300	77,700	140,000
JACKSON (0.50 MGD)............	556,000	685,700	800,000	1,485,700	43,500	50,700	94,200
SAUKVILLE (0.40 MGD)..........	165,000	266,000	496,000	762,000	16,800	31,500	48,300
GRAFTON (1.90 MGD)............	903,000	1,211,000	1,909,000	3,120,000	76,800	121,100	197,900
CEDARBURG (2.48 MGD)..........	839,500	1,211,500	2,400,000	3,611,500	76,800	152,300	229,100
THIENSVILLE (0.61 MGD)........	198,000	331,300	965,700	1,297,000	21,000	61,400	82,400
GROUP 2[b]							
RANDOM LAKE (0.30 MGD)........	$ 329,000	$ 400,400	$ 394,000	$ 794,400	$ 25;400	$ 25,000	$ 50,400
GROUP 3[c]							
NEWBURG (0.12 MGD)............	$ 92,000	$ 130,400	$ 214,000	$ 344,400	$ 8,300	$ 13,600	$ 21,900
FREDONIA (0.23 MGD)...........	137,000	198,700	312,000	510,700	12,600	19,800	32,400
ADELL (0.07 MGD)[d].............	--	--	--	--	--	--	--
CASCADE (0.26 MGD)............	293,000	361,300	402,000	763,300	22,900	25,500	48,400
SUBTOTAL TREATMENT FACILITIES.................	$ 6,293,200	$ 8,646,500	$15,175,700	$23,822,200	$ 547,900	$ 963,400	$ 1,511,300
TRUNK SEWER FACILITIES							
TRI-LAKES[e].....................	$ 994,600	$ 1,020,100	$ 102,000	$ 1,122,100	$ 64,500	$ 6,300	$ 70,800
WATERSHED TOTAL.................	$ 7,287,800	$ 9,666,600	$15,277,700	$24,944,300	$ 612,400	$ 969,700	$ 1,582,100

[a]EACH SEWAGE TREATMENT PLANT IN GROUP 1 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (85 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 2 (RANDOM LAKE) IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT, AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[c]EACH SEWAGE TREATMENT PLANT IN GROUP 3 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[d]NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED THAT IT CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[e]INCLUDES 10,850 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $332,530, 3,250 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $100,250, 15,650 FEET OF 10-INCH SEWER AT AN ESTIMATED COST OF $441,970, 650 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $10,250, AND 6 LIFT STATIONS AND ONE PUMPING STATION (ONE 20 GPM LIFT STATION AT 10 FEET OF HEAD, ONE 100 GPM LIFT STATION AT 10 FEET OF HEAD, ONE 200 GPM LIFT STATION AT 10 FEET OF HEAD, TWO 700 GPM LIFT STATIONS AT 10 FEET OF HEAD, ONE 700 GPM LIFT STATION AT 20 FEET OF HEAD, AND ONE 100 GPM PUMPING STATION AT 60 FEET OF HEAD) AT AN ESTIMATED COST OF $109,600, REQUIRED TO CONNECT THE PROPOSED TRI-LAKES SEWER SERVICE AREA TO A NEW SEWAGE TREATMENT FACILITY PROPOSED TO BE LOCATED AT THE SOUTH END OF LITTLE CEDAR LAKE.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

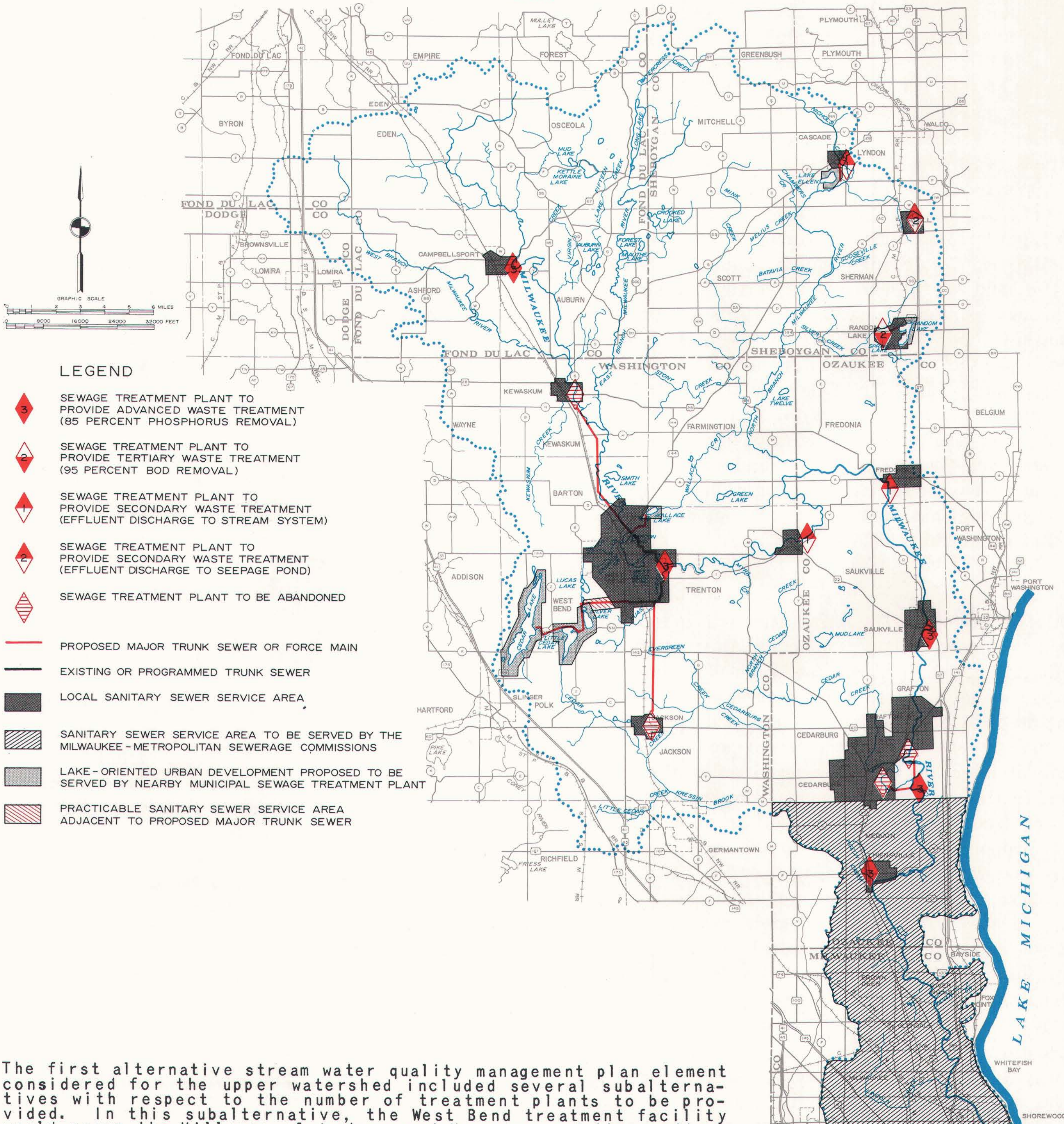
proposed to treat sewage from the Lake Ellen area, as described in a later section of this chapter. Secondary treatment, tertiary treatment, and post-chlorination for disinfection would be provided at the Random Lake sewage treatment facility, which facility would also be proposed to treat additional wastes generated in the unincorporated lake development along the north and east shores of Random Lake, as described in a later section of this chapter. Secondary treatment, advanced treatment (85 percent phosphorus removal), and post-chlorination would be provided at the following facilities: Campbellsport, Cedarburg-Grafton, Saukville, Thiensville, and West Bend.

The West Bend treatment facility would be an areawide facility, serving the Jackson, Kewaskum, Tri-Lakes, and West Bend sewer service areas. A system of trunk sewers, pumping stations, and force mains would be provided to convey wastes from the Jackson, Kewaskum, and Tri-Lakes service areas to the existing West Bend treatment site (see Map 40). The Cedarburg-Grafton treatment facility would be a new areawide facility located near the confluence of the Milwaukee River and Cedar Creek designed to treat wastes generated in the Cedarburg and Grafton sewer service areas. A system of trunk sewers would be constructed to convey wastes from the Cedarburg and Grafton service areas to the new plant site (see Map 40). Existing sewage treatment plants at Cedarburg, Grafton, Jackson, and Kewaskum would be abandoned upon implementation of this alternative subsystem plan element.

Implementation of this alternative subsystem plan element for the upper watershed would entail an

Map 40

UPPER MILWAUKEE RIVER WATERSHED
ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT IB
1990



The first alternative stream water quality management plan element considered for the upper watershed included several subalternatives with respect to the number of treatment plants to be provided. In this subalternative, the West Bend treatment facility would serve the Villages of Jackson and Kewaskum and the sanitary districts around Big Cedar, Little Cedar, and Silver Lakes, as well as the City of West Bend itself. Sewage treatment for the Village of Grafton and the City of Cedarburg would be provided at a new sewage treatment plant located near the confluence of the Milwaukee River and Cedar Creek. Existing sewage treatment plants at Cedarburg, Grafton, Jackson, and Kewaskum would be abandoned under this alternative.

Source: Harza Engineering Company and SEWRPC.

estimated initial capital cost of $9,476,900, with the total annual cost, including operation and maintenance, over a 50-year period estimated to be $1,572,000, or about $27 per capita per year. The per capita cost has, for analysis purposes, been based upon an estimated 1980 population of 57,580 to be served by the facilities. The present worth of this subsystem alternative plan element for 50 years at 6 percent interest is $24,779,300. These estimates include the costs of all required plant improvements and additions, including secondary treatment at all 10 plants; tertiary treatment at the Random Lake plant; advanced treatment (85 percent phosphorus removal) at the Campbellsport, Cedarburg-Grafton, Saukville, Thiensville, and West Bend plants; effluent disinfection through post-chlorination at all 10 plants; trunk sewers, pumping stations, and force mains to connect the sewer service areas of Jackson, Kewaskum, and Tri-Lakes to the West Bend plant; and trunk sewers to connect the Cedarburg and Grafton sewer service areas to the new Cedarburg-Grafton sewage treatment plant. The detailed cost estimates for each major element comprising this subsystem alternative are summarized in Table 60.

Alternative 1C: The third alternative subsystem plan element considered under Alternative 1 differs from the first and second subsystem alternatives only in the number of sewage treatment plants provided. Under this third subsystem alternative, secondary treatment and post-chlorination for disinfection would be provided at the following facilities: Adell, Cascade, Fredonia, and Newburg (see Map 41). The Adell treatment facility is proposed to continue to discharge partially treated wastes to a seepage pond. The Cascade treatment facility, which would be a new facility, would also be proposed to treat sewage from the Lake Ellen area, as described in a later section of this chapter. Secondary treatment, tertiary treatment, and post-chlorination for disinfection would be provided at the Random Lake sewage treatment facility, which facility would also be proposed to treat additional wastes generated in the unincorporated lake development along the north and east shores of Random Lake, as described in a later section of this chapter. Secondary treatment, advanced treatment (85 percent phosphorus removal), and post-chlorination would be provided at the following facilities: Campbellsport, Grafton-Cedarburg, Jackson, Kewaskum, Saukville, Thiensville, and West Bend. The West Bend treatment facility would be an areawide facility but, unlike the second subsystem alternative, would serve only the West Bend and Tri-Lakes tributary drainage areas. A system of trunk sewers would be provided to convey wastes from the Tri-Lakes service area to the existing West Bend treatment site (see Map 41). The Cedarburg-Grafton treatment facility would be an integrated facility providing secondary treatment at the existing Cedarburg and Grafton treatment plants and providing advanced treatment (85 percent phosphorus removal) and post-chlorination for disinfection at a new treatment facility located near the confluence of the Milwaukee River and Cedar Creek. A system of trunk sewers would be provided to convey the partially treated wastes from the existing Cedarburg and Grafton sewage treatment plants to the new advanced waste treatment plant (see Map 41). Under this alternative, no existing sewage treatment plant in the upper watershed would be abandoned.

Implementation of this alternative subsystem plan element for the upper watershed would entail an estimated initial capital cost of $7,385,400, with total annual costs, including operation and maintenance, over a 50-year period, estimated to be $1,519,600, or about $26 per capita per year. The per capita cost has, for analysis purposes, been based upon an estimated 1980 population of 57,580 to be served by the facilities. The present worth of this subsystem alternative plan element for 50 years at 6 percent interest is $23,956,700. These estimates include the costs of all required plant improvements and additions, including secondary waste treatment at all 13 plants; advanced waste treatment (85 percent phosphorus removal) at the Campbellsport, Grafton-Cedarburg, Jackson, Kewaskum, Saukville, Thiensville, and West Bend plants; effluent disinfection through post-chlorination at all 13 plants; trunk sewers to connect the Tri-Lakes tributary drainage area to the West Bend plant; and trunk sewers to connect the existing and to-be-retained Cedarburg and Grafton treatment plants to the new advanced Cedarburg-Grafton sewage treatment plant. The detailed cost estimates for each major element comprising this subsystem alternative are summarized in Table 61.

Alternative 1D: The fourth alternative subsystem plan element considered under Alternative 1 differs substantially from the first three subsystem alternatives considered. The basic difference lies in the connection of several sewer service areas now being served by individual sewage treatment

Table 60

DETAILED COST ESTIMATES ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT IB

PLAN SUBELEMENT	ESTIMATED COST						
		PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
	CAPITAL (CONSTRUCTION)	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
CAMPBELLSPORT (0.40 MGD)	$ 315,700	$ 414,700	$ 689,000	$ 1,103,700	$ 26,200	$ 43,700	$ 69,900
WEST BEND (7.08 MGD)[b]	1,910,000	2,707,000	5,700,000	8,407,000	171,700	361,500	533,200
SAUKVILLE (0.40 MGD)	165,000	266,000	496,000	762,000	16,800	31,500	48,300
CEDARBURG-GRAFTON (4.38 MGD)[c]	2,430,000	2,996,000	3,760,000	6,756,000	189,700	239,000	428,700
THIENSVILLE (0.61 MGD)	198,000	331,300	965,700	1,297,000	21,000	61,400	82,400
GROUP 2[d]							
RANDOM LAKE (0.30 MGD)	$ 329,000	$ 400,400	$ 394,000	$ 794,400	$ 25,400	$ 25,000	$ 50,400
GROUP 3[e]							
NEWBURG (0.12 MGD)	$ 92,000	$ 130,400	$ 214,000	$ 344,400	$ 8,300	$ 13,600	$ 21,900
FREDONIA (0.23 MGD)	137,000	198,700	312,000	510,700	12,600	19,800	32,400
ADELL (0.07 MGD)[f]	--	--	--	--	--	--	--
CASCADE (0.26 MGD)	293,000	361,300	402,000	763,300	22,900	25,500	48,400
SUBTOTAL TREATMENT FACILITIES	$ 5,869,700	$ 7,805,800	$12,932,700	$20,738,500	$ 494,600	$ 821,000	$ 1,315,600
TRUNK SEWERS							
WEST BEND SYSTEM[g]	$ 3,025,200	$ 3,071,300	$ 372,100	$ 3,443,400	$ 194,800	$ 23,700	$ 218,500
CEDARBURG-GRAFTON SYSTEM[h]	582,000	582,000	15,400	597,400	36,900	1,000	37,900
SUBTOTAL TRUNK SEWERS	$ 3,607,200	$ 3,653,300	$ 387,500	$ 4,040,800	$ 231,700	$ 24,700	$ 256,400
WATERSHED TOTAL	$ 9,476,900	$11,459,100	$13,320,200	$24,779,300	$ 726,300	$ 845,700	$ 1,572,000

[a] EACH SEWAGE TREATMENT PLANT IN GROUP 1 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (85 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b] THE WEST BEND SEWAGE TREATMENT FACILITY IS PROPOSED TO SERVE EXISTING AND PROPOSED URBAN DEVELOPMENT IN THE TRI-LAKES SEWER SERVICE AREA, AS WELL AS THE EXISTING AND PROPOSED SEWER SERVICE AREAS OF THE EXISTING KEWASKUM, JACKSON, AND WEST BEND SEWAGE TREATMENT FACILITIES. THE EXISTING SEWAGE TREATMENT FACILITIES AT KEWASKUM AND JACKSON WOULD BE ABANDONED UPON IMPLEMENTATION OF THIS ALTERNATIVE. PRIVATE WASTE TREATMENT FACILITIES WOULD CONTINUE TO BE USED AT THE LIBBY, MC NEIL, & LIBBY PLANT NEAR THE VILLAGE OF JACKSON UNDER THIS ALTERNATIVE.

[c] THE EXISTING AND PROPOSED SEWER SERVICE AREAS OF THE EXISTING CEDARBURG AND GRAFTON SEWAGE TREATMENT FACILITIES ARE PROPOSED TO BE SERVED BY A NEW TREATMENT FACILITY PROVIDING ADVANCED WASTE TREATMENT TO BE LOCATED NEAR THE CONFLUENCE OF CEDAR CREEK AND THE MILWAUKEE RIVER. THE EXISTING SEWAGE TREATMENT FACILITIES AT CEDARBURG AND GRAFTON WOULD BE ABANDONED UPON IMPLEMENTATION OF THIS ALTERNATIVE.

[d] THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 2 (RANDOM LAKE) IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT, AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[e] EACH SEWAGE TREATMENT PLANT IN GROUP 3 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[f] NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED THAT IT CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[g] INCLUDES 28,000 FEET OF 8-INCH SEWER AT AN ESTIMATED COST OF $520,000, 8,920 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $272,000, 14,600 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $591,000, 34,000 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $1,276,000, 9,600 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $163,400, 260 FEET OF 10-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $4,800, TWO 1,400 GPM LIFT STATIONS AT 7 FEET OF HEAD AT AN ESTIMATED TOTAL COST OF $100,000, TWO 300 GPM PUMPING STATIONS AT 100 FEET OF HEAD AT AN ESTIMATED COST OF $30,000, AND THREE 670 GPM PUMPING STATIONS AT 50 FEET OF HEAD AT AN ESTIMATED COST OF $68,000, REQUIRED TO CONNECT THE TRI-LAKES, KEWASKUM, AND JACKSON SEWER SERVICE AREAS TO THE WEST BEND SANITARY SEWERAGE SYSTEM.

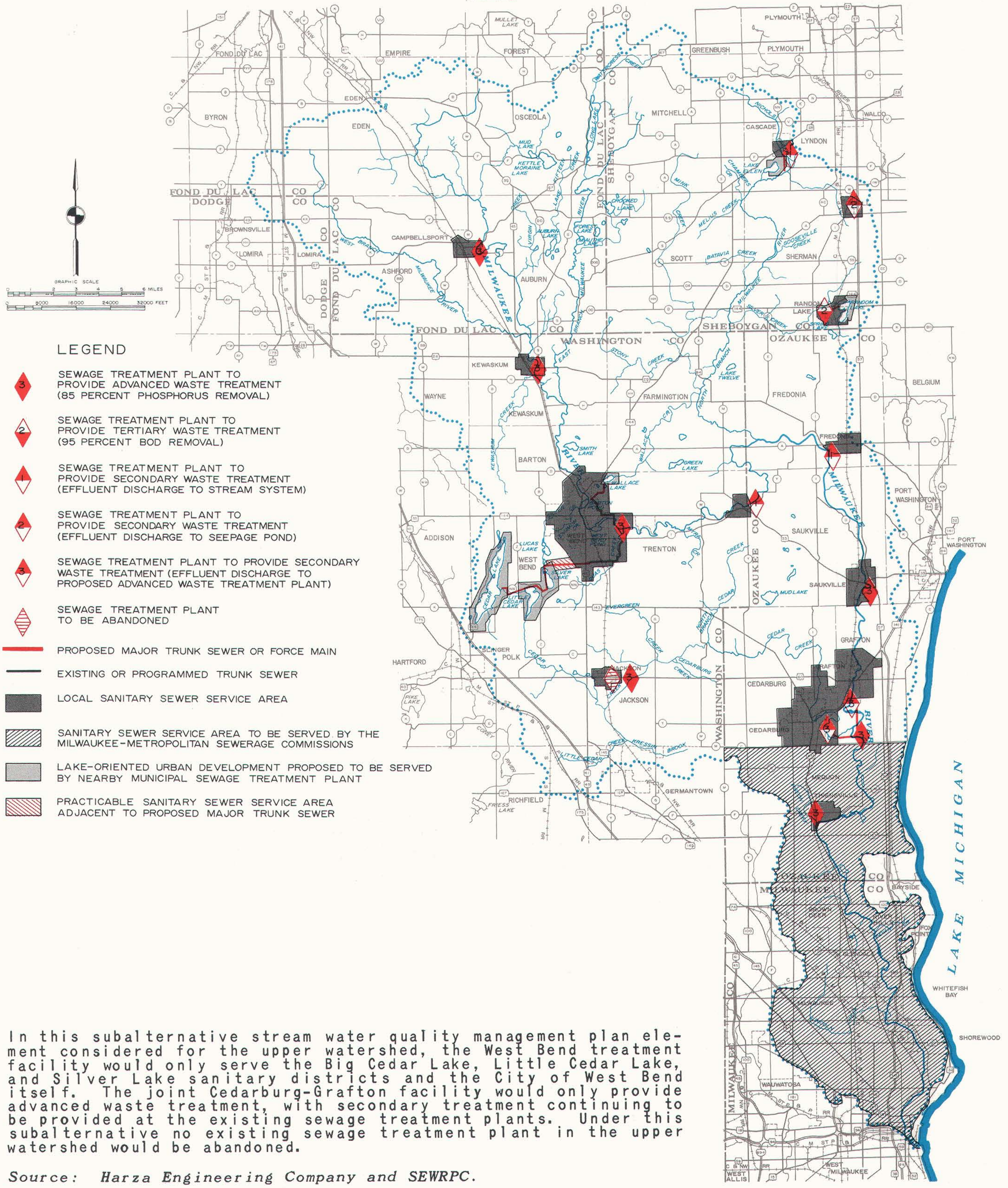
[h] INCLUDES 7,800 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $244,000 AND 7,050 FEET OF 21-INCH SEWER AT AN ESTIMATED COST OF $338,000 REQUIRED TO CONNECT THE EXISTING AND PROPOSED CEDARBURG AND GRAFTON SEWER SERVICE AREAS TO A NEW ADVANCED WASTE TREATMENT FACILITY PROPOSED TO BE LOCATED NEAR THE CONFLUENCE OF CEDAR CREEK AND THE MILWAUKEE RIVER.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

plants to the Metropolitan Sewerage District of Milwaukee County, with treatment to be provided at the Jones Island and South Shore sewage treatment facilities. Under this fourth subsystem alternative, secondary waste treatment and post-chlorination for disinfection of effluent would be provided at the following facilities: Adell, Cascade, Fredonia, and Newburg (see Map 42). The Adell treatment facility is proposed to continue to discharge partially treated wastes to a seepage pond. The Cascade treatment facility, which would be a new facility, would also be proposed to treat sewage from the Lake Ellen area, as described in a later section of this chapter. Secondary treatment, tertiary treatment, and post-chlorination for disinfection would be provided at the Random Lake treatment facility, which facility would also be proposed to treat additional wastes generated in the unincorporated lake development along the north and east shores of Random Lake,

Map 41

UPPER MILWAUKEE RIVER WATERSHED
ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT IC
1990



In this subalternative stream water quality management plan element considered for the upper watershed, the West Bend treatment facility would only serve the Big Cedar Lake, Little Cedar Lake, and Silver Lake sanitary districts and the City of West Bend itself. The joint Cedarburg-Grafton facility would only provide advanced waste treatment, with secondary treatment continuing to be provided at the existing sewage treatment plants. Under this subalternative no existing sewage treatment plant in the upper watershed would be abandoned.

Source: Harza Engineering Company and SEWRPC.

Table 61

DETAILED COST ESTIMATES ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT IC

PLAN SUBELEMENT	ESTIMATED COST						
		PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
	CAPITAL (CONSTRUCTION)	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
CAMPBELLSPORT (0.40 MGD)......	$ 315,700	$ 414,700	$ 689,000	$ 1,103,700	$ 26,200	$ 43,700	$ 69,900
KEWASKUM (0.74 MGD)...........	465,000	617,000	904,000	1,521,000	39,100	57,300	96,400
WEST BEND (6.10 MGD)[b].........	1,574,000	2,294,000	5,160,000	7,454,000	145,500	327,500	473,000
JACKSON (0.50 MGD)............	556,000	685,700	800,000	1,485,700	43,500	50,700	94,200
SAUKVILLE (0.40 MGD)..........	165,000	266,000	496,000	762,000	16,800	31,500	48,300
CEDARBURG-GRAFTON (4.38 MGD)[c]..................	1,701,500	2,267,500	3,900,000	6,167,500	143,800	247,400	391,200
THIENSVILLE (0.61 MGD)........	198,000	331,300	965,700	1,297,000	21,000	61,400	82,400
GROUP 2[d]							
RANDOM LAKE (0.30 MGD)........	$ 329,000	$ 400,400	$ 394,000	$ 794,400	$ 25,400	$ 25,000	$ 50,400
GROUP 3[e]							
NEWBURG (0.12 MGD)............	$ 92,000	$ 130,400	$ 214,000	$ 344,400	$ 8,300	$ 13,600	$ 21,900
FREDONIA (0.23 MGD)...........	137,000	198,700	312,000	510,700	12,600	19,800	32,400
ADELL (0.07 MGD)[f].............	--	--	--	--	--	--	--
CASCADE (0.26 MGD)............	293,000	361,300	402,000	763,300	22,900	25,500	48,400
SUBTOTAL TREATMENT FACILITIES..................	$ 5,826,200	$ 7,967,000	$14,236,700	$22,203,700	$ 505,100	$ 903,400	$ 1,408,500
TRUNK SEWERS							
WEST BEND SYSTEM[g].............	$ 977,200	$ 993,000	$ 162,600	$ 1,155,600	$ 62,900	$ 10,300	$ 73,200
CEDARBURG-GRAFTON SYSTEM[h].....	582,000	582,000	15,400	597,400	36,900	1,000	37,900
SUBTOTAL TRUNK SEWERS.......	$ 1,559,200	$ 1,575,000	$ 178,000	$ 1,753,000	$ 99,800	$ 11,300	$ 111,100
WATERSHED TOTAL.................	$ 7,385,400	$ 9,542,000	$14,414,700	$23,956,700	$ 604,900	$ 914,700	$ 1,519,600

[a]EACH SEWAGE TREATMENT PLANT IN GROUP 1 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (85 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b]THE WEST BEND SEWAGE TREATMENT FACILITY IS PROPOSED TO SERVE EXISTING AND PROPOSED URBAN DEVELOPMENT IN THE TRI-LAKES SEWER SERVICE AREA, AS WELL AS THE EXISTING AND PROPOSED SEWER SERVICE AREA OF THE EXISTING WEST BEND SEWAGE TREATMENT PLANT.

[c]THE CEDARBURG-GRAFTON AREA IS PROPOSED TO BE SERVED BY A TWO-PHASE TREATMENT FACILITY, WITH SECONDARY WASTE TREATMENT BEING PROVIDED AT THE EXISTING CEDARBURG AND GRAFTON SEWAGE TREATMENT PLANTS AND ADVANCED WASTE TREATMENT (85 PERCENT PHOSPHORUS REMOVAL) AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT BEING PROVIDED AT A SINGLE NEW TREATMENT FACILITY LOCATED NEAR THE CONFLUENCE OF CEDAR CREEK AND THE MILWAUKEE RIVER.

[d]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 2 (RANDOM LAKE) IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT, AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[e]EACH SEWAGE TREATMENT PLANT IN GROUP 3 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[f]NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED THAT IT CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[g]INCLUDES 10,300 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $314,000, 18,740 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $549,000, 2,200 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $41,400, 260 FEET OF 10-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $4,800, AND THREE 670 GPM PUMPING STATIONS AT 50 FEET OF HEAD AT AN ESTIMATED COST OF $68,000, REQUIRED TO CONNECT THE PROPOSED TRI-LAKES SEWER SERVICE AREA TO THE WEST BEND SANITARY SEWERAGE SYSTEM.

[h]INCLUDES 7,800 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $244,000 AND 7,050 FEET OF 21-INCH SEWER AT AN ESTIMATED COST OF $338,000 REQUIRED TO CONNECT THE EXISTING CEDARBURG AND GRAFTON SEWAGE TREATMENT PLANTS TO THE NEW ADVANCED WASTE TREATMENT FACILITY PROPOSED TO BE LOCATED NEAR THE CONFLUENCE OF CEDAR CREEK AND THE MILWAUKEE RIVER.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

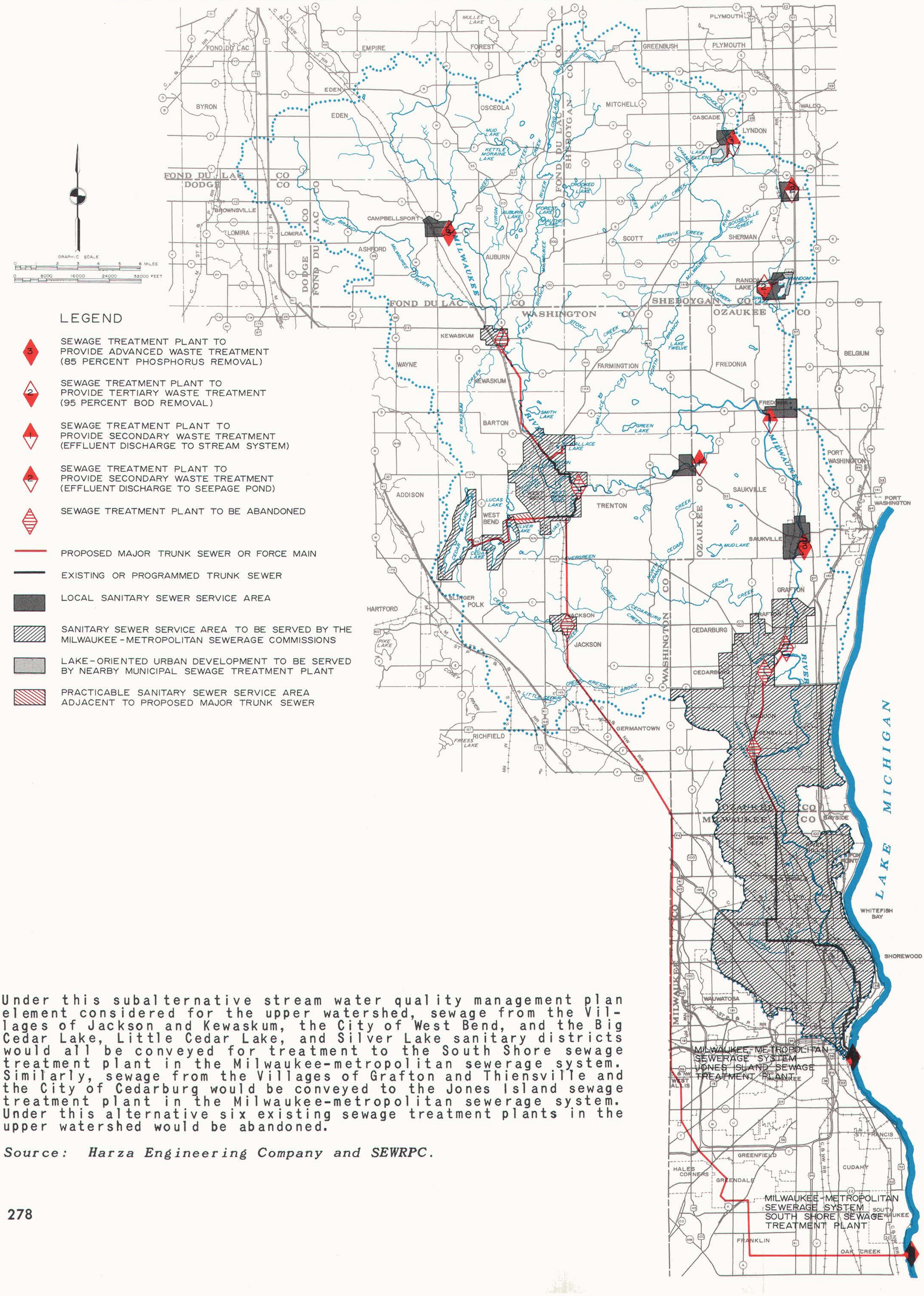
as described in a later section of this chapter. Secondary waste treatment, advanced waste treatment (85 percent phosphorus removal), and post-chlorination would be provided at the facilities at Campbellsport and Saukville. The following existing and proposed sewer service areas would be connected to the Milwaukee metropolitan sewerage system: Cedarburg, Grafton, Jackson, Kewaskum, Thiensville, Tri-Lakes, and West Bend.

Sewage originating in the Kewaskum-West Bend-Tri-Lakes-Jackson sewer service areas would be conveyed for treatment to the South Shore sewage treatment plant in the Milwaukee metropolitan sewerage system by a trunk sewer extending from Kewaskum southeastward through West Bend and Jackson and then south and east to the existing South Shore sewage treatment plant (see Map 42). Capacity would not be available in the existing or proposed trunk and relief sewers of the Milwaukee metropolitan sewerage system in Milwaukee County for sewage flow from the Kewaskum-West Bend-Tri-Lakes-Jackson sewer service areas.

Sewage from the Cedarburg, Grafton, and Thiensville sewer service areas would similarly be

Map 42

UPPER MILWAUKEE RIVER WATERSHED
ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT ID: 1990



Under this subalternative stream water quality management plan element considered for the upper watershed, sewage from the Villages of Jackson and Kewaskum, the City of West Bend, and the Big Cedar Lake, Little Cedar Lake, and Silver Lake sanitary districts would all be conveyed for treatment to the South Shore sewage treatment plant in the Milwaukee-metropolitan sewerage system. Similarly, sewage from the Villages of Grafton and Thiensville and the City of Cedarburg would be conveyed to the Jones Island sewage treatment plant in the Milwaukee-metropolitan sewerage system. Under this alternative six existing sewage treatment plants in the upper watershed would be abandoned.

Source: Harza Engineering Company and SEWRPC.

conveyed by a trunk sewer to the Milwaukee metropolitan sewerage system. A new trunk sewer would be constructed from the Milwaukee County line northerly along STH 57 to Thiensville and from Thiensville north to the treatment plant at Cedarburg, with a branch extending northeastward to Grafton (see Map 42). Sufficient capacity would be available in the existing and proposed trunk sewers in Milwaukee County for the transmission of the dry-weather sewage flow from these three communities up to the 1990 plan design year, thereby avoiding the need to construct a new trunk sewer from the Milwaukee County line to either the Jones Island or South Shore sewage treatment plants.[27] Existing sewage treatment plants in the upper watershed at Cedarburg, Grafton, Jackson, Kewaskum, Thiensville, and West Bend would be abandoned upon implementation of this alternative subsystem plan element.

Implementation of this alternative subsystem plan element for the upper watershed would entail an estimated initial capital cost of $14,965,900, with total annual costs, including operation and maintenance, over a 50-year period, is estimated to be $2,065,600, or about $36 per capita per year. The per capita cost was, for analysis purposes, based upon an estimated 1980 population of 57,580 to be served at the facilities. The present worth of this subsystem alternative plan element for 50 years at 6 percent interest is $32,558,100. These estimates include the costs of all required plant improvements and additions, including secondary waste treatment at seven individual plants in the upper watershed; tertiary waste treatment at the Random Lake plant; advanced waste treatment (85 percent phosphorus removal) at the Campbellsport and Saukville plants; effluent disinfection through post-chlorination at all seven plants in the upper watershed; trunk sewers, pumping stations, force mains, and appurtenant facilities to connect the existing and proposed sewer service areas of Cedarburg, Grafton, Jackson, Kewaskum, Thiensville, Tri-Lakes, and West Bend to the Milwaukee metropolitan sewerage system; and the estimated contract service costs for treatment at the South Shore sewage treatment plant. The detailed cost estimates for each major element comprising this subsystem alternative are summarized in Table 62.

Concluding Remarks—Alternative 1: The four alternative subsystem plan elements presented above differ not only in costs but in their relative ability to meet the state-established water quality objectives and standards. Implementation of Alternative 1A would not fully meet the standards, since substandard DO concentrations could be expected to occur on the Milwaukee River main stem for a distance of two miles below the Campbellsport sewage treatment plant, along the entire reach on the main stem downstream from the West Bend sewage treatment plant to the Newburg Weir, along the North Branch of the Milwaukee River for a distance of about one mile below the proposed Cascade sewage treatment plant, and along Cedar Creek, where the DO content could be expected to sag to anerobic conditions in the Hamilton Pond. Implementation of Alternative Subsystem Plan Element 1B would result in the same substandard DO concentrations as Alternative 1A, except for Cedar Creek, since the existing Cedarburg sewage treatment plant would be abandoned and the wastes conveyed to a combined Cedarburg-Grafton sewage treatment plant which would discharge directly to the Milwaukee River. Implementation of Alternative Subsystem Plan Element 1C would similarly not meet the standards except that, as in Alternative 1B, no effluent from the existing Cedarburg sewage treatment plant would be discharged above the Hamilton Dam. Implementation of Alternative Subsystem Plan Element 1D would result in meeting the water quality standards on all streams except for a two-mile reach of the Milwaukee River main stem below Campbellsport and a one-mile reach of the North Branch of the Milwaukee River below Cascade, since the treatment plants at Cedarburg, Grafton, Jackson, Kewaskum, Thiensville, and West Bend would be abandoned and their sewer service areas connected to the Milwaukee metropolitan sewerage system.

Alternative 2—Tertiary and Advanced Waste Treatment (80 Percent NOD, 95 Percent BOD, and 90 Percent Phosphorus Removal)

The second alternative stream water quality management plan element considered for the upper Milwaukee River watershed would provide for a

[27] *The existing and proposed trunk sewers in Milwaukee County are designed to carry the wet-weather flow from a tributary area which includes all of the Village of Thiensville and the City of Mequon up to the year 2000. It was assumed, however, that elimination of clear waters by 1972 from the sewerage systems of all the communities served by the Metropolitan Sewage District of Milwaukee County in compliance with orders issued by the Wisconsin Department of Natural Resources in 1968 and 1970 would result in sufficient additional capacity being made available to carry the additional 6.3 cfs of flow from the City of Cedarburg and the Village of Grafton through the 1990 watershed plan design year. Additional relief sewers may be needed to supplement the capacity of the existing and proposed trunk sewers in Milwaukee County beyond the 1990 plan design year.*

Table 62

DETAILED COST ESTIMATES ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT ID

PLAN SUBELEMENT	ESTIMATED COST						
		PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
	CAPITAL (CONSTRUCTION)	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
CAMPBELLSPORT (0.40 MGD)......	$ 315,700	$ 414,700	$ 689,000	$ 1,103,700	$ 26,200	$ 43,700	$ 69,900
SAUKVILLE (0.40 MGD)..........	165,000	266,000	496,000	762,000	16,800	31,500	48,300
GROUP 2[b]							
RANDOM LAKE (0.30 MGD)........	$ 329,000	$ 400,400	$ 394,000	$ 794,400	$ 25,400	$ 25,000	$ 50,400
GROUP 3[c]							
NEWBURG (0.12 MGD)............	$ 92,000	$ 130,400	$ 214,000	$ 344,400	$ 8,300	$ 13,600	$ 21,900
FREDONIA (0.23 MGD)...........	137,000	198,700	312,000	510,700	12,600	19,800	32,400
ADELL (0.07 MGD)[d].............	--	--	--	--	--	--	--
CASCADE (0.26 MGD)............	293,000	361,300	402,000	763,300	22,900	25,500	48,400
GROUP 4[e]							
METROPOLITAN SYSTEM (12.07 MGD)[f]................	$ --	$ --	$13,394,000	$13,394,000	$ --	$ 850,000	$ 850,000
SUBTOTAL--TREATMENT FACILITIES..................	$ 1,331,700	$ 1,771,500	$15,901,000	$17,672,500	$ 112,200	$ 1,009,100	$ 1,121,300
TRUNK SEWERS							
CEDARBURG-GRAFTON-THIENSVILLE SYSTEM[g].........	$ 2,288,000	$ 2,298,600	$ 119,800	$ 2,418,400	$ 145,500	$ 7,600	$ 153,100
WEST BEND-TRI-LAKES-KEWASKUM-JACKSON SYSTEM[h]......................	11,346,200	11,472,200	995,000	12,467,200	728,000	63,200	791,200
SUBTOTAL--TRUNK SEWERS......	$13,634,200	$13,770,800	$ 1,114,800	$14,885,600	$ 873,500	$ 70,800	$ 944,300
WATERSHED TOTAL.................	$14,965,900	$15,542,300	$17,015,800	$32,558,100	$ 985,700	$ 1,079,900	$ 2,065,600

[a]EACH SEWAGE TREATMENT PLANT IN GROUP 1 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (85 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 2 (RANDOM LAKE) IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT (95 PERCENT BOD REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[c]EACH SEWAGE TREATMENT PLANT IN GROUP 3 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[d]NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED THAT IT CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[e]EXISTING AND PROPOSED URBAN DEVELOPMENT IN THE TRI-LAKES AREA AND THE EXISTING AND PROPOSED SEWER SERVICE AREAS OF THE EXISTING KEWASKUM, JACKSON, WEST BEND, GRAFTON, CEDARBURG, AND THIENSVILLE SEWAGE TREATMENT FACILITIES ARE PROPOSED TO BE CONNECTED TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM. SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (85 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT WOULD BE PROVIDED AT THE EXISTING JONES ISLAND AND SOUTH SHORE SEWAGE TREATMENT FACILITIES. THE EXISTING SEWAGE TREATMENT FACILITIES AT KEWASKUM, JACKSON, WEST BEND, GRAFTON, CEDARBURG, AND THIENSVILLE WOULD BE ABANDONED UPON IMPLEMENTATION OF THIS ALTERNATIVE. PRIVATE WASTE TREATMENT FACILITIES WOULD CONTINUE TO BE USED AT THE LIBBY, MC NEILL, AND LIBBY PLANT NEAR THE VILLAGE OF JACKSON UNDER THIS ALTERNATIVE.

[f]AN ASSUMED CONTRACT SERVICE COST OF $240 PER MILLION GALLONS, REPRESENTING THE EXISTING (1970) CONTRACT SERVICE COST, WAS UTILIZED TO DETERMINE THE APPORTIONED TREATMENT COST IN THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM FOR KEWASKUM, JACKSON, WEST BEND, TRI-LAKES, GRAFTON, CEDARBURG, AND THIENSVILLE.

[g]INCLUDES 2,800 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $67,200, 4,800 FEET OF 21-INCH SEWER AT AN ESTIMATED COST OF $144,000, 6,400 FEET OF 24-INCH SEWER AT AN ESTIMATED COST OF $256,000, 5,800 FEET OF 27-INCH SEWER AT AN ESTIMATED COST OF $290,000, 5,600 FEET OF 30-INCH SEWER AT AN ESTIMATED COST OF $302,000, 15,200 FEET OF 36-INCH SEWER AT AN ESTIMATED COST OF $944,000, 2,800 FEET OF 12-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $67,200, 3,600 FEET OF 24-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $172,000, AND PUMPING STATIONS, LIFT STATIONS, AND APPURTENANT FACILITIES AT AN ESTIMATED TOTAL COST OF $45,600, REQUIRED TO CONNECT THE CEDARBURG, GRAFTON, AND THIENSVILLE SEWER SERVICE AREAS TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM.

[h]INCLUDES 8,920 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $272,000, 14,600 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $591,000, 34,000 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $1,276,000, 2,200 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $41,400, 260 FEET OF 10-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $4,800, 26,400 FEET OF 30-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $900,000, 203,000 FEET OF 36-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $7,720,000, AND PUMPING STATIONS, LIFT STATIONS, AND APPURTENANT FACILITIES AT AN ESTIMATED TOTAL COST OF $541,000, REQUIRED TO CONNECT THE KEWASKUM, WEST BEND, TRI-LAKES, AND JACKSON SEWER SERVICE AREAS TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

level of tertiary and advanced waste treatment beyond that now required by the Wisconsin Department of Natural Resources. These greater levels of treatment would be required to meet the stream water use objectives and supporting standards established by that Department. Under this alternative all sewage treatment plants serving a population or population equivalent of 2,500 or less persons would, as in Alternative 1, provide only secondary treatment and post-chlorination for effluent disinfection. Those plants serving a population or population equivalent of 2,500 persons or more, however, would be proposed, on a selective basis, to provide tertiary and/or advanced waste treatment to remove 90 percent of the phosphorus, 92 to 95 percent of the biochemical oxygen demand (BOD), and 30 to 80 percent of the nitrogenous oxygen demand (NOD).

The following treatment process could be utilized to accomplish these levels of tertiary and advanced waste treatment: 1) standard secondary treatment by trickling filters or activated sludge; 2) phosphorus and incidental BOD removal by alum coagulation and precipitation;[28] 3) oxidation of ammonia nitrogen to nitrites and nitrates by aeration; and 4) effluent disinfection by post-chlorination. Sludge disposal from the various treatment steps noted above could be handled by any suitable method that would not result in air, land, or water pollution, such as digestion and landfill.

Two alternative subsystem plan elements were considered in the watershed study for the provision of such tertiary and advanced waste treatment in the upper Milwaukee River watershed. These two subsystem alternatives provide essentially the same level of waste treatment throughout the upper watershed but differ with respect to the system configuration. Alternative 2A envisions the provision of advanced and tertiary waste treatment at two sewage treatment plants; the provision of advanced waste treatment at three sewage treatment plants; the provision of tertiary waste treatment at two sewage treatment plants; the provision of secondary treatment only at three sewage treatment plants; and the abandonment of the Thiensville sewage treatment plant and connection of its sewer service area to the Milwaukee metropolitan sewerage system. Alternative 2B envisions the provision of advanced and tertiary waste treatment at one sewage treatment plant; the provision of advanced waste treatment at five sewage treatment plants; the provision of tertiary waste treatment at two sewage treatment plants; the provision of secondary treatment only at three sewage treatment plants; and the abandonment of the Thiensville sewage treatment plant and connection of its sewer service area to the Milwaukee metropolitan sewerage system. Each of these two subsystem alternative plan elements is described in more detail below. It is important to note once again that the alternative subsystem configurations presented do not represent all of the potential combinations of alternative configurations possible. Those presented, however, do represent the most reasonable alternatives in terms of engineering and economic feasibility and potential for implementation.

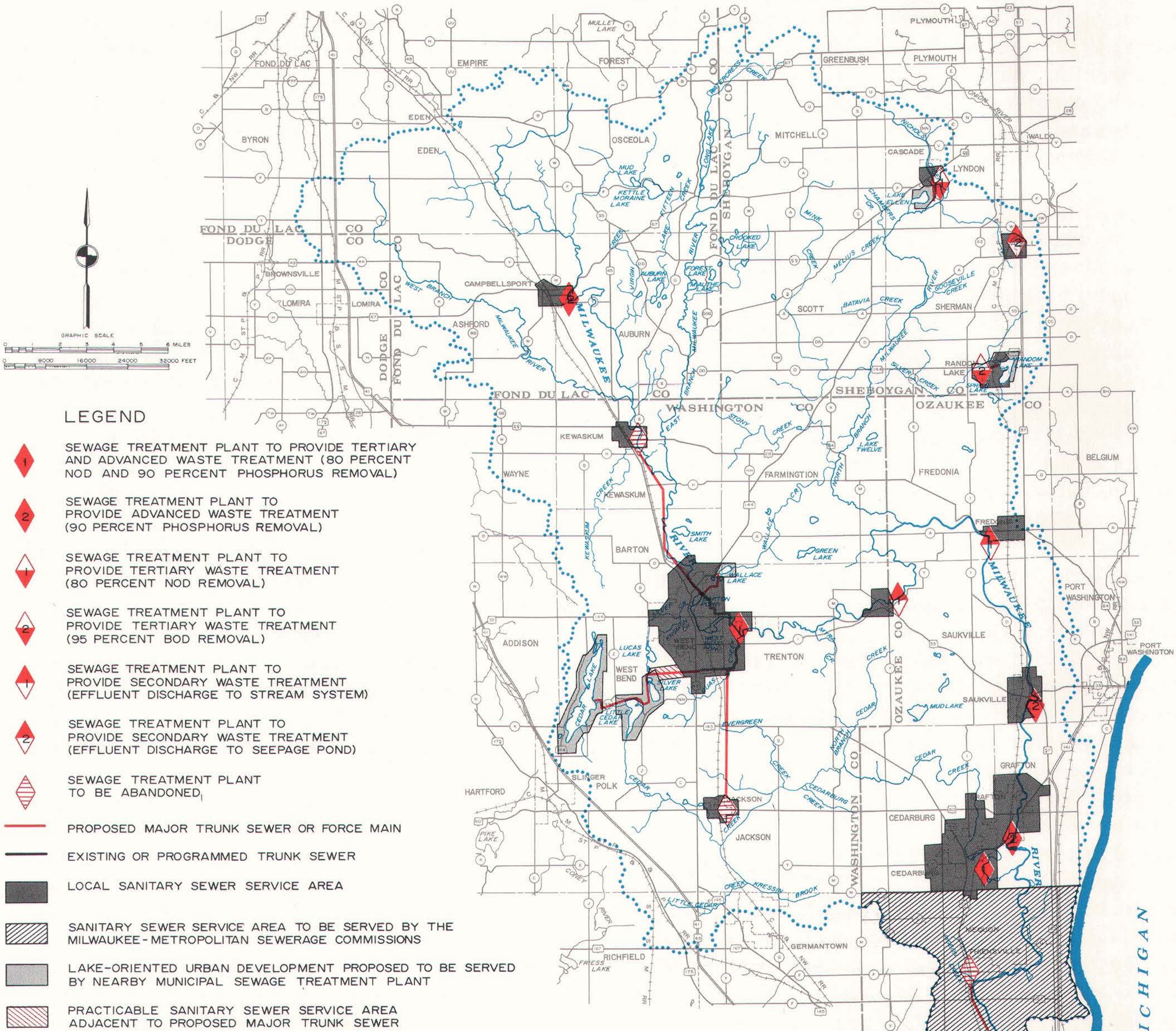
<u>Alternative 2A:</u> Secondary treatment and post-chlorination for disinfection of effluent would, under the first alternative subsystem considered under the second basic alternative stream water quality management plan element for the upper watershed, be provided at the following facilities: Adell, Fredonia, and Newburg (see Map 43). The Adell treatment facility is proposed to continue to discharge partially treated wastes to a seepage pond. Secondary waste treatment, tertiary waste treatment, and post-chlorination for disinfection of effluent would be provided at the following facilities: Cascade and Random Lake. The Cascade treatment facility, which would be a new facility, would also be proposed to treat sewage from the Lake Ellen area, as described in a later section of this chapter. Tertiary waste treatment at the Cascade plant would provide 80 percent NOD removal. The Random Lake sewage treatment facility would also be proposed to treat additional wastes generated in the unincorporated lake development along the north and east shores of Random Lake, as described in a later section of this chapter. Tertiary waste treatment at the Random Lake sewage treatment facility would consist of 95 percent BOD removal. Secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination would be provided at the following facilities: Campbellsport, Grafton, and Saukville. Secondary waste treatment, tertiary waste treatment (80 percent NOD removal), advanced waste treatment (90 percent phosphorus removal), and post-chlorination would be provided at the following facilities: West Bend and Cedarburg.

The West Bend treatment facility would be an areawide facility serving the West Bend, Tri-Lakes, Kewaskum, and Jackson sewer service areas. A system of trunk sewers would be provided to convey wastes from the Tri-Lakes, Kewaskum, and Jackson sewer service areas to the existing West Bend treatment plant site for secondary, tertiary, and advanced waste treatment

[28] *Sodium aluminate may be preferable to alum in certain circumstances due to lower costs or to pH conditions.*

Map 43

UPPER MILWAUKEE RIVER WATERSHED
ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 2A
1990



The second alternative stream water quality management plan element considered for the upper watershed would provide for a level of tertiary and advanced waste treatment beyond that now required by the outstanding water pollution abatement orders of the Wisconsin Department of Natural Resources. The larger sewage treatment facilities in the watershed would be proposed, on a selective basis, to provide tertiary and/or advanced waste treatment to remove 90 percent of the phosphorus, as opposed to 85 percent under the state orders; 92 to 95 percent of the biochemical oxygen demand; and 30 to 80 percent of the nitrogeneous oxygen demand. The first subalternative would provide an areawide treatment facility at West Bend to serve not only the City of West Bend but also the Villages of Kewaskum and Jackson and the Big Cedar Lake, Little Cedar Lake, and Silver Lake sanitary districts. Also, the Thiensville treatment plant would be abandoned and its service area connected to the Milwaukee-metropolitan sewerage system. Implementation of this subalternative would fully meet the adopted water use objectives and standards.

Source: Harza Engineering Company and SEWRPC.

(see Map 43). Sewage from the Thiensville sewer service area would be conveyed by a trunk sewer to the Milwaukee metropolitan sewerage system. The proposed trunk sewer would serve both the Village of Thiensville and a portion of the City of Mequon (see Map 43). In turn, this new trunk sewer would be connected to an existing Mequon trunk sewer paralleling STH 57, which sewer has sufficient capacity to serve both the Village of Thiensville and the City of Mequon.

Implementation of this alternative subsystem plan element for the upper watershed would entail an estimated initial capital cost of $9,679,700, with the total annual cost, including operation and maintenance, over a 50-year period, estimated to be $1,729,900, or about $30 per capita per year. The per capita cost has, for analytical purposes, been based upon an estimated 1980 population of 57,580 to be served by the facilities. The present worth of this subsystem alternative plan element for 50 years at 6 percent interest is $27,276,200. These estimates include the costs of all required plant improvements and additions, including the provision of secondary waste treatment at 10 individual sewage treatment plants in the upper watershed; the provision of tertiary waste treatment (80 percent NOD removal) at the Cascade treatment plant; the provision of tertiary waste treatment (95 percent BOD removal) at the Random Lake treatment plant; the provision of advanced waste treatment (90 percent phosphorus removal) at the Campbellsport, Grafton, and Saukville treatment plants; the provision of tertiary waste treatment (80 percent NOD removal) and advanced waste treatment (90 percent phosphorus removal) at the West Bend and Cedarburg treatment plants; effluent disinfection through post-chlorination at all 10 plants; the provision of trunk sewers to connect the Tri-Lakes, Kewaskum, and Jackson sewer service areas to the West Bend plant; the provision of trunk sewers to connect the Thiensville sewer service area to the Mequon sewerage system and thence to the Milwaukee metropolitan sewerage system; and the estimated contract service cost for treatment at the Jones Island and South Shore sewage treatment plants. The detailed cost estimates for each major element comprising this subsystem alternative are summarized in Table 63.

Alternative 2B: Secondary treatment and post-chlorination for disinfection of effluent would, under the second alternative subsystem considered under the second basic alternative stream water quality management plan element for the upper watershed, be provided at the following facilities: Adell, Fredonia, and Newburg (see Map 44). The Adell treatment facility is proposed to continue to discharge partially treated wastes to a seepage pond. Secondary waste treatment, tertiary waste treatment, and post-chlorination for disinfection of effluent would be provided at the following facilities: Cascade and Random Lake. The Cascade treatment facility, which would be a new facility, would also be proposed to treat sewage from the Lake Ellen area, as described in a later section of this chapter. Tertiary waste treatment at the Cascade sewage treatment facility would provide 80 percent NOD removal. The Random Lake treatment facility would also be proposed to treat additional wastes generated in the unincorporated lake development along the north and east shores of Random Lake, as described in a later section of this chapter. Tertiary waste treatment at the Random Lake sewage treatment facility would provide 95 percent BOD removal. Secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination would be provided at the following facilities: Campbellsport, Cedarburg-Grafton, Jackson, Kewaskum, and Saukville. Secondary waste treatment, tertiary waste treatment (80 percent NOD removal), advanced waste treatment (90 percent phosphorus removal), and post-chlorination would be provided at the West Bend facility.

The West Bend treatment facility would be an areawide facility serving the West Bend and Tri-Lakes sewer service areas. A system of trunk sewers, pumping stations, and force mains would be provided to convey wastes from the Tri-Lakes service area to the existing West Bend treatment plant site for secondary, tertiary, and advanced waste treatment (see Map 44). A two-phase treatment plant configuration would be used to serve the Cedarburg and Grafton areas, with secondary treatment being provided at the existing Cedarburg and Grafton treatment plants and advanced treatment (90 percent phosphorus removal) and post-chlorination being provided at a new treatment facility proposed to be located near the confluence of the Milwaukee River and Cedar Creek. A system of trunk sewers would be provided to convey the partially treated wastes from the existing Cedarburg and Grafton treatment plants to the new advanced waste treatment plant (see Map 44). Sewage from the Thiensville sewer service area would be conveyed by a trunk sewer

Table 63

DETAILED COST ESTIMATES ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 2A

PLAN SUBELEMENT	ESTIMATED COST						
		PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
	CAPITAL (CONSTRUCTION)	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
WEST BEND (7.98 MGD)[b]	$ 2,882,500	$ 3,905,900	$ 6,664,000	$10,569,900	$ 248,000	$ 422,100	$ 670,100
CEDARBURG (2.48 MGD)	1,289,500	1,766,500	2,871,000	4,637,500	112,000	182,200	294,200
GROUP 2[c]							
CAMPBELLSPORT (0.40 MGD)	$ 315,700	$ 414,700	$ 703,000	$ 1,117,700	$ 26,200	$ 44,700	$ 70,900
SAUKVILLE (0.40 MGD)	165,000	266,000	502,000	768,000	16,800	31,800	48,600
GRAFTON (1.90 MGD)	903,000	1,211,000	1,980,000	3,191,000	76,800	125,600	202,400
GROUP 3[d]							
CASCADE (0.26 MGD)	$ 321,300	$ 393,200	$ 449,200	$ 842,400	$ 24,900	$ 28,500	$ 53,400
RANDOM LAKE (0.30 MGD)	329,000	400,400	394,000	794,400	25,400	25,000	50,400
GROUP 4[e]							
NEWBURG (0.12 MGD)	$ 92,000	$ 130,400	$ 214,000	$ 344,400	$ 8,300	$ 13,600	$ 21,900
FREDONIA (0.23 MGD)	137,000	198,700	312,000	510,700	12,600	19,800	32,400
ADELL (0.07 MGD)[f]	--	--	--	--	--	--	--
GROUP 5[g]							
THIENSVILLE (0.61 MGD)[h]	$ --	$ --	$ 789,000	$ 789,000	$ --	$ 50,000	$ 50,000
SUBTOTAL--TREATMENT FACILITIES	$ 6,435,000	$ 8,686,800	$14,878,200	$23,565,000	$ 551,000	$ 943,300	$ 1,494,300
TRUNK SEWERS							
WEST BEND SYSTEM[i]	$ 3,025,200	$ 3,071,300	$ 372,100	$ 3,443,400	$ 194,800	$ 23,600	$ 218,400
THIENSVILLE SYSTEM[j]	219,500	224,800	43,000	267,800	14,300	2,800	17,100
SUBTOTAL--TRUNK SEWERS	$ 3,244,700	$ 3,296,100	$ 415,100	$ 3,711,200	$ 209,100	$ 26,400	$ 235,500
WATERSHED TOTAL	$ 9,679,700	$11,982,900	$15,293,300	$27,276,200	$ 760,100	$ 969,800	$ 1,729,900

[a]EACH SEWAGE TREATMENT PLANT IN GROUP 1 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT (80 PERCENT NOD REMOVAL), ADVANCED WASTE TREATMENT (90 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b]THE WEST BEND SEWAGE TREATMENT FACILITY IS PROPOSED TO SERVE EXISTING AND PROPOSED URBAN DEVELOPMENT IN THE TRI-LAKES SEWER SERVICE AREA, AS WELL AS THE EXISTING AND PROPOSED SEWER SERVICE AREAS OF THE EXISTING KEWASKUM, JACKSON, AND WEST BEND SEWAGE TREATMENT FACILITIES. THE EXISTING SEWAGE TREATMENT FACILITIES AT KEWASKUM AND JACKSON WOULD BE ABANDONED UPON IMPLEMENTATION OF THIS ALTERNATIVE. PRIVATE WASTE TREATMENT FACILITIES WOULD CONTINUE TO BE USED AT THE LIBBY, MC NEILL, AND LIBBY PLANT NEAR THE VILLAGE OF JACKSON UNDER THIS ALTERNATIVE.

[c]EACH SEWAGE TREATMENT PLANT IN GROUP 2 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (90 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[d]EACH SEWAGE TREATMENT PLANT IN GROUP 3 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT, AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT. TERTIARY WASTE TREATMENT AT THE CASCADE PLANT WOULD CONSIST OF 80 PERCENT NOD REMOVAL. TERTIARY WASTE TREATMENT AT THE RANDOM LAKE PLANT WOULD CONSIST OF 95 PERCENT BOD REMOVAL.

[e]EACH SEWAGE TREATMENT PLANT IN GROUP 4 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[f]NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED THAT IT CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[g]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 5 (THIENSVILLE) IS PROPOSED TO BE ABANDONED AND ITS EXISTING AND PROPOSED SEWER SERVICE AREA CONNECTED TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM.

[h]AN ASSUMED CONTRACT SERVICE COST OF $240 PER MILLION GALLONS, REPRESENTING THE EXISTING (1970) CONTRACT SERVICE COST, WAS UTILIZED TO DETERMINE THE APPORTIONED TREATMENT COST IN THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM FOR THIENSVILLE.

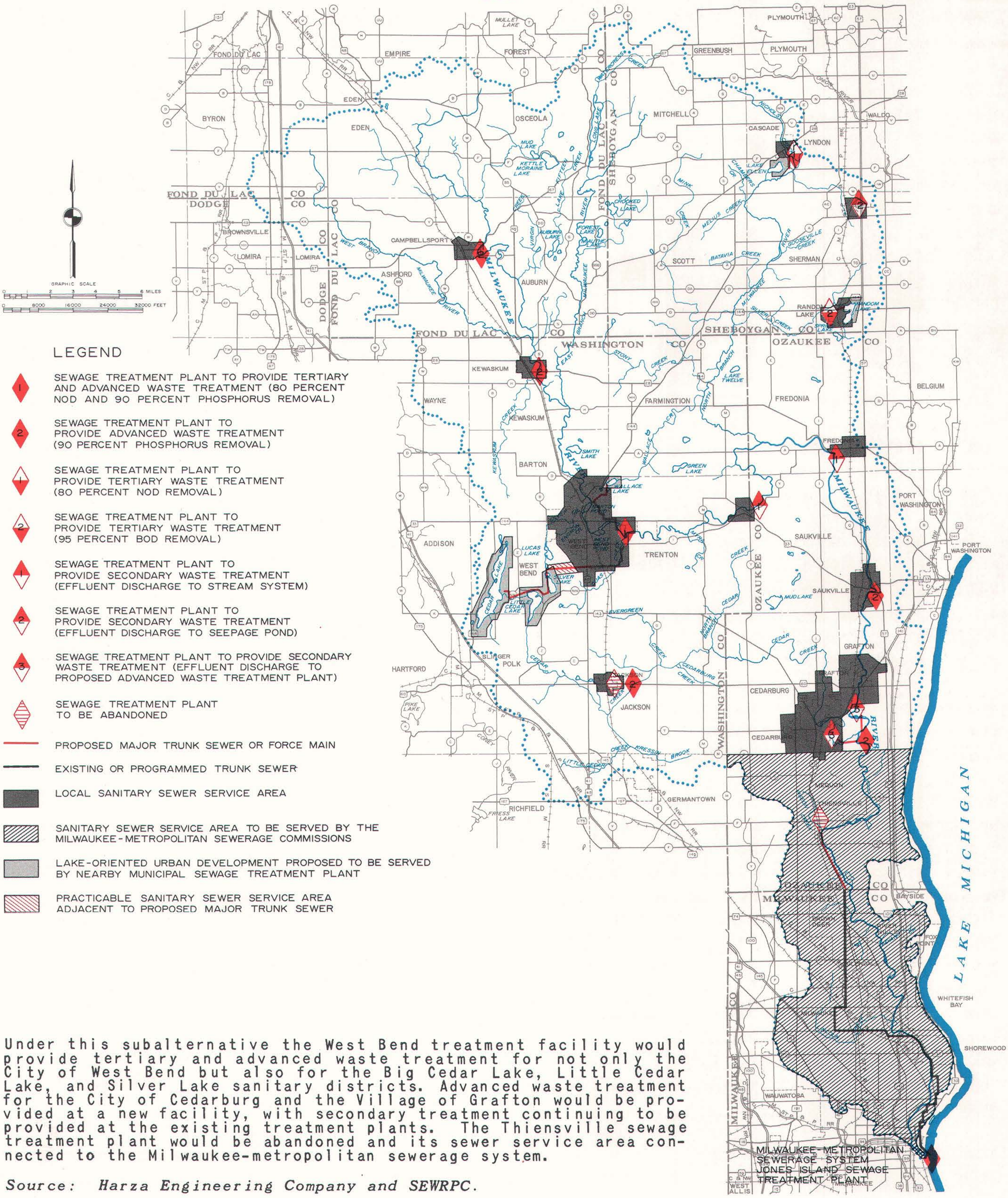
[i]INCLUDES 28,000 FEET OF 8-INCH SEWER AT AN ESTIMATED COST OF $520,000, 8,920 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $272,000, 14,600 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $591,000, 34,000 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $1,276,000, 9,600 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $163,450, 260 FEET OF 10-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $4,750, TWO 1,400 GPM LIFT STATIONS AT 7 FEET OF HEAD AT AN ESTIMATED TOTAL COST OF $100,000, TWO 300 GPM PUMPING STATIONS AT 100 FEET OF HEAD AT AN ESTIMATED TOTAL COST OF $30,000, AND THREE 670 GPM PUMPING STATIONS AT 50 FEET OF HEAD AT AN ESTIMATED TOTAL COST OF $68,000, REQUIRED TO CONNECT THE TRI-LAKES, KEWASKUM, AND JACKSON SEWER SERVICE AREAS TO THE CITY OF WEST BEND SANITARY SEWERAGE SYSTEM.

[j]THE TRUNK SEWER PROPOSED TO CONNECT THE THIENSVILLE SEWER SERVICE AREA TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM IS ALSO PROPOSED TO SERVE A PORTION OF THE CITY OF MEQUON. IT WAS ASSUMED, BASED ON ANTICIPATED FUTURE FLOWS, THAT THIENSVILLE WOULD BEAR ABOUT 54 PERCENT OF THE TOTAL COST OF THE PROPOSED TRUNK SEWER AND LIFT STATION. THIS INCLUDES 600 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $15,100, 10,400 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $277,500, AND ONE 2.26 MGD LIFT STATION AT 7 FEET OF HEAD AT AN ESTIMATED COST OF $42,300.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Map 44

UPPER MILWAUKEE RIVER WATERSHED
ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 2B
1990



Under this subalternative the West Bend treatment facility would provide tertiary and advanced waste treatment for not only the City of West Bend but also for the Big Cedar Lake, Little Cedar Lake, and Silver Lake sanitary districts. Advanced waste treatment for the City of Cedarburg and the Village of Grafton would be provided at a new facility, with secondary treatment continuing to be provided at the existing treatment plants. The Thiensville sewage treatment plant would be abandoned and its sewer service area connected to the Milwaukee-metropolitan sewerage system.

Source: Harza Engineering Company and SEWRPC.

to the Milwaukee metropolitan sewerage system in the same manner as proposed under Alternative 2A (see Map 44). Only the existing Thiensville sewage treatment plant would be abandoned upon implementation of this alternative subsystem plan element.

Implementation of this alternative subsystem plan element for the upper watershed would entail an estimated initial capital cost of $8,310,200, with the total annual cost, including operation and maintenance, over a 50-year period, estimated to be $1,644,000, or about $28 per capita per year. The per capita cost has, for analytical purposes, been based upon an estimated 1980 population of 57,580 to be served by the facility. The present worth of this subsystem alternative plan element for 50 years at 6 percent interest is $25,931,200. These estimates include the costs of all required plant improvements and additions, including the provision of secondary waste treatment at 12 individual sewage treatment plants in the upper watershed; the provision of tertiary waste treatment (80 percent NOD removal) at the Cascade treatment plant; the provision of tertiary waste treatment (95 percent BOD removal) at the Random Lake treatment plant, the provision of advanced waste treatment (90 percent phosphorus removal) at the Campbellsport, Cedarburg-Grafton, Jackson, Kewaskum, and Saukville treatment plants; the provision of tertiary waste treatment (80 percent NOD removal) and advanced waste treatment (90 percent phosphorus removal) at the West Bend treatment plant; effluent disinfection through post-chlorination at 11 plants; the provision of trunk sewers, pumping stations, and force mains to connect the Tri-Lakes sewer service area to the West Bend plant; the provision of trunk sewers to connect the existing and to-be-retained Cedarburg and Grafton secondary treatment plants to the new Cedarburg-Grafton advanced treatment plant; the provision of trunk sewers to connect the Thiensville sewer service area to the Mequon sewerage system and thence to the Milwaukee metropolitan sewerage system; and the estimated contract service cost for treatment at the Jones Island and South Shore sewage treatment plants. The detailed cost estimates for each major element comprising this subsystem alternative are summarized in Table 64.

Concluding Remarks—Alternative 2: The two alternative subsystem plan elements presented above differ only in costs. Their relative ability to meet the state-established water quality objectives and standards are equal. Implementation of either of the two foregoing subalternatives would fully meet the standards, since satisfactory DO concentrations could be expected to occur along the entire main stem of the Milwaukee River, along the North Branch of the Milwaukee River, and along Cedar Creek. Alternative Subsystem Plan Element 2A meets the standards on Cedar Creek through a high level of in-plant treatment, whereas for Alternative Subsystem Plan Element 2B, effluent from the existing Cedarburg sewage treatment plant would be conveyed downstream to a proposed Cedarburg-Grafton advanced treatment plant, which plant would discharge effluent directly to the Milwaukee River.

Alternative 3—Effluent Disposal by Land Irrigation
The third alternative stream water quality management plan element considered for the upper Milwaukee River watershed would eliminate all major waste discharges to the stream system through effluent disposal by land irrigation. Under this alternative secondary waste treatment and disinfection of all wastes would be provided and the resulting effluent used for irrigating nearby agricultural lands. This would provide for ultimate disposal of wastes without polluting the surface waters of the watershed.

The feasibility of using secondary treatment plant effluent for land irrigation has been studied at Pennsylvania State University since 1962. These investigations indicate that effluent could be applied on agricultural land at the rate of at least one inch per week during the growing season without harmful effects. Passage of the effluent through several feet of soil may be expected to remove essentially all of the phosphorus, BOD, coliform bacteria, and perhaps viruses. In addition, the nutrients in the treated waste water are made available for plant growth. The removal of most contaminants in the first few feet of soil would serve to protect the ground and surface waters from pollution, although inorganic minerals, such as nitrates and chlorides, could accumulate in the shallow ground water supply. Utilization of the effluent on agricultural land would result in increased crop yields due to the supplemental irrigation and the additional nutrients being applied to the land.

Under this alternative secondary waste treatment and post-chlorination for disinfection would be provided at the following facilities: Adell, Camp-

Table 64

DETAILED COST ESTIMATES ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 2B

PLAN SUBELEMENT	ESTIMATED COST						
	CAPITAL (CONSTRUCTION)	PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
		CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
WEST BEND (6.10 MGD)[b].........	$ 2,449,000	$ 3,373,000	$ 6,008,000	$ 9,381,000	$ 213,700	$ 380,700	$ 594,400
GROUP 2[c]							
CEDARBURG-GRAFTON (4.38 MGD)[d].................	$ 1,701,500	$ 2,267,500	$ 4,051,000	$ 6,318,500	$ 143,800	$ 257,000	$ 400,800
CAMPBELLSPORT (0.40 MGD)......	315,700	414,700	703,000	1,117,700	26,200	44,700	70,900
KEWASKUM (0.74 MGD)...........	465,000	617,000	927,600	1,544,600	39,100	58,800	97,900
SAUKVILLE (0.40 MGD)..........	165,000	266,000	502,000	768,000	16,800	31,800	48,600
JACKSON (0.50 MGD)............	556,000	685,700	814,000	1,499,700	43,500	51,600	95,100
GROUP 3[e]							
CASCADE (0.26 MGD)............	$ 321,300	$ 393,200	$ 449,200	$ 842,400	$ 24,900	$ 28,500	$ 53,400
RANDOM LAKE (0.30 MGD)........	329,000	400,400	394,000	794,400	25,400	25,000	50,400
GROUP 4[f]							
NEWBURG (0.12 MGD)............	$ 92,000	$ 130,400	$ 214,000	$ 344,400	$ 8,300	$ 13,600	$ 21,900
FREDONIA (0.23 MGD)...........	137,000	198,700	312,000	510,700	12,600	19,800	32,400
ADELL (0.07 MGD)[g].............	--	--	--	--	--	--	--
GROUP 5[h]							
THIENSVILLE (0.61 MGD)[i]........	$ --	$ --	$ 789,000	$ 789,000	$ --	$ 50,000	$ 50,000
SUBTOTAL--TREATMENT FACILITIES..................	$ 6,531,500	$ 8,746,600	$15,163,800	$23,910,400	$ 554,300	$ 961,500	$ 1,515,800
TRUNK SEWERS							
WEST BEND SYSTEM[j].............	$ 977,200	$ 993,000	$ 162,600	$ 1,155,600	$ 62,900	$ 10,300	$ 73,200
THIENSVILLE SYSTEM[k]...........	219,500	224,800	43,000	267,800	14,300	2,800	17,100
CEDARBURG-GRAFTON SYSTEM[l].....	582,000	582,000	15,400	597,400	36,900	1,000	37,900
SUBTOTAL--TRUNK SEWERS......	$ 1,778,700	$ 1,799,800	$ 221,000	$ 2,020,800	$ 114,100	$ 14,100	$ 128,200
WATERSHED TOTAL.................	$ 8,310,200	$10,546,400	$15,384,800	$25,931,200	$ 668,400	$ 975,600	$ 1,644,000

[a]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 1 (WEST BEND) IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT (80 PERCENT NOD REMOVAL), ADVANCED WASTE TREATMENT (90 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b]THE WEST BEND SEWAGE TREATMENT FACILITY IS PROPOSED TO SERVE EXISTING AND PROPOSED URBAN DEVELOPMENT IN THE TRI-LAKES SEWER SERVICE AREA, AS WELL AS THE EXISTING AND PROPOSED SEWER SERVICE AREAS OF THE EXISTING WEST BEND SEWAGE TREATMENT FACILITY.

[c]EACH SEWAGE TREATMENT PLANT IN GROUP 2 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (90 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[d]THE CEDARBURG-GRAFTON AREA IS PROPOSED TO BE SERVED BY A TWO-PHASE TREATMENT FACILITY, WITH SECONDARY WASTE TREATMENT BEING PROVIDED AT THE EXISTING CEDARBURG AND GRAFTON SEWAGE TREATMENT PLANTS AND ADVANCED WASTE TREATMENT (90 PERCENT PHOSPHORUS REMOVAL) AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT BEING PROVIDED AT A SINGLE NEW TREATMENT FACILITY LOCATED NEAR THE CONFLUENCE OF CEDAR CREEK AND THE MILWAUKEE RIVER.

[e]EACH SEWAGE TREATMENT PLANT IN GROUP 3 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT, AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT. TERTIARY WASTE TREATMENT AT THE CASCADE PLANT WOULD CONSIST OF 80 PERCENT NOD REMOVAL. TERTIARY WASTE TREATMENT AT THE RANDOM LAKE PLANT WOULD CONSIST OF 95 PERCENT BOD REMOVAL.

[f]EACH SEWAGE TREATMENT PLANT IN GROUP 4 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[g]NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED THAT IT CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[h]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 5 (THIENSVILLE) IS PROPOSED TO BE ABANDONED AND ITS EXISTING AND PROPOSED SEWER SERVICE AREA CONNECTED TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM.

[i]AN ASSUMED CONTRACT SERVICE COST OF $240 PER MILLION GALLONS, REPRESENTING THE EXISTING (1970) CONTRACT SERVICE COST, WAS UTILIZED TO DETERMINE THE APPORTIONED TREATMENT COST IN THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM FOR THIENSVILLE.

[j]INCLUDES 10,300 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $314,000, 18,740 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $549,000, 2,200 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $41,400, 260 FEET OF 10-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $4,800, AND THREE 670 GPM PUMPING STATIONS AT 50 FEET OF HEAD AT AN ESTIMATED COST OF $68,000, REQUIRED TO CONNECT THE PROPOSED TRI-LAKES SEWER SERVICE AREA TO THE WEST BEND SANITARY SEWERAGE SYSTEM.

[k]THE TRUNK SEWER PROPOSED TO CONNECT THE THIENSVILLE SEWER SERVICE AREA TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM IS ALSO PROPOSED TO SERVE A PORTION OF THE CITY OF MEQUON. IT WAS ASSUMED, BASED ON ANTICIPATED FUTURE FLOWS, THAT THIENSVILLE WOULD BEAR ABOUT 54 PERCENT OF THE TOTAL COST OF THE PROPOSED TRUNK SEWER AND LIFT STATION. THIS INCLUDES 800 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $15,100, 10,400 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $277,500, AND ONE 2.26 MGD LIFT STATION AT 7 FEET OF HEAD AT AN ESTIMATED COST OF $42,300.

[l]INCLUDES 7,800 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $244,000 AND 7,050 FEET OF 21-INCH SEWER AT AN ESTIMATED COST OF $338,000 REQUIRED TO CONNECT THE EXISTING CEDARBURG AND GRAFTON SEWAGE TREATMENT PLANTS TO THE NEW ADVANCED WASTE TREATMENT FACILITY PROPOSED TO BE LOCATED NEAR THE CONFLUENCE OF CEDAR CREEK AND THE MILWAUKEE RIVER.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

bellsport, Cascade, Cedarburg, Fredonia, Grafton, Jackson, Kewaskum, Newburg, Random Lake, Saukville, and West Bend (see Map 45). The Random Lake treatment facility would also be used to treat the wastes generated by the lake-oriented urban development located along the north and east shores of Random Lake, as described in a later section of this chapter. The Cascade treatment facility, which would be a new facility, would also be used to treat sewage from the Lake Ellen area, as described in a later section of this chapter. The West Bend treatment facility would be an areawide facility serving the West Bend and Tri-Lakes tributary drainage area. A system of trunk sewers would be provided to convey wastes from the Tri-Lakes service area to the existing West Bend treatment site (see Map 45). Sewage from the Thiensville tributary drainage area would be conveyed by a trunk sewer to the Milwaukee metropolitan sewerage system in the same manner as proposed under Alternative 2A (see Map 45). Only the existing Thiensville sewage treatment plant would be abandoned under this alternative plan element.

Implementation of this alternative plan element for the upper watershed would entail an estimated initial capital cost of $12,569,100, with total annual costs, including operation and maintenance, over a 50-year period estimated to be $1,835,000, or about $32 per capita per year. This total annual cost includes an offset for estimated benefits derived from increased crop yields due to the irrigation of agricultural lands. The per capita cost has, for analytical purposes, been based upon an estimated 1980 population of 57,580 to be served by the facilities. The present worth of this alternative plan element for 50 years at 6 percent interest is $28,694,700. These estimates include the costs of all required plant improvements and additions, including secondary waste treatment, sludge disposal, and disinfection facilities at all 12 plants in the upper watershed; complete irrigation systems at all 12 plants in the upper watershed, including the necessary pipelines, pumping stations, irrigation distribution systems, and drainage facilities for the agricultural land; land acquisition costs involved in purchasing an estimated 4,490 acres of land at sites nearby the 12 treatment plants; trunk sewers to connect the Thiensville sewer service area to the Mequon sewerage system and thence to the Milwaukee metropolitan sewerage system; and estimated contract service costs for treatment at the South Shore sewage treatment plant.

The agricultural land areas required for this plan element would probably have to be purchased for public use, since it is desirable to have complete control over the irrigation operation to assure that the effluent can be disposed of continuously. The land could also be obtained under a lease arrangement, but this would require assurance that the effluent could be applied whenever necessary for sewage disposal purposes without regard to weather or soil moisture conditions. Detailed cost estimates for each subsystem element comprising this plan alternative are summarized in Table 65.

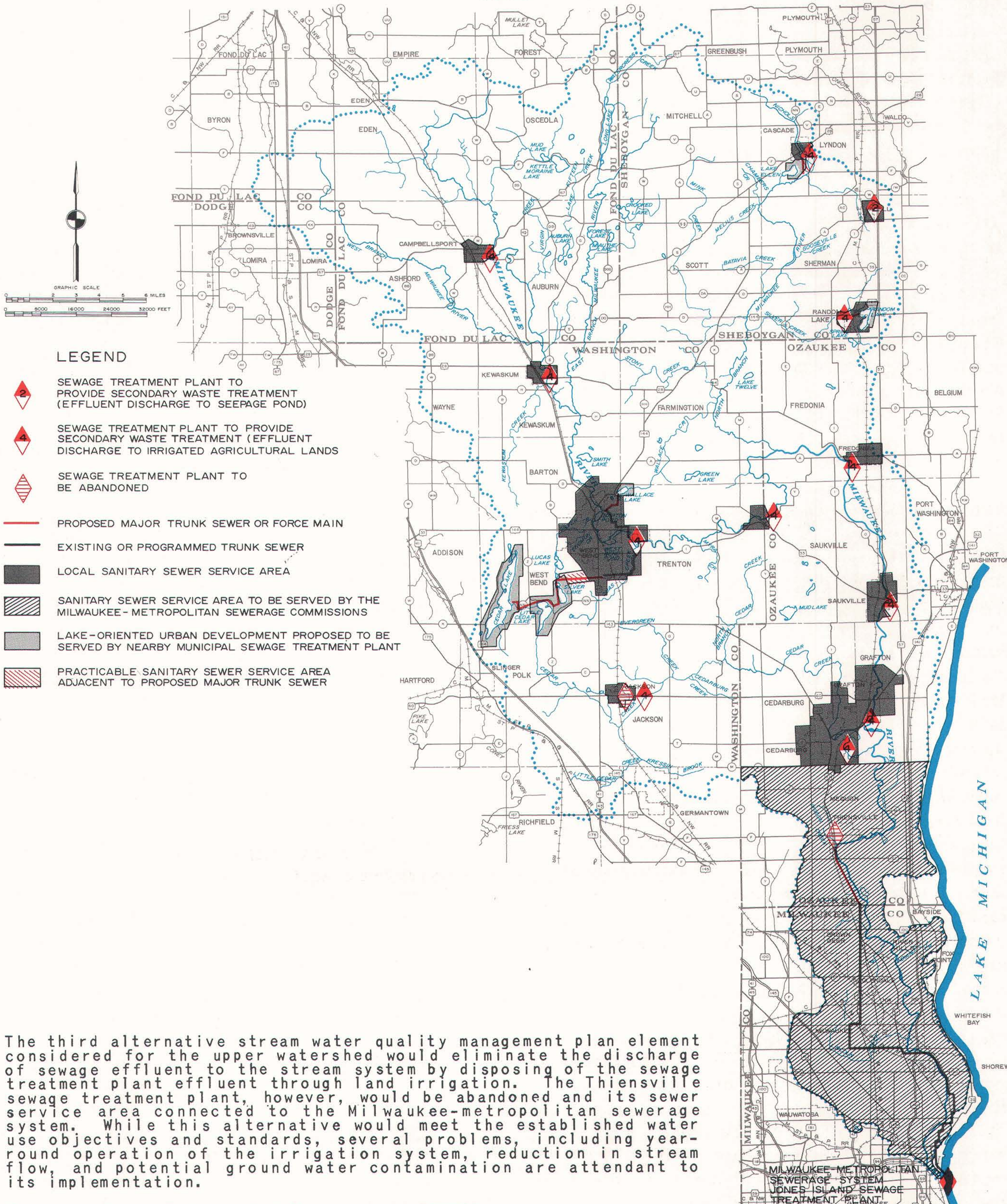
Although this alternative plan element could be expected to provide a high level of stream water quality by elimination of all major waste discharges to streams in the watershed without diversion to Lake Michigan, thus meeting the state-established water quality objectives and standards, it has several serious disadvantages. A significant limitation would be the necessity of purchasing or leasing about 4,490 acres of land near the 12 communities to be served. Other limitations include the problems that would be involved in continuous operation of the irrigation systems, particularly during wet weather and during the winter months. A reduction in streamflow would occur as a result of removing the waste discharges from the stream; and ground water may be contaminated by inorganic materials, such as nitrates and chlorides, which are not completely removed in passage through the soil complex.

Alternative 4—Instream Aeration

The fourth alternative stream water quality management plan element considered for the upper Milwaukee River watershed would combine secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and instream aeration to achieve the state-established water use objectives and standards throughout the stream system. As noted above under the discussion of Alternative 1, the operation of the stream water quality model indicated that, if the state pollution abatement orders were carried out, the DO level of the Milwaukee River and its tributaries could be maintained at or above the recommended standards for the preservation of fish life, except in certain reaches below the Campbellsport, Cascade, Cedarburg, and West Bend sewage treatment plants. Under this fourth alternative plan element, it is proposed that special measures be taken to maintain a DO level of

Map 45

UPPER MILWAUKEE RIVER WATERSHED
ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 3
1990



The third alternative stream water quality management plan element considered for the upper watershed would eliminate the discharge of sewage effluent to the stream system by disposing of the sewage treatment plant effluent through land irrigation. The Thiensville sewage treatment plant, however, would be abandoned and its sewer service area connected to the Milwaukee-metropolitan sewerage system. While this alternative would meet the established water use objectives and standards, several problems, including year-round operation of the irrigation system, reduction in stream flow, and potential ground water contamination are attendant to its implementation.

Source: Harza Engineering Company and SEWRPC.

Table 65

DETAILED COST ESTIMATES ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 3

PLAN SUBELEMENT	ESTIMATED COST						
	CAPITAL (CONSTRUCTION)	PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
		CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
CAMPBELLSPORT (0.40 MGD)......	$ 288,000	$ 380,500	$ 468,000	$ 848,500	$ 24,100	$ 29,700	$ 53,800
KEWASKUM (0.74 MGD)...........	437,600	583,400	579,000	1,162,400	37,000	36,700	73,700
WEST BEND (6.10 MGD)[b].........	1,479,000	2,175,000	2,510,000	4,685,000	137,800	159,200	297,000
NEWBURG (0.12 MGD)............	92,000	130,400	214,000	344,400	8,300	13,600	21,900
CASCADE (0.26 MGD)............	293,000	361,300	402,000	763,300	22,900	25,500	48,400
ADELL (0.07 MGD)[c].............	--	--	--	--	--	--	--
RANDOM LAKE (0.30 MGD)........	320,000	391,400	394,000	785,400	24,800	25,000	49,800
FREDONIA (0.23 MGD)...........	137,000	198,700	312,000	510,700	12,600	19,800	32,400
SAUKVILLE (0.40 MGD)..........	165,000	257,400	427,000	684,400	16,300	27,100	43,400
GRAFTON (1.90 MGD)............	855,700	1,152,700	1,075,000	2,227,700	73,100	68,300	141,400
JACKSON (0.50 MGD)............	476,000	587,000	705,000	1,292,000	37,200	44,700	81,900
CEDARBURG (2.48 MGD)..........	784,100	1,142,500	1,296,000	2,438,500	72,500	82,300	154,800
GROUP 2[d]							
THIENSVILLE[e].................	$ --	$ --	$ 789,000	$ 789,000	$ --	$ 50,000	$ 50,000
SUBTOTAL--TREATMENT FACILITIES.................	$ 5,327,400	$ 7,360,300	$ 9,171,000	$16,531,300	$ 466,600	$ 581,900	$ 1,048,500
TRUNK SEWERS							
WEST BEND SYSTEM[f].............	$ 977,200	$ 993,000	$ 162,600	$ 1,155,600	$ 62,900	$ 10,300	$ 73,200
THIENSVILLE SYSTEM[g]...........	219,500	224,800	43,000	267,800	14,300	2,800	17,100
SUBTOTAL--TRUNK SEWERS......	$ 1,196,700	$ 1,217,800	$ 205,600	$ 1,423,400	$ 77,200	$ 13,100	$ 90,300
SUBTOTAL--TREATMENT FACILITIES AND TRUNK SEWERS.....................	$ 6,524,100	$ 8,578,100	$ 9,376,600	$17,954,700	$ 543,800	$ 595,000	$ 1,138,800
IRRIGATION FACILITIES[h]							
FIELD EQUIPMENT[i]...............	$ 1,840,000	$ 2,270,000	$ 1,400,000	$ 3,670,000	$ 144,000	$ 89,000	$ 233,000
TRANSMISSION LINES TO FIELD[j]......................	1,120,000	1,380,000	35,000	1,415,000	88,000	2,200	90,200
PUMPING STATIONS[k].............	840,000	1,030,000	3,580,000	4,610,000	66,000	228,000	294,000
LAND[l].........................	2,245,000	2,245,000	--	2,245,000	155,000	--	155,000
SUBTOTAL--IRRIGATION FACILITIES.................	$ 6,045,000	$ 6,925,000	$ 5,015,000	$11,940,000	$ 453,000	$ 319,200	$ 772,200
WATERSHED TOTAL.................	$12,569,100	$15,503,100	$14,391,600	$29,894,700	$ 996,800	$ 914,200	$ 1,911,000
LESS BENEFITS INCURRED FROM ANNUAL CROP YIELD[m].......	$ --	$ --	$-1,200,000	$-1,200,000	$ --	$ -76,000	$ -76,000
NET WATERSHED TOTAL.............	$12,569,100	$15,503,100	$13,191,600	$28,694,700	$ 996,800	$ 838,200	$ 1,835,000

[a]EACH SEWAGE TREATMENT PLANT IN GROUP 1 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b]THE WEST BEND SEWAGE TREATMENT FACILITY IS PROPOSED TO SERVE EXISTING AND PROPOSED URBAN DEVELOPMENT IN THE TRI-LAKES SEWER SERVICE AREA, AS WELL AS THE EXISTING AND PROPOSED SEWER SERVICE AREAS OF THE EXISTING WEST BEND SEWAGE TREATMENT PLANT.

[c]NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED TO CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[d]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 2 (THIENSVILLE) IS PROPOSED TO BE ABANDONED AND ITS EXISTING AND PROPOSED SEWER SERVICE AREA CONNECTED TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM.

[e]AN ASSUMED CONTRACT SERVICE COST OF $240 PER MILLION GALLONS, REPRESENTING THE EXISTING (1970) CONTRACT SERVICE COST, WAS UTILIZED TO DETERMINE THE APPORTIONED TREATMENT COST IN THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM FOR THIENSVILLE.

[f]INCLUDES 10,300 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $314,000, 18,740 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $549,000, 2,200 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $41,400, 260 FEET OF 10-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $4,800, AND THREE 670 GPM PUMPING STATIONS AT 50 FEET OF HEAD AT AN ESTIMATED COST OF $68,000, REQUIRED TO CONNECT THE PROPOSED TRI-LAKES SEWER SERVICE AREA TO THE WEST BEND SANITARY SEWERAGE SYSTEM.

[g]THE TRUNK SEWER PROPOSED TO CONNECT THE THIENSVILLE SEWER SERVICE AREA TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM IS ALSO PROPOSED TO SERVE A PORTION OF THE CITY OF MEQUON. IT WAS ASSUMED, BASED UPON ANTICIPATED FUTURE FLOWS, THAT THIENSVILLE WOULD BEAR ABOUT 54 PERCENT OF THE TOTAL COST OF THE PROPOSED TRUNK SEWER AND LIFT STATION. THIS INCLUDES 800 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $15,100, 10,400 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $277,500, AND ONE 2.26 MGD LIFT STATION AT 7 FEET OF HEAD AT AN ESTIMATED COST OF $42,300.

[h]NEARBY AGRICULTURAL LANDS ARE PROPOSED TO BE IRRIGATED BY THE PARTIALLY TREATED EFFLUENTS OF THE CAMPBELLSPORT, KEWASKUM, WEST BEND, NEWBURG, CASCADE, RANDOM LAKE, FREDONIA, SAUKVILLE, GRAFTON, CEDARBURG, AND JACKSON SEWAGE TREATMENT PLANTS.

[i]INCLUDES SUCH ELEMENTS AS SPRAY NOZZLES, DISTRIBUTION PIPING, VALVES, AND OTHER APPURTENANCES.

[j]INCLUDES 12,000 FEET OF 4-INCH CAST IRON TRANSMISSION LINE AT AN ESTIMATED COST OF $96,000, 36,000 FEET OF 6-INCH CAST IRON TRANSMISSION LINE AT AN ESTIMATED COST OF $432,000, 5,000 FEET OF 8-INCH CAST IRON TRANSMISSION LINE AT AN ESTIMATED COST OF $80,000, 16,000 FEET OF 10-INCH CAST IRON TRANSMISSION LINE AT AN ESTIMATED COST OF $320,000, AND 8,000 FEET OF 12-INCH CAST IRON TRANSMISSION LINE AT AN ESTIMATED COST OF $192,000.

[k]IT IS ESTIMATED THAT 11 PUMPING STATIONS WOULD BE REQUIRED, ONE AT EACH TREATMENT FACILITY DISCHARGING TO LAND IRRIGATION.

[l]INCLUDES AN ESTIMATED 4,490 ACRES IN THE UPPER WATERSHED AT AN ESTIMATED AVERAGE ACQUISITION COST OF $500 PER ACRE, INVESTMENT RECOVERED IN 50 YEARS. THE FOLLOWING LAND AREAS WOULD BE REQUIRED AT EACH SEWAGE TREATMENT PLANT, 130 ACRES AT CAMPBELLSPORT, 250 ACRES AT KEWASKUM, 2,040 ACRES AT WEST BEND, 40 ACRES AT NEWBURG, 90 ACRES AT CASCADE, 100 ACRES AT RANDOM LAKE, 80 ACRES AT FREDONIA, 130 ACRES AT SAUKVILLE, 630 ACRES AT GRAFTON, 170 ACRES AT JACKSON, AND 830 ACRES AT CEDARBURG.

[m]ASSUMES A $21.20 PER ACRE ANNUAL BENEFIT ON 3,590 ACRES OF IRRIGATED LAND, WITH 900 ACRES OUT OF CROP PRODUCTION ANNUALLY.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

6 mg/l in the effluent discharge of these four treatment facilities during the low-flow season. This action alone would be adequate to assure the required DO levels in the Milwaukee River main stem downstream from the Campbellsport sewage treatment plant. Additional instream aeration, however, would be required in the nine-mile river reach from the West Bend treatment plant to the Newburg Weir; in the 0.3-mile reach of Cedar Creek from the Cedarburg treatment plant to the Hamilton Dam; and in the one-mile reach of the North Branch of the Milwaukee River downstream from the Cascade treatment plant.

Under this alternative secondary waste treatment and post-chlorination for disinfection of effluent would be provided at the following facilities: Adell, Cascade, Fredonia, and Newburg (see Map 46). The Adell treatment facility is proposed to continue to discharge partially treated wastes to a seepage pond. The Cascade treatment facility, which would be a new facility, would also be proposed to treat sewage from the Lake Ellen area, as described in a later section of this chapter. Secondary waste treatment, tertiary waste treatment (95 percent BOD removal), and post-chlorination for disinfection would be provided at the Random Lake treatment facility, which facility would also be proposed to treat additional wastes generated in the unincorporated lake development along the north and east shores of Random Lake, as described in a later section of this chapter. Secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination for disinfection would be provided at the following facilities: Campbellsport, Cedarburg, Grafton, Jackson, Kewaskum, Saukville, and West Bend.

The West Bend treatment facility would be an areawide facility serving the West Bend and Tri-Lakes sewer service areas. A system of trunk sewers would be provided to convey wastes from the Tri-Lakes service area to the existing West Bend treatment site (see Map 46). Sewage from the Thiensville tributary drainage area would be conveyed by a trunk sewer to the Milwaukee metropolitan sewerage system in the same manner as proposed under Alternative 2A (see Map 46). Only the existing sewage treatment plant at Thiensville would be abandoned upon implementation of this alternative plan element.

As noted above, instream aeration would be provided below the Cascade, Cedarburg, and West Bend sewage treatment plants. The quantity of air required for aeration to maintain the required DO standards with design low-flow conditions was analyzed for these three stream reaches. It was concluded that instream aeration units, located along these reaches, as shown on Map 46, would provide the required level of aeration. These units would have a combined capacity of about 80 horsepower when located at two sites along the Milwaukee River and in the Newburg impoundment between the West Bend treatment plant and Newburg; a capacity of about 75 horsepower when located in the Hamilton impoundment on Cedar Creek downstream from the Cedarburg treatment plant; and a capacity of about 10 horsepower at a site on the North Branch of the Milwaukee River below the Cascade treatment plant. As stated above, the effluent of these three treatment plants, together with the Campbellsport sewage treatment plant, would also be aerated to a level equal to or more than 6 mg/l dissolved oxygen before discharge to the receiving stream. These levels of treatment would be required to prevent the municipal waste organic discharges from reducing the dissolved oxygen content of the stream below 5.0 mg/l, the amount required for the preservation of fish life. Under this alternative plan element, instream aeration facilities would be necessary to maintain dissolved oxygen above 5.0 mg/l, in lieu of the operation of the Cascade, Cedarburg, and West Bend sewage treatment plants to achieve a high degree of nitrification, or in lieu of the provision of facilities for ammonia nitrogen removal to reduce the nitrogenous oxygen demand of the effluent. The provision of instream aeration in Cedar Creek below the Cedarburg treatment plant would eliminate the need to convey and discharge the effluent from the Cedarburg plant to the Milwaukee River, which river has higher flows and a greater waste assimilative capacity.

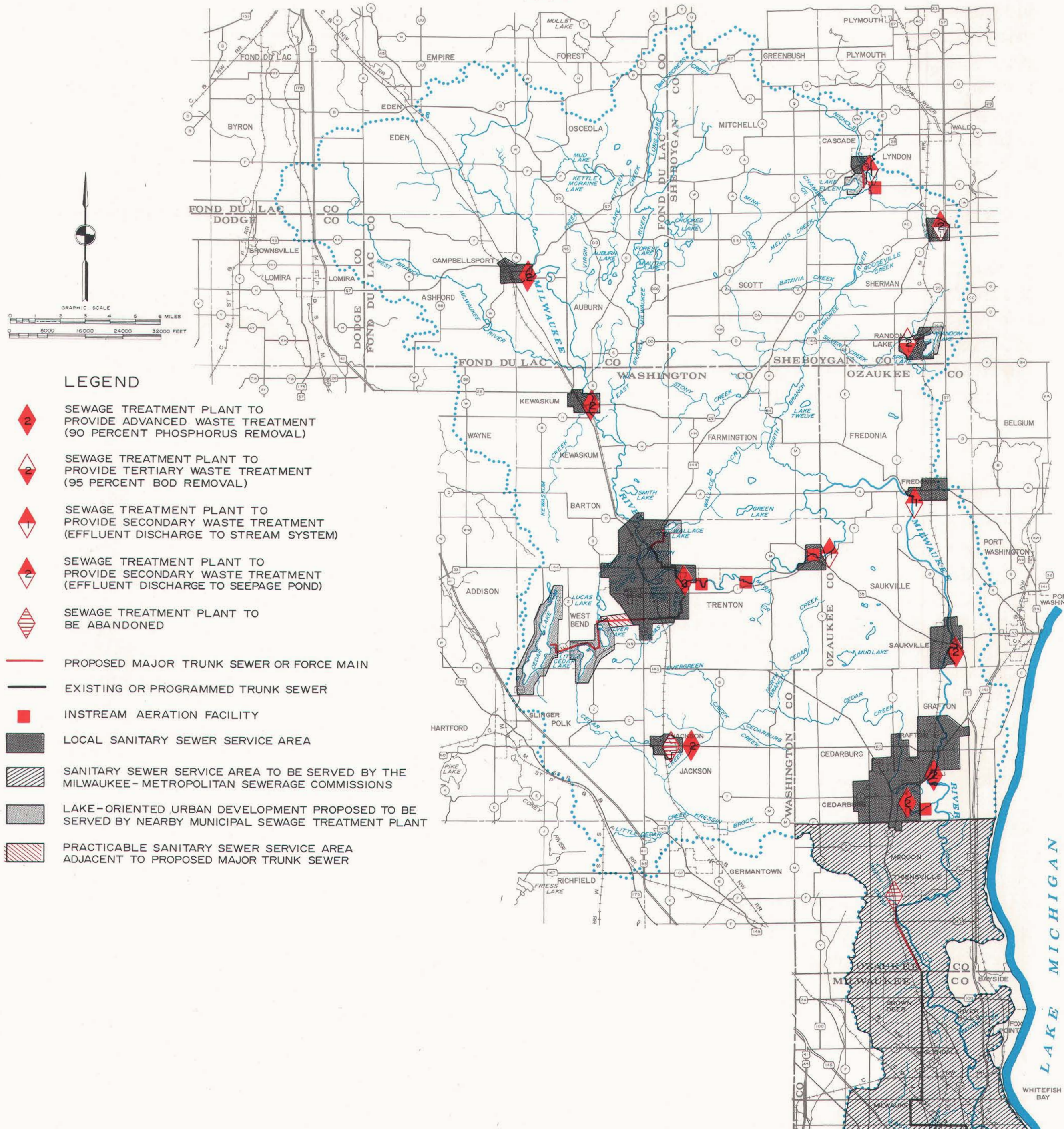
The feasibility of using instream aeration to maintain dissolved oxygen levels in streams where secondary treatment of waste-water flows is not sufficient to meet the established water quality standards has been studied on a 12-mile reach of the Passaic River in New Jersey.[29] These investigations indicate that mechanical aerators and aeration diffusers made from commercial equipment can be installed and operated at reasonable costs. The equipment used in the Passaic

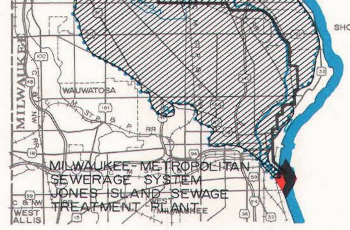
---

[29] *William Whipple, Jr., Joseph V. Hunter, Burton Davidson, Frank Dittman, and Shaw Yu, Instream Aeration of Polluted Rivers, Water Resources Institute, Rutgers University, New Brunswick, New Jersey, August 1969.*

Map 46

UPPER MILWAUKEE RIVER WATERSHED
ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 4
1990





The fourth alternative stream water quality management plan element considered for the upper watershed would combine tertiary and advanced waste treatment with the provision of instream aeration at selected locations along the stream system in order to maintain desired oxygen levels in the stream water and thereby meet the water use objectives and standards. Under this alternative instream aeration would be provided downstream from the West Bend, Cedarburg, and Cascade sewage treatment plants.

Source: Harza Engineering Company and SEWRPC.

River consisted of two basic types of aeration devices, including, at one location, a 75 horsepower surface mechanical aerator, and at a second location, diffusion aerators using coarse double Link Belt diffusers installed in manifolds laid on the river bottom. The aerators were installed in waters 8 to 10 feet deep. Since water depth was not sufficient to accommodate the equipment, basins were formed in the riverbed. Conditions in the critical reach of the Milwaukee River below the West Bend sewage treatment plant were considered to be sufficiently similar to conditions on the Passaic River so that the experience gained in working with the latter stream would be generally applicable.

A third type of air-water mixing device, consisting of 18-inch polyvinylchloride (PVC), or polyethelene, tubes each with a fixed helical member inside, was also considered for use to maintain DO levels in the Milwaukee River. The tubes would be anchored to the stream bed, and compressed air would be delivered to the tubes from a submerged pipe. The air rising inside the tubes would cause water to flow up the tube where the helix would impart a rotary effect to ensure thorough mixing of air and water and maximum transfer of oxygen.

Costs presented under this alternative stream water quality plan element were based on the installation of three 10-horsepower mechanical aerators at intervals required to raise the instream DO level from about 5 mg/l to 6 mg/l; and for installation of diffuser aerators to deliver the required weight of oxygen in the Newburg and Hamilton impoundments. Although diffuser aerators would be more costly than mechanical aerators, they were proposed for the impoundments, because they would not detract from the aesthetic value of the impoundments and because they would present no moving parts which could be hazardous to swimmers or form barriers to the passage of boats, as would mechanical aerators.

Implementation of this alternative plan element for the upper watershed would entail an estimated initial capital cost of $7,018,400, with total annual costs, including operation and maintenance, over a 50-year period, estimated to be $1,577,000, or about $27 per capita per year. The per capita cost has, for analytical purposes, been based upon an estimated 1980 population of 57,580 to be served by the facilities. The present worth of this alternative plan element for 50 years at 6 percent interest is $24,859,100. These estimates include the costs of all required plant improvements and additions, including the provision of secondary waste treatment at all 12 plants in the upper watershed; the provision of tertiary waste treatment (95 percent BOD removal) at the Random Lake plant; the provision of advanced waste treatment (90 percent phosphorus removal) at the Campbellsport, Cedarburg, Grafton, Jackson, Kewaskum, and West Bend plants; effluent disinfection through post-chlorination at all 12 plants in the upper watershed; the provision of trunk sewers to connect the Tri-Lakes tributary drainage area to the West Bend sewage treatment plant; the provision of trunk sewers to connect the Thiensville tributary drainage area to the Mequon sewerage system and thence to the Milwaukee metropolitan sewerage system; the estimated contract service cost for treatment at the Jones Island and South Shore sewage treatment plants; and complete aeration facilities, as described above. The detailed cost estimates for each major element comprising this alternative plan element are summarized in Table 66.

Alternative 5—Low-Flow Augmentation

The fifth alternative stream water quality management plan element considered for the upper Milwaukee River watershed would combine secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and low-flow augmentation to achieve the state-established water use objectives and standards throughout the Milwaukee River stream system. As noted above, the operation of the stream water quality model indicated that, if the presently outstanding state pollution abatement orders were carried out, the DO level of the Milwaukee River and its tributaries would not fall below the recommended standards except in certain reaches below the Campbellsport, Cascade, Cedarburg, and West Bend sewage treatment plants. Under this fifth alternative plan element, it is proposed that special measures be taken to maintain a DO level of 6 mg/l in the effluent discharge of these four treatment facilities during the low-flow season. This action alone would be adequate to assure the maintenance of the required DO levels in the Milwaukee River main stem downstream from the Campbellsport sewage treatment plant. Low-flow augmentation would be provided in the nine-mile river reach from the West Bend treatment plant to the Newburg Weir, in the 0.3-mile reach of Cedar Creek from the Cedarburg treatment plant to the Hamilton Dam, and in the one-mile reach of the North Branch of the Milwaukee River downstream from the Cascade treatment plant.

Table 66

DETAILED COST ESTIMATES ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 4

PLAN SUBELEMENT	ESTIMATED COST						
		PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
	CAPITAL (CONSTRUCTION)	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
CAMPBELLSPORT (0.40 MGD)	$ 315,700	$ 414,700	$ 703,000	$ 1,117,700	$ 26,200	$ 44,700	$ 70,900
KEWASKUM (0.74 MGD)	465,000	617,000	927,600	1,544,600	39,100	58,800	97,900
WEST BEND (6.10 MGD)[b]	1,574,000	2,294,000	5,388,000	7,682,000	145,500	342,000	487,500
JACKSON (0.50 MGD)	556,000	685,700	814,000	1,499,700	43,500	51,600	95,100
SAUKVILLE (0.40 MGD)	165,000	266,000	502,000	768,000	16,800	31,800	48,600
GRAFTON (1.90 MGD)	903,000	1,211,000	1,980,000	3,191,000	76,800	125,600	202,400
CEDARBURG (2.48 MGD)	839,500	1,211,500	2,545,000	3,756,500	76,800	161,500	238,300
GROUP 2[c]							
RANDOM LAKE (0.30 MGD)	$ 329,000	$ 400,400	$ 394,000	$ 794,400	$ 25,400	$ 25,000	$ 50,400
GROUP 3[d]							
NEWBURG (0.12 MGD)	$ 92,000	$ 130,400	$ 214,000	$ 344,400	$ 8,300	$ 13,600	$ 21,900
FREDONIA (0.23 MGD)	137,000	198,700	312,000	510,700	12,600	19,800	32,400
ADELL (0.07 MGD)[e]	--	--	--	--	--	--	--
CASCADE (0.26 MGD)	293,000	361,300	402,000	763,300	22,900	25,500	48,400
GROUP 4[f]							
THIENSVILLE (0.61 MGD)[g]	$ --	$ --	$ 789,000	$ 789,000	$ --	$ 50,000	$ 50,000
SUBTOTAL--TREATMENT FACILITIES	$ 5,669,200	$ 7,790,700	$14,970,600	$22,761,300	$ 493,900	$ 949,900	$ 1,443,800
TRUNK SEWERS							
WEST BEND SYSTEM[h]	$ 977,200	$ 993,000	$ 162,600	$ 1,155,600	$ 62,900	$ 10,300	$ 73,200
THIENSVILLE SYSTEM[i]	219,500	224,800	43,000	267,800	14,300	2,800	17,100
SUBTOTAL--TRUNK SEWERS	$ 1,196,700	$ 1,217,800	$ 205,600	$ 1,423,400	$ 77,200	$ 13,100	$ 90,300
SUBTOTAL--TREATMENT FACILITIES AND TRUNK SEWERS	$ 6,865,900	$ 9,008,500	$15,176,200	$24,184,700	$ 571,100	$ 963,000	$ 1,534,100
INSTREAM AERATION FACILITIES[j]							
BELOW CASCADE	$ 13,000	$ 21,600	$ 26,800	$ 48,400	$ 1,400	$ 1,700	$ 3,100
WEST BEND TO NEWBURG	83,000	138,000	224,000	362,000	8,800	14,200	23,000
CEDARBURG TO MILWAUKEE RIVER	56,500	94,000	170,000	264,000	6,000	10,800	16,800
SUBTOTAL AERATION FACILITIES	$ 152,500	$ 253,600	$ 420,800	$ 674,400	$ 16,200	$ 26,700	$ 42,900
WATERSHED TOTAL	$ 7,018,400	$ 9,262,100	$15,597,000	$24,859,100	$ 587,300	$ 989,700	$ 1,577,000

[a]EACH SEWAGE TREATMENT PLANT IN GROUP 1 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (90 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b]THE WEST BEND SEWAGE TREATMENT FACILITY IS PROPOSED TO SERVE EXISTING AND PROPOSED URBAN DEVELOPMENT IN THE TRI-LAKES SEWER SERVICE AREA, AS WELL AS THE EXISTING AND PROPOSED SEWER SERVICE AREAS OF THE EXISTING WEST BEND SEWAGE TREATMENT PLANT.

[c]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 2 (RANDOM LAKE) IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT (95 PERCENT BOD REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[d]EACH SEWAGE TREATMENT PLANT IN GROUP 3 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[e]NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED THAT IT CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[f]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 4 (THIENSVILLE) IS PROPOSED TO BE ABANDONED AND ITS EXISTING AND PROPOSED SEWER SERVICE AREA CONNECTED TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM.

[g]AN ASSUMED CONTRACT SERVICE COST OF $240 PER MILLION GALLONS, REPRESENTING THE EXISTING (1970) CONTRACT SERVICE COST, WAS UTILIZED TO DETERMINE THE APPORTIONED TREATMENT COST IN THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM FOR THIENSVILLE.

[h]INCLUDES 10,300 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $314,000, 18,740 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $549,000, 2,200 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $41,400, 260 FEET OF 10-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $4,800, AND THREE 670 GPM PUMPING STATIONS AT 50 FEET OF HEAD AT AN ESTIMATED COST OF $68,000, REQUIRED TO CONNECT THE PROPOSED TRI-LAKES SEWER SERVICE AREA TO THE WEST BEND SANITARY SEWERAGE SYSTEM.

[i]THE TRUNK SEWER PROPOSED TO CONNECT THE THIENSVILLE SEWER SERVICE AREA TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM IS ALSO PROPOSED TO SERVE A PORTION OF THE CITY OF MEQUON. IT WAS ASSUMED, BASED ON ANTICIPATED FUTURE FLOWS, THAT THIENSVILLE WOULD BEAR ABOUT 54 PERCENT OF THE TOTAL COST OF THE PROPOSED TRUNK SEWER AND LIFT STATION. THIS INCLUDES 800 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $15,100, 10,400 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $277,500, AND ONE 2.26 MGD LIFT STATION AT 7 FEET OF HEAD AT AN ESTIMATED COST OF $42,300.

[j]INCLUDES TWO 10 HORSEPOWER MECHANICAL AERATORS INSTALLED IN THE MILWAUKEE RIVER AT DISTANCES OF 0.7 AND 1.8 MILES DOWNSTREAM OF THE WEST BEND SEWAGE TREATMENT PLANT, ONE 10 HORSEPOWER MECHANICAL AERATOR INSTALLED IN THE NORTH BRANCH OF THE MILWAUKEE RIVER AT A DISTANCE OF 0.5 MILE DOWNSTREAM OF THE PROPOSED CASCADE SEWAGE TREATMENT PLANT, FOUR DIFFUSER AERATOR UNITS INSTALLED IN THE NEWBURG POND, AND FOUR DIFFUSER AERATOR UNITS INSTALLED IN THE HAMILTON POND, TOGETHER WITH NECESSARY STANDBY EQUIPMENT.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Under this alternative secondary waste treatment and post-chlorination for disinfection of effluent would be provided at the following facilities: Adell, Cascade, Fredonia, and Newburg (see Map 47). The Adell treatment facility is proposed to continue to discharge partially treated wastes to a seepage pond. The Cascade treatment facility, which would be a new facility, would also be proposed to treat sewage from the Lake Ellen area, as described in a later section of this chapter. Secondary waste treatment, tertiary waste treatment (95 percent BOD removal), and post-chlorination for disinfection would be provided at the Random Lake treatment facility, which facility would also be proposed to treat additional wastes generated in the unincorporated lake development along the north and east shores of Random Lake, as described in a later section of this chapter. Secondary treatment, advanced treatment (90 percent phosphorus removal), and post-chlorination for disinfection would be provided at the following facilities: Campbellsport, Cedarburg, Grafton, Jackson, Kewaskum, Saukville, and West Bend.

The West Bend treatment facility would be an areawide facility serving the West Bend and Tri-Lakes tributary drainage areas. A system of trunk sewers would be provided to convey wastes from the Tri-Lakes sewer service area to the existing West Bend treatment plant site (see Map 47). Sewage from the Thiensville sewer service area would be conveyed by a trunk sewer to the Milwaukee metropolitan sewerage system in the same manner as proposed under Alternative 2A (see Map 47). Only the existing sewage treatment plant at Thiensville would be abandoned upon implementation under this alternative plan element.

As noted above, low-flow augmentation would be provided below the Cascade, Cedarburg, and West Bend sewage treatment plants. The amount of water needed for flow augmentation purposes in order to maintain suitable water quality levels while providing secondary and advanced (90 percent phosphorus removal) waste treatment would be dependent upon the amount of waste discharged and the natural flow in the stream. For 1990 forecast waste loadings, it would be necessary to have a capacity sufficient to supply, during drought conditions,[30] 35 cfs of water for the Milwaukee River above West Bend and between West Bend and the Newburg Weir; 0.5 cfs of water for the North Branch of the Milwaukee River at or above Cascade; and 30 cfs of water for Cedar Creek at or above the Hamilton Pond.

The flow augmentation requirements for the Milwaukee River main stem downstream from the West Bend treatment plant are dictated by the conditions in the Newburg Pond. To maintain the the required DO level in the Milwaukee River above the Newburg backwater would require only about 10 cfs of flow augmentation, whereas the longer detention time in the impoundment generates a high demand for oxygen, thereby creating the need for 35 cfs of flow augmentation. Similar conditions prevail in the Hamilton Pond on Cedar Creek. Even with secondary and advanced (90 percent phosphorus removal) waste treatment, due to the long detention time, the pond could be expected to become anerobic without flow augmentation. A very high level of flow augmentation would be required to prevent the development of anerobic conditions and to maintain required DO levels in Cedar Creek.

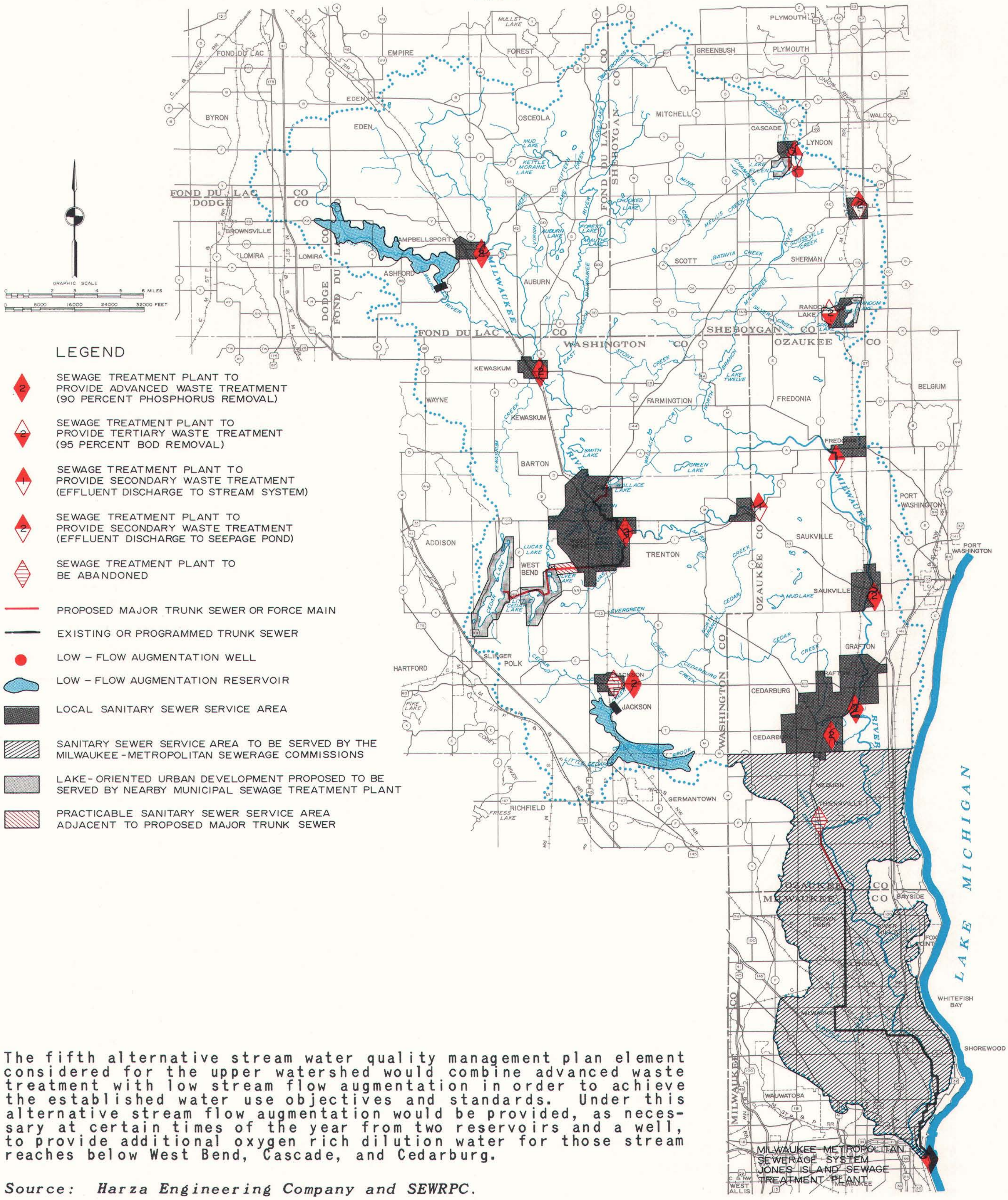
Normally a need for flow augmentation in the Milwaukee River would exist only during the months of July and August. The average augmentation requirement during these two months in an average year would be about 13 cfs, or about 1,600 acre-feet. In drought years flow augmentation might be required during the months of June through September. The average augmentation flow for these four months would be 18 cfs, or about 4,400 acre-feet. On Cedar Creek the flow augmentation requirement during an average flow year would be about 17 cfs, or 4,000 acre-feet for a continuous four-month period between June and September. In drought years the augmentation requirement on Cedar Creek would be about 25 cfs for a continuous six-month period and would total about 9,000 acre-feet. On the North Branch of the Milwaukee River, the augmentation requirements would be about 0.5 cfs for a four-month period, or about 120 acre-feet.

Several potential sources for providing the required flow augmentation water were considered, including lakes, ponds, reservoirs, and ground water supplies. Three reservoir sites identified as potential alternative flood control plan elements in Chapter IV of this volume would be suitable for providing augmentation water to the Milwaukee River between West Bend and Newburg. These sites are the Campbellsport North site, the Smith Lake site, and the Elmore site (see Map 10

[30] *Design drought conditions were defined as the lowest natural flows which occurred for seven consecutive days during the period 1960-1969, adjusted for effluent discharges, projected for the year 1990 upstream from sewage treatment plants. These flows are 10.1 cfs at West Bend, 4.8 cfs at Cedarburg, and 0.4 cfs at Cascade.*

Map 47

UPPER MILWAUKEE RIVER WATERSHED
ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 5
1990



The fifth alternative stream water quality management plan element considered for the upper watershed would combine advanced waste treatment with low stream flow augmentation in order to achieve the established water use objectives and standards. Under this alternative stream flow augmentation would be provided, as necessary at certain times of the year from two reservoirs and a well, to provide additional oxygen rich dilution water for those stream reaches below West Bend, Cascade, and Cedarburg.

Source: Harza Engineering Company and SEWRPC.

and Table 14). Two additional reservoir sites on Cedar Creek, also identified in the flood control alternative plan element chapter, would be suitable for flow augmentation use on Cedar Creek; namely, the Horns Corners Reservoir and the Jackson Reservoir (see Map 10). There were no identified reservoir sites above Cascade on the North Branch of the Milwaukee River. Any one of these reservoirs could provide adequate augmentation flows for the stream reaches indicated. If these reservoirs were constructed and operated only for the single purpose of flow augmentation, they would not require development to their full topographic potential, as identified in Chapter IV of this volume.

The use of ground water from the glacial drift (sand and gravel aquifer) would be the most desirable alternative for augmentation on the North Branch of the Milwaukee River, since only one small well, together with an aeration device at the outlet, would be required. Wells, however, would not be attractive for augmentation flow on the Milwaukee River main stem between West Bend and Newburg and on Cedar Creek below the Cedarburg treatment plant, since about sixty-five 1 cfs wells or their equivalent capacity would be required for developing the glacial drift (sand and gravel) aquifer and since the potential water yield in this aquifer along the Upper Milwaukee River is uncertain. The location of wells in deeper limestone and sandstone aquifers in the Cedar Creek and West Bend areas of the upper watershed would not only increase pumping costs but could create interference with existing wells. The use of Lake Michigan water for flow augmentation is similarly unattractive, since it would require long conveyance lines and substantial pumping facilities.

Also, as noted in Chapter V of Volume 1 of this report, existing ponds and lakes have some potential for emergency flow augmentation. The requirement for dependable, large releases from storage could not, however, be met from these existing sources.

Implementation of this alternative plan element for the upper watershed would entail an estimated initial capital cost of $12,378,900, with total annual costs, including operation and maintenance, over a 50-year period, estimated to be $1,933,500 or about $34 per capita per year. The per capita cost has, for analysis purposes, been based on an estimated 1980 population of 57,580 to be served by the facilities. The present worth of this alternative plan element for 50 years at 6 percent interest is $30,542,000. These estimates include the costs of all required plant improvements and additions, including the provision of secondary waste treatment at all 12 plants in the upper watershed; the provision of tertiary waste treatment (95 percent BOD removal) at the Random Lake plant; the provision of advanced waste treatment (90 percent phosphorus removal) at the Campbellsport, Cedarburg, Grafton, Jackson, Kewaskum, Saukville, and West Bend plants; effluent disinfection through post-chlorination at all 12 plants in the upper watershed; the provision of trunk sewers to connect the Tri-Lakes sewer service area to the West Bend sewage treatment plant; the provision of trunk sewers to connect the Thiensville sewer service area to the Mequon sewerage system and thence to the Milwaukee metropolitan sewerage system; the estimated contract service cost for treatment at the Jones Island and South Shore sewage treatment plants; a 0.5 cfs well near Cascade to provide flow augmentation below the Cascade sewage treatment plant; a dam on the West Branch of the Milwaukee River near Elmore, Section 23, Town 13 North, Range 18 East, which would impound an 1,100 acre surface area lake with a conservation pool elevation of 1,008 msl, and appurtenant augmentation facilities to provide for flow augmentation of the Milwaukee River below the West Bend sewage treatment plant; and a dam on Cedar Creek near Jackson, Section 20, Town 10 North, Range 20 East, which would impound a 2,100 acre surface area lake with a conservation pool elevation of 854 msl, and appurtenant augmentation facilities to provide for flow augmentation on Cedar Creek below the Cedarburg sewage treatment plant. The detailed cost estimates for each major element comprising this alternative plan element are summarized in Table 67.

Concluding Remarks—Alternative Stream Water Quality Management Plan Elements—Upper Watershed

Five alternative stream water quality management plan elements were investigated for abatement of the stream pollution caused by the 12 municipal sewage treatment plants located in the upper Milwaukee River watershed. The first alternative plan element would essentially provide for waste treatment levels as currently required by the Wisconsin Department of Natural Resources. This would include secondary waste treatment, advanced waste treatment (85 percent phosphorus removal) at the larger treatment facilities, and

Table 67

DETAILED COST ESTIMATES ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT 5

PLAN SUBELEMENT	ESTIMATED COST						
		PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
	CAPITAL (CONSTRUCTION)	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
CAMPBELLSPORT (0.40 MGD)......	$ 315,700	$ 414,700	$ 703,000	$ 1,117,700	$ 26,200	$ 44,700	$ 70,900
KEWASKUM (0.74 MGD)...........	465,000	617,000	927,600	1,544,600	39,100	58,800	97,900
WEST BEND (6.10 MGD)[b]........	1,574,000	2,294,000	5,388,000	7,682,000	145,500	342,000	487,500
JACKSON (0.50 MGD)............	556,000	685,700	814,000	1,499,700	43,500	51,600	95,100
SAUKVILLE (0.40 MGD)..........	165,000	266,000	502,000	768,000	16,800	31,800	48,600
GRAFTON (1.90 MGD)............	903,000	1,211,000	1,980,000	3,191,000	76,800	125,600	202,400
CEDARBURG (2.48 MGD)..........	839,500	1,211,500	2,545,000	3,756,500	76,800	161,500	238,300
GROUP 2[c]							
RANDOM LAKE (0.30 MGD)........	$ 329,000	$ 400,400	$ 394,000	$ 794,400	$ 25,400	$ 25,000	$ 50,400
GROUP 3[d]							
NEWBURG (0.12 MGD)............	92,000	130,400	214,000	344,400	8,300	13,600	21,900
FREDONIA (0.23 MGD)...........	137,000	198,700	312,000	510,700	12,600	19,800	32,400
ADELL (0.07 MGD)[e]............	--	--	--	--	--	--	--
CASCADE (0.26 MGD)............	293,000	361,300	402,000	763,300	22,900	25,500	48,400
GROUP 4[f]							
THIENSVILLE[g]..................	$ --	$ --	$ 789,000	$ 789,000	$ --	$ 50,000	$ 50,000
SUBTOTAL--TREATMENT FACILITIES..................	$ 5,669,200	$ 7,790,700	$14,970,600	$22,761,300	$ 493,900	$ 949,900	$ 1,443,800
TRUNK SEWERS							
WEST BEND SYSTEM[h].............	$ 977,200	$ 993,000	$ 162,600	$ 1,155,600	$ 62,900	$ 10,300	$ 73,200
THIENSVILLE SYSTEM[i]...........	219,500	224,800	43,000	267,800	14,300	2,800	17,100
SUBTOTAL--TRUNK SEWERS......	$ 1,196,700	$ 1,217,800	$ 205,600	$ 1,423,400	$ 77,200	$ 13,100	$ 90,300
SUBTOTAL--TREATMENT FACILITIES AND TRUNK SEWERS......................	$ 6,865,900	$ 9,008,500	$15,176,200	$24,184,700	$ 571,100	$ 963,000	$ 1,534,100
LOW-FLOW AUGMENTATION FACILITIES[j]							
NORTH BRANCH MILWAUKEE RIVER........................	$ 13,000	$ 21,600	$ 15,700	$ 37,300	$ 1,400	$ 1,000	$ 2,400
MILWAUKEE RIVER BELOW WEST BRANCH.................	1,500,000	1,500,000	410,000	1,910,000	95,000	26,000	121,000
CEDAR CREEK BELOW JACKSON......................	4,000,000	4,000,000	410,000	4,410,000	250,000	26,000	276,000
SUBTOTAL--LOW-FLOW AUGMENTATION FACILITIES..................	$ 5,513,000	$ 5,521,600	$ 835,700	$ 6,357,300	$ 346,400	$ 53,000	$ 399,400
WATERSHED TOTAL.................	$12,378,900	$14,530,100	$16,011,900	$30,542,000	$ 917,500	$ 1,016,000	$ 1,933,500

[a]EACH SEWAGE TREATMENT PLANT IN GROUP 1 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (90 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b]THE WEST BEND SEWAGE TREATMENT FACILITY IS PROPOSED TO SERVE THE EXISTING AND PROPOSED URBAN DEVELOPMENT IN THE TRI-LAKES SEWER SERVICE AREA, AS WELL AS THE EXISTING AND PROPOSED SEWER SERVICE AREAS OF THE EXISTING WEST BEND SEWAGE TREATMENT PLANT.

[c]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 2 (RANDOM LAKE) IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT (95 PERCENT BOD REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[d]EACH SEWAGE TREATMENT PLANT IN GROUP 3 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[e]NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED THAT IT CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[f]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 4 (THIENSVILLE) IS PROPOSED TO BE ABANDONED AND ITS EXISTING AND PROPOSED SEWER SERVICE AREA CONNECTED TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM.

[g]AN ASSUMED CONTRACT SERVICE COST OF $240 PER MILLION GALLONS, REPRESENTING THE EXISTING (1970) CONTRACT SERVICE COST, WAS UTILIZED TO DETERMINE THE APPORTIONED TREATMENT COST IN THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM FOR THIENSVILLE.

[h]INCLUDES 10,300 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $314,000, 18,740 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $549,000, 2,200 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $41,400, 260 FEET OF 10-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $4,800, AND THREE 670 GPM PUMPING STATIONS AT 50 FEET OF HEAD AT AN ESTIMATED COST OF $68,000, REQUIRED TO CONNECT THE PROPOSED TRI-LAKES SEWER SERVICE AREA TO THE WEST BEND SANITARY SEWERAGE SYSTEM.

[i]THE TRUNK SEWER PROPOSED TO CONNECT THE THIENSVILLE SEWER SERVICE AREA TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM IS ALSO PROPOSED TO SERVE A PORTION OF THE CITY OF MEQUON. IT WAS ASSUMED, BASED ON ANTICIPATED FUTURE FLOWS, THAT THIENSVILLE WOULD BEAR ABOUT 54 PERCENT OF THE TOTAL COST OF THE PROPOSED TRUNK SEWER AND LIFT STATION. THIS INCLUDES 800 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $15,100, 10,400 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $277,500, AND ONE 2.26 MGD LIFT STATION AT 7 FEET OF HEAD AT AN ESTIMATED COST OF $42,300.

[j]INCLUDES A 1,100-ACRE RESERVOIR PROPOSED TO BE CONSTRUCTED ON THE WEST BRANCH OF THE MILWAUKEE RIVER NEAR ELMORE, A 2,100-ACRE RESERVOIR PROPOSED TO BE CONSTRUCTED ON CEDAR CREEK SOUTH OF JACKSON, AND A 0.5 CFS WELL AT CASCADE.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

post-chlorination for effluent disinfection. It was determined that, if this plan element were implemented, the state-established water use objectives and standards for the watershed would not be fully met. The extent to which these objectives and standards would be met varied with the subalternatives considered under Alternative 1.

Four subalternatives were considered, differing only with respect to the system configuration within the upper watershed and to the number of sewage treatment plants provided. Under Alternative 1A, which would provide the desired level of treatment at 14 individual sewage treatment plants, the analyses revealed that substandard DO concentrations would remain in four reaches of the stream system; namely, below the Campbellsport, Cascade, Cedarburg, and West Bend sewage treatment facilities. Under Alternative 1B, which would provide for the desired levels of treatment at two areawide and ten individual sewage treatment plants in the upper watershed, the analyses revealed that substandard DO concentrations could be expected to occur below the Campbellsport, Cascade, and West Bend sewage treatment plants. Similarly, under Alternative 1C, which would provide for the desired levels of treatment at two areawide and ten individual sewage treatment plants, the analyses revealed that substandard DO concentrations could be expected to occur below the Campbellsport, Cascade, and West Bend sewage treatment facilities. Finally, under Alternative 1D, which would provide for the desired levels of treatment at seven individual treatment plants in the upper watershed while diverting sewage from seven sewer service areas to the Milwaukee metropolitan sewerage system, the analyses revealed that substandard DO concentrations could be expected to occur below the Campbellsport and Cascade sewage treatment facilities.

The second alternative plan element considered would provide for a level of advanced waste treatment beyond that now required by the Wisconsin Department of Natural Resources. As in Alternative 1, the smaller sewage treatment plants would continue to provide only secondary waste treatment and post-chlorination for effluent disinfection. The larger plants, however, would be proposed to provide advanced waste treatment to remove 90 percent of the phosphorus and, on a selective basis, 95 percent of the BOD and 80 percent of the NOD. Two alternative subsystem plan elements were considered under this basic alternative, the two subsystems differing only with respect to the system configuration and the number of treatment plants provided. The analyses revealed that implementation of either Alternative 2A or Alternative 2B could be expected to fully meet the state-established water use objectives and standards, since satisfactory DO concentrations could be expected to occur along the entire stream system downstream from the sewage treatment plants.

The third alternative stream water quality management plan element considered would eliminate all major waste discharges to streams through effluent disposal by land irrigation. This would provide for ultimate disposal of the wastes without polluting surface waters of the watershed. The analyses revealed that this alternative plan element could be expected to fully meet the state-established water use objectives and standards.

The fourth alternative stream water quality management plan element considered would combine secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and instream aeration to achieve the state-established water quality objectives and standards throughout the entire stream system. The fifth alternative plan element would similarly combine secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and low-flow augmentation to achieve the state-established water quality objectives and standards throughout the entire stream system.

By design, then, Alternatives 2A, 2B, 3, 4, and 5 would fully meet the water use objectives and standards as set by the State of Wisconsin for the streams in the Milwaukee River watershed. A summary description of each of the alternative stream water quality management plan elements considered, together with the estimated costs and the relative ability of each alternative to meet the state-established water use objectives and standards, is provided in Table 68.

The analyses conducted in the development and evaluation of the various alternatives presented in this subsection demonstrated the desirability of using different measures to achieve the stream water quality use objectives and standards in various reaches of the perennial stream system of the upper watershed. Based on the relative costs, performance, and limitations of each of the major alternatives considered, it is recommended that a plan combining features of Alter-

Table 68

SUMMARY OF THE ALTERNATIVE STREAM WATER QUALITY MANAGEMENT PLAN ELEMENTS FOR THE UPPER MILWAUKEE RIVER WATERSHED

ALTERNATIVE PLAN ELEMENT		ESTIMATED COST					MEETS STATE-ESTABLISHED WATER USE OBJECTIVES AND STANDARDS
NUMBER DESIGNATION	DESCRIPTION[a]	CAPITAL	ANNUAL OPERATION AND MAINTENANCE (1970-2020)	PRESENT WORTH (50 YEARS-6 PERCENT)	TOTAL ANNUAL (1970-2020)	ANNUAL PER CAPITA[b] (1970-2020)	
1A	ADVANCED WASTE TREATMENT--STATE ORDERS--85 PERCENT PHOSPHORUS REMOVAL (FOURTEEN INDIVIDUAL PLANTS)	$ 7,287,800	$ 969,700	$24,944,300	$ 1,582,100	$ $27	NO
1B	ADVANCED WASTE TREATMENT--STATE ORDERS--85 PERCENT PHOSPHORUS REMOVAL (TWO AREA-WIDE PLANTS AND EIGHT INDIVIDUAL PLANTS)	9,476,900	845,700	24,779,300	1,572,000	27	NO
1C	ADVANCED WASTE TREATMENT--STATE ORDERS--85 PERCENT PHOSPHORUS REMOVAL (TWO AREA-WIDE PLANTS AND TEN INDIVIDUAL PLANTS)	7,385,400	914,700	23,956,700	1,519,600	26	NO
1D	ADVANCED WASTE TREATMENT--STATE ORDERS--85 PERCENT PHOSPHORUS REMOVAL (SEVEN INDIVIDUAL PLANTS AND SEWAGE DIVERSION TO MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM)	14,965,900	1,079,900	32,558,100	2,065,600	36	NO
2A	TERTIARY AND ADVANCED WASTE TREATMENT--80 PERCENT NOD, 95 PERCENT BOD, AND 90 PERCENT PHOSPHORUS REMOVAL (ONE AREA-WIDE PLANT AND TEN INDIVIDUAL PLANTS)	9,679,700	969,800	27,276,200	1,729,900	30	YES
2B	TERTIARY AND ADVANCED WASTE TREATMENT--80 PERCENT NOD, 95 PERCENT BOD, AND 90 PERCENT PHOSPHORUS REMOVAL (TWO AREA-WIDE PLANTS AND TEN INDIVIDUAL PLANTS)	8,310,200	975,600	25,931,200	1,644,000	28	YES
3	SECONDARY WASTE TREATMENT AND EFFLUENT DISPOSAL BY LAND IRRIGATION	12,569,100	838,200	28,694,700	1,835,000	32	YES
4	ADVANCED WASTE TREATMENT AND INSTREAM AERATION	7,018,400	989,700	24,859,100	1,577,000	27	YES
5	ADVANCED WASTE TREATMENT AND LOW-FLOW AUGMENTATION	12,378,900	1,016,000	30,542,000	1,933,500	34	YES

[a]SEE ACCOMPANYING TEXT FOR A MORE COMPLETE DESCRIPTION OF EACH ALTERNATIVE PLAN ELEMENT.

[b]BASED ON AN ESTIMATED 1980 POPULATION OF 57,580 TO BE SERVED BY THE FACILITIES.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

native 2—advanced waste treatment (90 percent phosphorus removal), Alternative 4—instream aeration, and Alternative 5—low-flow augmentation, be adopted as the recommended stream water quality management plan element for the upper Milwaukee River watershed (see Map 48). This plan would include the following salient features:

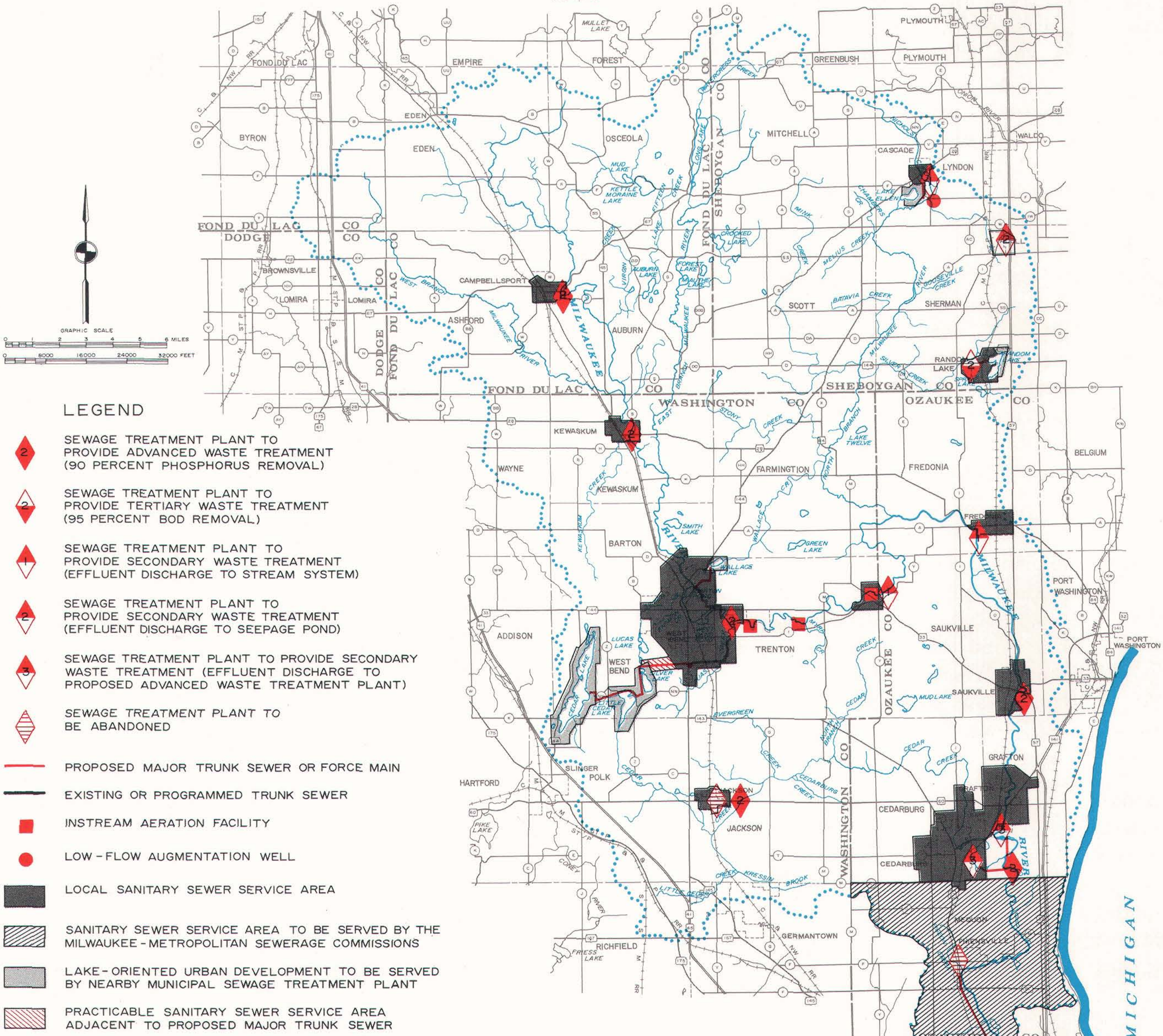
1. The provision of secondary waste treatment and post-chlorination for disinfection at the municipal sewage treatment facilities serving the following communities: Adell, Fredonia, and Newburg. It is proposed that the Adell treatment facility continue to discharge its effluent to a seepage pond rather than to the stream system.

2. The provision of secondary waste treatment, post-chlorination for disinfection, and streamflow augmentation during low-flow periods at a new sewage treatment facility proposed to serve the Village of Cascade and urban development in the nearby Lake Ellen area. Streamflow augmentation would be accomplished by utilizing a single small-capacity well (0.5 cfs) located near the proposed sewage treatment plant site. In the alternative to streamflow augmentation, the treatment plant effluent could be discharged to a seepage pond.

3. The provision of secondary waste treatment, tertiary waste treatment (95 percent BOD removal), and post-chlorination for disinfection at the existing sewage treatment facility serving the Village of Random Lake. This facility would also be used to treat the wastes generated by the lake-oriented development located outside the Village along the north and east shores of Random Lake.

Map 48

RECOMMENDED STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT FOR THE UPPER MILWAUKEE RIVER WATERSHED 1990



The recommended stream water quality management plan element for the upper watershed combines tertiary and advanced waste treatment, instream aeration, and stream flow augmentation in order to provide the most economical means of meeting the state-established water use objectives and standards. Under this alternative, advanced waste treatment, consisting of 90 percent phosphorus removal, would be provided at selected sewage treatment facilities, with tertiary waste treatment being provided at other facilities; instream aeration would be provided by mechanical and diffuser aerators below the West Bend sewage treatment plant, by low stream flow augmentation below the Cascade sewage treatment plant with the necessary water being provided by a well, and by the provision of a new advanced waste treatment facility to serve the Cedarburg and Grafton areas. The existing Cedarburg and Grafton sewage treatment plants would be retained in order to provide secondary treatment prior to advanced treatment at the new plant. The Thiensville sewage treatment plant will be abandoned and its service area connected to the Milwaukee-metropolitan sewerage system. This combination of subalternatives constitutes the least cost alternative that would meet the state-established water use objectives and standards and would not require a drastic revision of the existing pattern of sewage collection and treatment in the upper watershed.

Source: Harza Engineering Company and SEWRPC.

4. The provision of secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination for disinfection at the municipal sewage treatment facilities serving the following communities: Campbellsport, Cedarburg-Grafton, Jackson, Kewaskum, and Saukville. The Jackson sewage treatment facility would be proposed to be relocated at a new site at about 0.5 mile east of the present plant site in order to accommodate a major industrial waste source and to provide a more rational sewer service area. Advanced treatment of wastes generated in the Cedarburg-Grafton sewer service areas would be accomplished at a new sewage treatment facility located near the confluence of the Milwaukee River and Cedar Creek, with secondary waste treatment continuing to be provided at the existing Cedarburg and Grafton sewage treatment plants. The layout of the trunk sewers needed to connect the existing Cedarburg and Grafton plants with the new plant is shown in Figure 21.

5. The provision of secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), post-chlorination for disinfection, and instream aeration at the West Bend sewage treatment facility. The West Bend treatment facility would be an areawide facility serving not only the West Bend sewer service area but also sanitary sewer service areas around Tri-Lakes (Little Cedar, Big Cedar, and Silver Lakes) and Wallace Lake. The layout of the trunk sewers needed to connect the Tri-Lakes areas with the West Bend plant is shown in Figure 22. Instream aeration would be provided by mechanical aerators located on the Milwaukee River main stem below the West Bend sewage treatment plant at distances of 0.7 and 1.8 miles and diffuser aerator units located in the Newburg Pond.

6. Connection of the Thiensville sanitary sewer service area to the Milwaukee metropolitan sewerage system through the City of Mequon sewerage system, together with the abandonment of the existing Thiensville sewage treatment facility The layout of the trunk sewer needed to connect the Thiensville area to the Milwaukee system is shown in Figure 23.

The above described recommended plan element represents the best combination of subalternatives considered in this chapter and constitutes the least cost alternative which would meet the state-established water use objectives and standards. The plan as proposed would not require a drastic revision of the existing pattern of sewage collection and treatment in the upper Milwaukee River watershed. Implementation of the recommended stream water quality management plan for the upper Milwaukee River watershed would entail an estimated initial capital cost of $7,502,900, with total annual costs, including operation and maintenance, over a 50-year period, estimated to be $1,557,500, or about $27 per capita per year. The per capita cost has, for analysis purposes, been based on an estimated 1980 population of 57,580 to be served by the facilities. The present worth of this recommended plan element for 50 years at 6 percent interest is $24,552,400. The detailed cost estimates for each major subelement comprising the recommended plan are summarized in Table 69.

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS

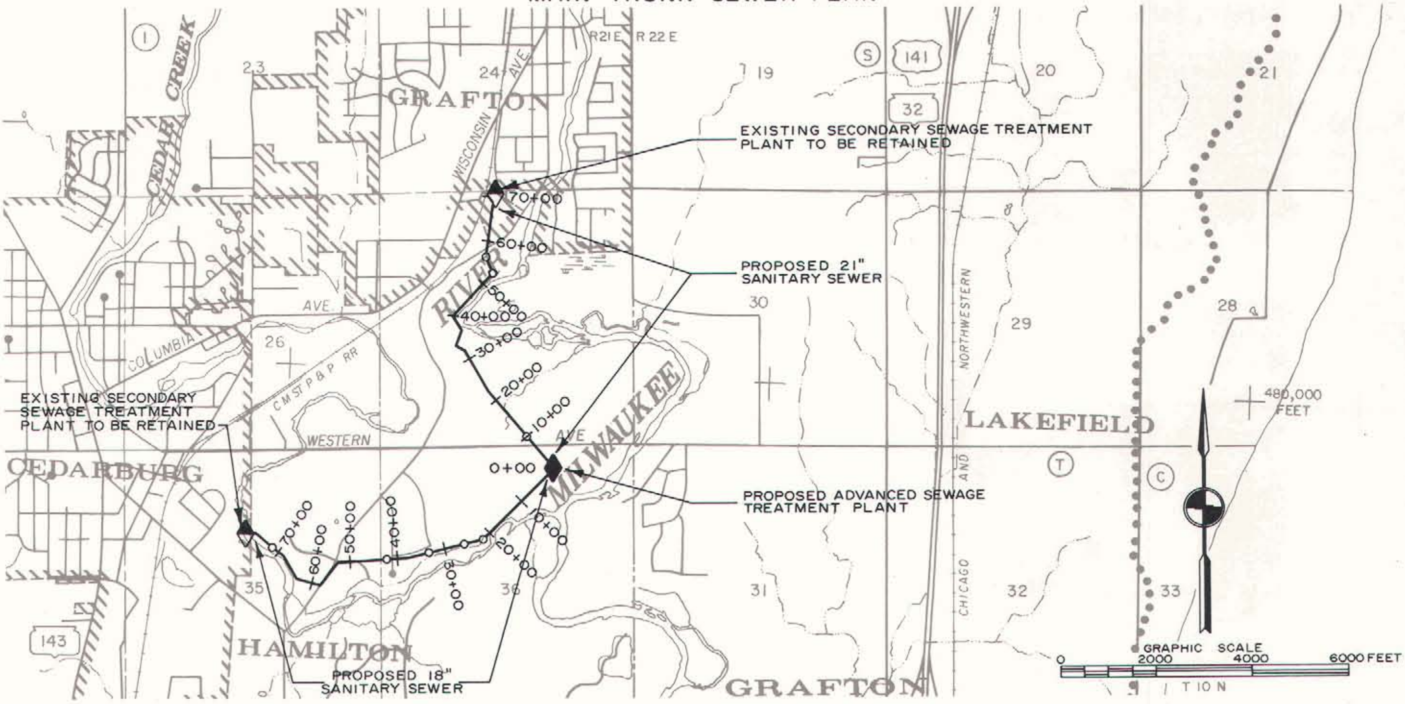
As already noted in the introductory section of this chapter and as documented in Chapter IX of Volume 1 of this report, the lakes of the Milwaukee River watershed are generally in an advanced state of eutrophication, as indicated by high phosphorus content, dissolved oxygen depletion, and heavy growths of algae and aquatic weeds. Degradation of lake water quality has been generally accelerated in recent years, although some lakes, such as Silver Lake and Auburn Lake, have evidenced little change, while others, such as Wallace Lake and Random Lake, have evidenced sharp declines in water quality. Eutrophication—the natural aging process of lakes—is caused by a complex series of actions and reactions between the lake itself, additives to the lake, and the aquatic life in the lake. Although the process is not well understood, sunlight; basin hydrology; and the physical, chemical, and biological characteristics of the lake all affect the rate of eutrophication, as does land use and management in the tributary drainage basin.

Phosphorus and nitrogen, the two elements generally considered as limiting algae and weed growth in lake waters, are supplied primarily by partially treated municipal sewage, septic tank seepage, and runoff containing fertilizers, either commercial types applied to urban lawns and agricultural lands or animal manure spread over agricultural

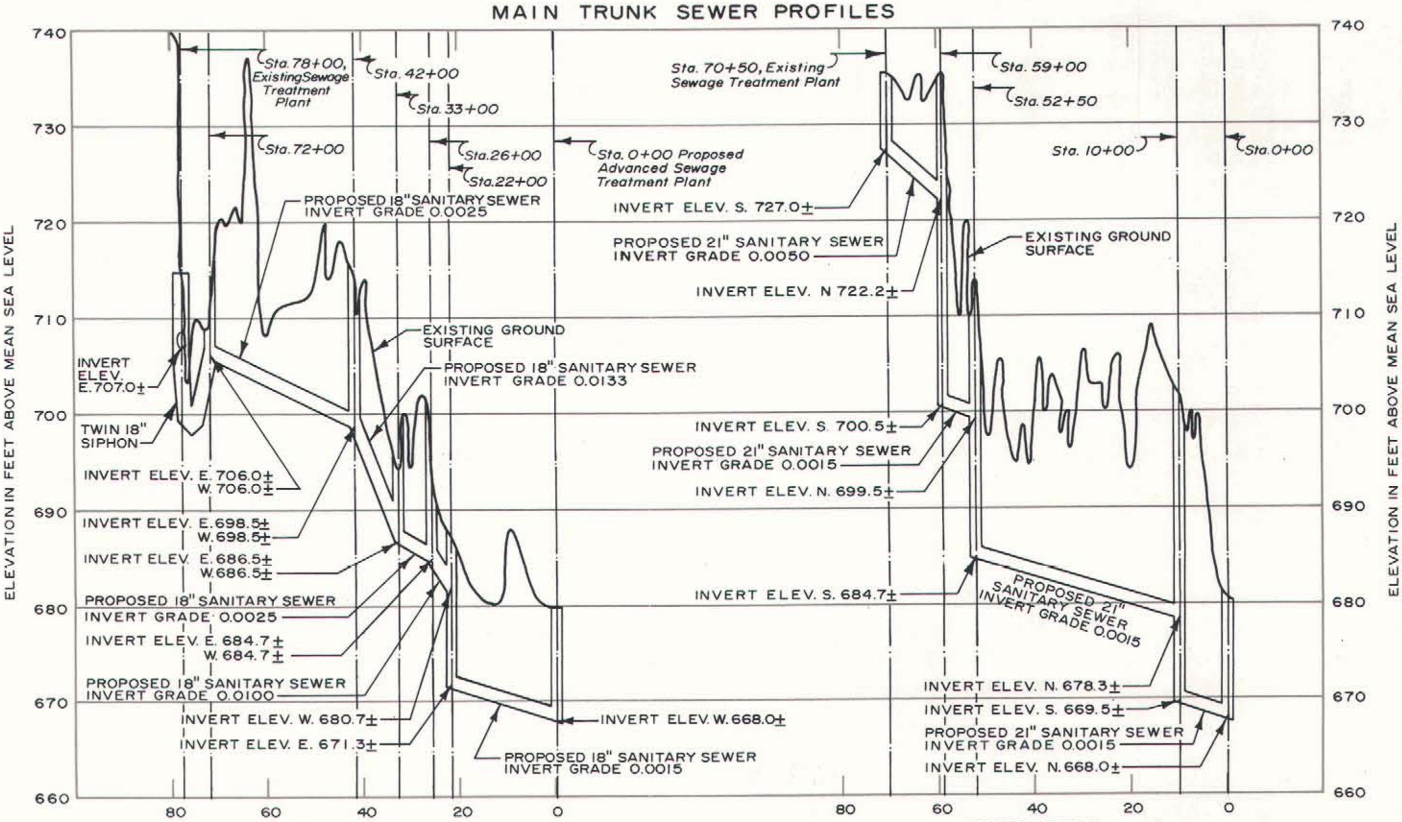
Figure 21

RECOMMENDED TRUNK SEWER SYSTEM TO CONNECT EXISTING CITY OF CEDARBURG AND VILLAGE OF GRAFTON SEWAGE TREATMENT PLANTS TO PROPOSED ADVANCED WASTE TREATMENT PLANT

MAIN TRUNK SEWER PLAN



MAIN TRUNK SEWER PROFILES



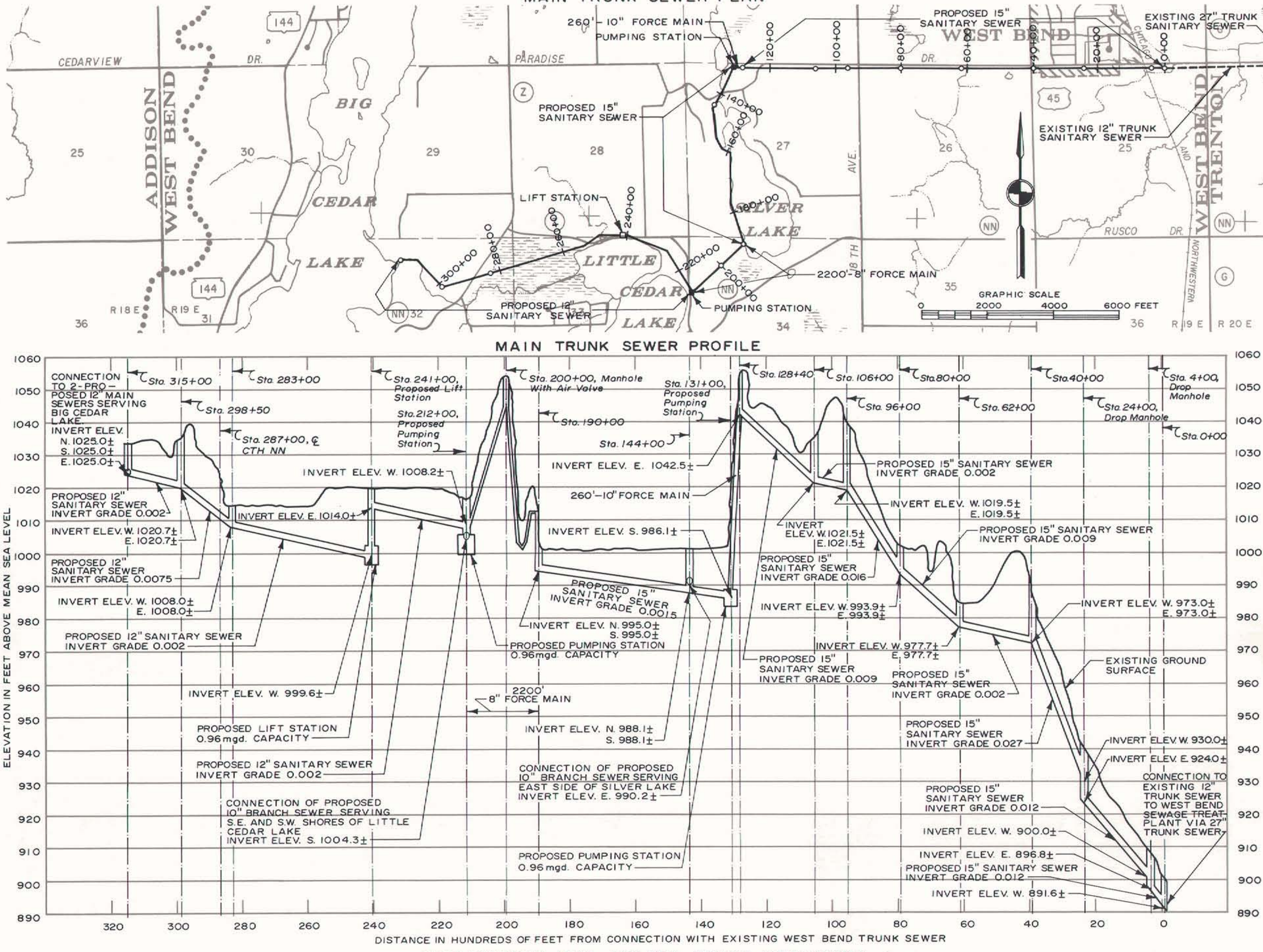
DISTANCE IN HUNDREDS OF FEET FROM THE SITE OF THE PROPOSED ADVANCED WASTE TREATMENT FACILITY

SCALE; HORIZONTAL 1 INCH = 4000 FEET; VERTICAL 1 INCH = 20 FEET

Source: Harza Engineering Company and SEWRPC.

Figure 22

RECOMMENDED TRUNK SEWER SYSTEM TO CONNECT PROPOSED TRI – LAKES SEWER SERVICE AREA TO WEST BEND SEWAGE TREATMENT PLANT

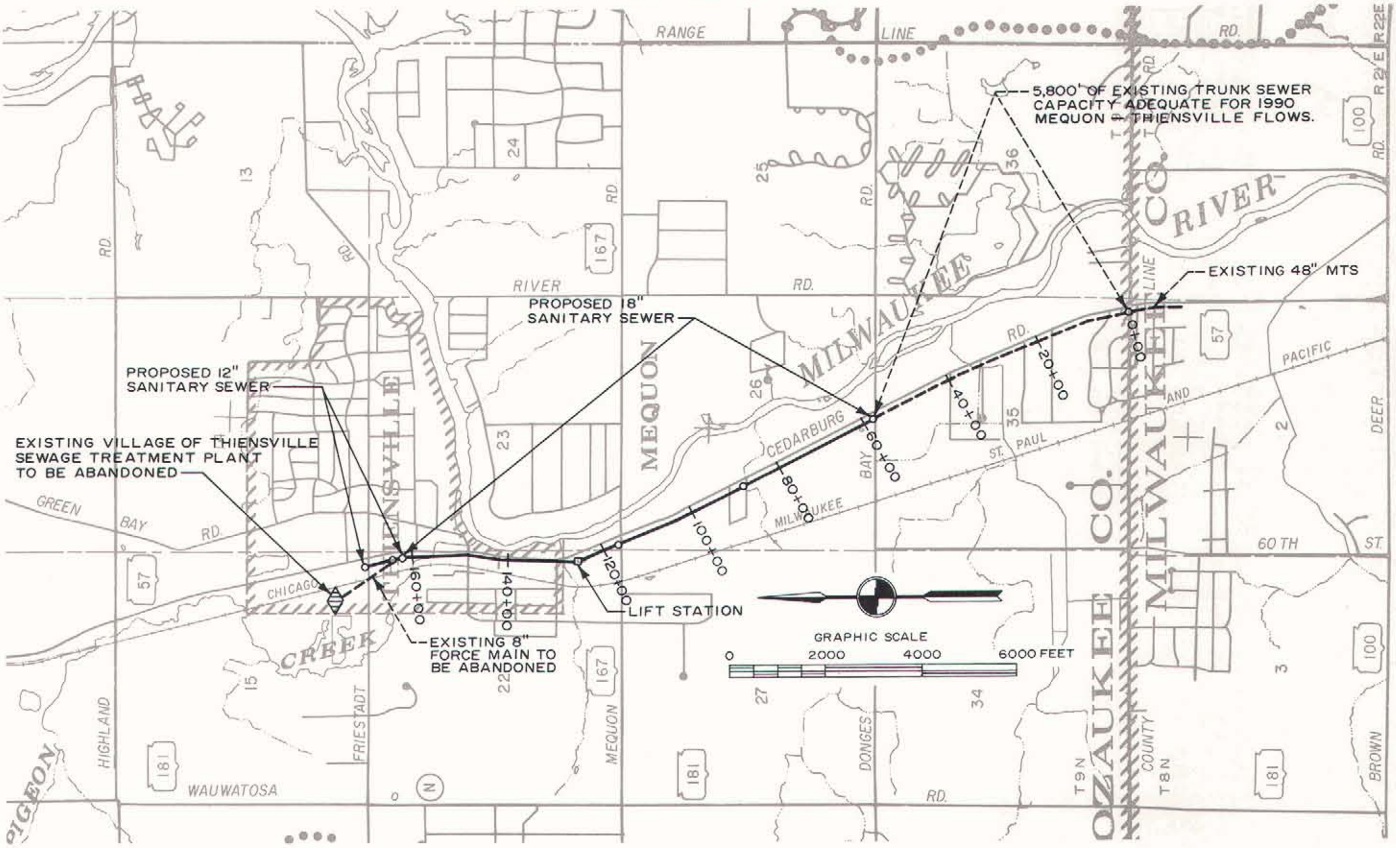


Source: Harza Engineering Company and SEWRPC.

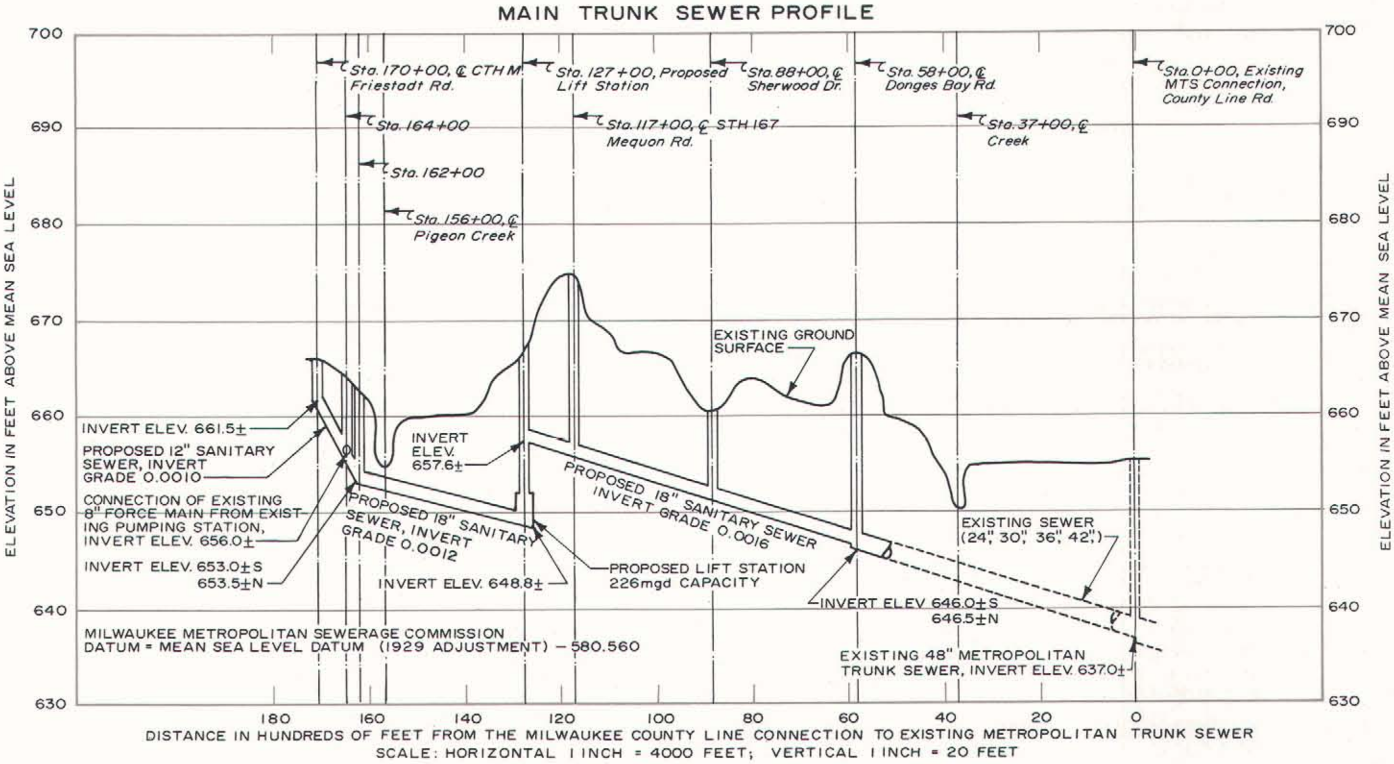
Figure 23

RECOMMENDED TRUNK SEWER SYSTEM TO CONNECT VILLAGE OF THIENSVILLE TO THE MILWAUKEE METROPOLITAN SEWERAGE SYSTEM

MAIN TRUNK SEWER PLAN



MAIN TRUNK SEWER PROFILE



Source: Harza Engineering Company and SEWRPC.

Table 69

DETAILED COST ESTIMATES RECOMMENDED STREAM WATER QUALITY MANAGEMENT PLAN ELEMENT FOR THE UPPER MILWAUKEE RIVER WATERSHED

PLAN SUBELEMENT	ESTIMATED COST						
		PRESENT WORTH (1970-2020)			EQUIVALENT ANNUAL		
	CAPITAL (CONSTRUCTION)	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL	CONSTRUCTION	OPERATION AND MAINTENANCE	TOTAL
TREATMENT FACILITIES							
GROUP 1[a]							
CAMPBELLSPORT (0.40 MGD)......	$ 315,700	$ 414,700	$ 703,000	$ 1,117,700	$ 26,200	$ 44,700	$ 70,900
KEWASKUM (0.74 MGD)...........	465,000	617,000	927,600	1,544,600	39,100	58,800	97,900
WEST BEND (6.10 MGD)[b]........	1,574,000	2,294,000	5,388,000	7,682,000	145,500	342,000	487,500
JACKSON (0.50 MGD)............	556,000	685,700	814,000	1,499,700	43,500	51,600	95,100
SAUKVILLE (0.40 MGD)..........	165,000	266,000	502,000	768,000	16,800	31,800	48,600
CEDARBURG-GRAFTON (4.38 MGD)[c]..................	1,701,500	2,267,500	4,051,000	6,318,500	143,800	257,000	400,800
GROUP 2[d]							
RANDOM LAKE (0.30 MGD)........	$ 329,000	$ 400,400	$ 394,000	$ 794,400	$ 25,400	$ 25,000	$ 50,400
GROUP 3[e]							
NEWBURG (0.12 MGD)............	$ 92,000	$ 130,400	$ 214,000	$ 344,400	$ 8,300	$ 13,600	$ 21,900
FREDONIA (0.23 MGD)...........	137,000	198,700	312,000	510,700	12,600	19,800	32,400
CASCADE (0.26 MGD)............	293,000	361,300	402,000	763,300	22,900	25,500	48,400
ADELL (0.07 MGD)[f].............	--	--	--	--	--	--	--
GROUP 4[g]							
THIENSVILLE (0.61 MGD)[h].......	$ --	$ --	$ 789,000	$ 789,000	$ --	$ 50,000	$ 50,000
SUBTOTAL--TREATMENT FACILITIES.................	$ 5,628,200	$ 7,635,700	$14,496,600	$22,132,300	$ 484,100	$ 919,800	$ 1,403,900
TRUNK SEWERS							
WEST BEND SYSTEM[i].............	$ 977,200	$ 993,000	$ 162,600	$ 1,155,600	$ 62,900	$ 10,300	$ 73,200
CEDARBURG-GRAFTON SYSTEM[j].....	582,000	582,000	15,400	597,400	36,900	1,000	37,900
THIENSVILLE SYSTEM[k]...........	219,500	224,800	43,000	267,800	14,300	2,800	17,100
SUBTOTAL--TRUNK SEWERS......	$ 1,778,700	$ 1,799,800	$ 221,000	$ 2,020,800	$ 114,100	$ 14,100	$ 128,200
SUBTOTAL--TREATMENT FACILITIES AND TRUNK SEWERS......................	$ 7,406,900	$ 9,435,500	$14,717,600	$24,153,100	$ 598,200	$ 933,900	$ 1,532,100
LOW-FLOW AUGMENTATION AT CASCADE[l].........................	$ 13,000	$ 21,600	$ 15,700	$ 37,300	$ 1,400	$ 1,000	$ 2,400
STREAM AERATION AT WEST BEND[m]...	$ 83,000	$ 138,000	$ 224,000	$ 362,000	$ 8,800	$ 14,200	$ 23,000
WATERSHED TOTAL.................	$ 7,502,900	$ 9,595,100	$14,957,300	$24,552,400	$ 608,400	$ 949,100	$ 1,575,500

[a]EACH SEWAGE TREATMENT PLANT IN GROUP 1 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, ADVANCED WASTE TREATMENT (90 PERCENT PHOSPHORUS REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[b]THE WEST BEND SEWAGE TREATMENT FACILITY IS PROPOSED TO SERVE EXISTING AND PROPOSED DEVELOPMENT IN THE TRI-LAKES SEWER SERVICE AREA, AS WELL AS THE EXISTING AND PROPOSED SEWER SERVICE AREAS OF THE EXISTING WEST BEND SEWAGE TREATMENT PLANT.

[c]THE CEDARBURG-GRAFTON AREA IS PROPOSED TO BE SERVED BY A TWO-PHASE TREATMENT FACILITY, WITH SECONDARY WASTE TREATMENT BEING PROVIDED AT THE EXISTING CEDARBURG AND GRAFTON SEWAGE TREATMENT PLANTS AND ADVANCED WASTE TREATMENT (90 PERCENT PHOSPHORUS REMOVAL) AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT BEING PROVIDED AT A SINGLE NEW TREATMENT FACILITY LOCATED NEAR THE CONFLUENCE OF CEDAR CREEK AND THE MILWAUKEE RIVER.

[d]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 2 (RANDOM LAKE) IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT, TERTIARY WASTE TREATMENT (95 PERCENT BOD REMOVAL), AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[e]EACH SEWAGE TREATMENT PLANT IN GROUP 3 IS PROPOSED TO PROVIDE SECONDARY WASTE TREATMENT AND POST-CHLORINATION FOR DISINFECTION OF EFFLUENT.

[f]NO COSTS WERE ASSIGNED TO THE ADELL TREATMENT FACILITY BECAUSE IT IS PROPOSED THAT IT CONTINUE TO BE OPERATED AS A SECONDARY TREATMENT PLANT DISCHARGING PARTIALLY TREATED EFFLUENT TO A SEEPAGE POND.

[g]THE SINGLE SEWAGE TREATMENT PLANT IN GROUP 4 (THIENSVILLE) IS PROPOSED TO BE ABANDONED AND ITS EXISTING AND PROPOSED SEWER SERVICE AREA CONNECTED TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM.

[h]AN ASSUMED CONTRACT SERVICE COST OF $240 PER MILLION GALLONS, REPRESENTING THE EXISTING (1970) CONTRACT SERVICE COST, WAS UTILIZED TO DETERMINE THE APPORTIONED TREATMENT COST IN THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM FOR THIENSVILLE.

[i]INCLUDES 10,300 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $314,000, 18,740 FEET OF 15-INCH SEWER AT AN ESTIMATED COST OF $549,000, 2,200 FEET OF 8-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $41,400, 260 FEET OF 10-INCH CAST IRON FORCE MAIN AT AN ESTIMATED COST OF $4,800, AND THREE 670 GPM PUMPING STATIONS AT 50 FEET OF HEAD AT AN ESTIMATED COST OF $68,000, REQUIRED TO CONNECT THE PROPOSED TRI-LAKES SEWER SERVICE AREA TO THE WEST BEND SANITARY SEWERAGE SYSTEM.

[j]INCLUDES 7,800 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $244,000 AND 7,050 FEET OF 21-INCH SEWER AT AN ESTIMATED COST OF $338,000 REQUIRED TO CONNECT THE EXISTING CEDARBURG AND GRAFTON SEWAGE TREATMENT PLANTS TO THE NEW ADVANCED WASTE TREATMENT FACILITY PROPOSED TO BE LOCATED NEAR THE CONFLUENCE OF CEDAR CREEK AND THE MILWAUKEE RIVER.

[k]THE TRUNK SEWER PROPOSED TO CONNECT THE THIENSVILLE SEWER SERVICE AREA TO THE MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM IS ALSO PROPOSED TO SERVE A PORTION OF THE CITY OF MEQUON. IT WAS ASSUMED, BASED ON ANTICIPATED FUTURE FLOWS, THAT THIENSVILLE WOULD BEAR ABOUT 54 PERCENT OF THE TOTAL COST OF THE PROPOSED TRUNK SEWER AND LIFT STATION. THIS INCLUDES 800 FEET OF 12-INCH SEWER AT AN ESTIMATED COST OF $15,100, 10,400 FEET OF 18-INCH SEWER AT AN ESTIMATED COST OF $277,500, AND ONE 2.26 MGD LIFT STATION AT 7 FEET OF HEAD AT AN ESTIMATED COST OF $42,300.

[l]INCLUDES THE CONSTRUCTION OF A 0.5 CFS WELL DOWNSTREAM FROM THE CASCADE SEWAGE TREATMENT PLANT FOR LOW-FLOW AUGMENTATION PURPOSES.

[m]INCLUDES TWO 10 HORSEPOWER MECHANICAL AERATORS INSTALLED IN THE MILWAUKEE RIVER AT DISTANCES OF 0.7 AND 1.8 MILES DOWNSTREAM OF THE WEST BEND SEWAGE TREATMENT PLANT AND FOUR DIFFUSER AERATOR UNITS INSTALLED IN THE NEWBURG POND.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

lands. The spring runoff from frozen farmland receiving manure throughout the winter usually contributes a major portion of the annual phosphorus input to the lakes. Algae and weed growth can be reduced either by preventing the discharge of phosphorus to a lake or by removing phosphorus from the lake. Although action to limit the input of phosphorus has retarded the eutrophication of some lakes within the United States, such as Lake Washington near Seattle, Washington; Lake Waubesa near Madison, Wisconsin; and Lake Zoar near Waterbury, Connecticut, results have not been consistent. Until such time that additional knowledge about this complex problem becomes available through more basic research, however, phosphorus reduction will have to continue to be the primary focus of any action to retard eutrophication.

A number of different methods, or potential plan elements, were considered in this study for limiting or reducing the phosphorus input to, and content of, the lakes of the Milwaukee River watershed and thereby retarding the eutrophication process. Some of these methods are more appropriate for application to a particular lake than others. Based upon analysis of the nutrient sources, alternative combinations of these methods for pollution abatement and water quality control were considered for each major natural lake within the watershed, thereby, formulating alternative water quality control plan elements for each lake. Each of the alternative nutrient control methods, initially considered in the alternative plan element formulation for each of the lakes, is described below, including for each a general discussion of the relative costs and effectiveness. This general discussion is followed by a description of the specific alternative plans considered for improving lake water quality at the 19 largest and most important lakes in the basin.[31] Although estimates of the costs attendant to application of each of the alternative plan elements considered for each of the 19 lakes were made, the degree of improvement in water quality which may be expected from these investments cannot, given the present state of technology, be quantitatively nor even certainly predicted. Evaluation of the effectiveness of the alternative plan elements, therefore, was limited to a general assessment of probable performance expressed in qualitative terms.

[31] *A total of 21 major lakes in the Milwaukee River watershed were identified in Volume 1 of this report. Two of the 21 lakes--the West Bend and Barton Ponds--are actually impoundments on the main stem of the Milwaukee River in the City of West Bend and are not considered lakes for the purposes of this section of the report.*

Potential Plan Elements

As already noted, a number of methods were investigated for lake water quality management in the Milwaukee River watershed. These methods, either singly or in combination, formed the basis for the alternative plan elements considered for each lake. The plan elements cover a wide range of costs and anticipated effectiveness. Costs vary from almost no initial capital investment with high operating expenses, an extreme which provides flexibility to adapt and change the procedures as knowledge of lakes in general and of each of the individual lakes within the Milwaukee River watershed increases and as the technology to manage lake water quality improves, to a very large initial capital investment with low operating costs, an extreme which restricts flexibility because of the large sums of money initially committed under such a plan element. The effectiveness of the plan elements varies from the probable removal of substantial amounts of nutrients either entering or in the lake waters to no removal of nutrients from the lake water but control of the nuisances that result from overfertilization of the lakes by suppression of the attendant symptoms. Each of the alternative plan elements considered for application to the major lakes in the watershed is discussed generally in the following sections.

Installation of Sanitary Sewerage Systems: Provision of a sanitary sewerage system and treatment facilities to serve the developed areas around a lake would serve to eliminate the sanitary (public health) hazards and reduce nutrient inputs resulting from inoperative and malfunctioning private soil absorption (septic tank) sewage disposal systems. Discharge of the treated and disinfected effluent should be downstream from the lake outlet. Where feasible, consideration should be given to connection of proposed lake sanitary sewerage systems to existing municipal sewerage systems, in accordance with the recommendations of the federal Lake Michigan Enforcement Conference and subsequent Wisconsin Department of Natural Resources policy statements against the unnecessary proliferation of sewage treatment plants (see Chapter XV, Volume 1, of this report). Provision of a sewerage system is indicated for those lakes which have relatively large areas of their tributary drainage basins devoted to intensely developed urban-type land uses that are dependent upon soil absorption systems for waste disposal and are situated on soils having very severe to severe limitations for the use of such systems. It is in such areas that malfunctioning of the on-site sewage disposal systems will most probably result in contamination of the lake water and cause a serious public health hazard. In areas situated on soils suitable for waste disposal by soil absorption systems, these systems may not cause a serious public health hazard if properly constructed and maintained, although they may, under certain ground water conditions, contribute nutrients to the lake.

The provision of sewerage systems and treatment plants discharging to a stream below the lake outlets for the lakes within the Milwaukee River watershed may be expected to reduce the phosphorus input by 28 to 73 percent and the nitrogen input by 5 to 61 percent, depending upon the particular lake being considered. The amount of anticipated nutrients prevented from entering the lake in the future could be expected to increase proportionately to the increased population and urbanization occurring around the lake. Sanitary sewerage system alternatives were considered for 13 of the 19 major natural lakes within the watershed. The remaining six major lakes—Lucas, Mauthe, Mud (Fond du Lac County), Mud (Ozaukee County), Smith, and Spring—did not have enough urban development around their shorelines to warrant such consideration.

Since the discharge from the sewage treatment plants serving the lake communities would generally be to streams with little dry-weather flow, a high degree of treatment would be necessary. Secondary treatment and disinfection, followed by effluent discharge to a seepage lagoon, would reduce the possibility of stream pollution and would eliminate the need for higher degrees of treatment. Further investigations would be required at each lake to determine the size of seepage pond needed or the degree of treatment required if no pond were provided and the effluent were discharged to a stream. Advanced waste treatment would be necessary where proposed lake sewerage systems comprise, or are a part of, a sewerage system serving a population or population equivalent of 2,500 persons or more, in accordance with Wisconsin Department of Natural Resources' policy implementing the recommendations of the federal Lake Michigan Enforcement Conference.

Cost estimates for this plan element were based on present and anticipated future (1990) population levels around each lake and preliminary system plans showing the configuration of the required sewerage system, including the approximate length, size, and depth of all trunk and of selected branch sewers and the size of treatment and disinfection facilities needed. Design criteria used were based on the Recommended Standards for Sewage Works (1968 Edition) adopted by the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, (Ten States Standards) of which Wisconsin is a member state. Estimates of dry-weather sewage flow were based on a flow contribution of 125 gallons per capita per day for the estimated year-round population and 50 gallons per capita per day for the incremental seasonal peak population. Lateral and branch sewers were sized to flow full at peak rates of flow equal to two times the average daily dry-weather flow rate, while trunk sewers, lift and pumping stations, and sewage treatment plants were designed to carry peak rates of flow equal to two times the average daily dry-weather flow rate. Cost estimates include costs of lateral, branch, and trunk sewers, all required lift and pumping stations, and waste treatment facilities providing either secondary or advanced waste treatment as required. This plan element invariably involves a large initial capital investment for construction of the required facilities, as well as substantial annual costs for operation and maintenance of the sewerage system and treatment facilities.

Agricultural Runoff Control: The nutrient budgets prepared for each of the 19 major natural lakes within the Milwaukee River watershed indicate that generally more than half of the phosphorus input to the lakes results from agricultural lands fertilized with animal manure or inorganic fertilizers. Phosphorus movement from such agricultural lands is almost exclusively by surface runoff, with much of the phosphorus input to the lakes being contributed by spring snowmelt and rainfall runoff carrying manure spread on frozen ground throughout the preceding winter. Summer rainfall runoff may also contribute phosphorus to the lakes by carrying manure and fertilizers adsorbed on eroded soil particles. The phosphates are adsorbed by soil colloids and move from the agricultural lands into the lakes and streams through erosion of the surface soil. Thus, elimination of the practice of spreading manure on frozen ground and good soil conservation practices that prevent erosion are the most effective means of controlling pollution from agricultural runoff.

Two specific approaches for the control of agricultural nutrient flows to lakes and streams were considered. One was the storage of manure produced during the frozen-ground season, and the other, erosion control by means of bench terracing[32] with blind tile outlets. In addition, consideration was given to the use of the various other land management and soil conservation practices developed and applied by the U. S. Soil Conservation Service.

Manure Storage Tanks: The provision and use of tanks in which manure could be stored during the months that the ground is frozen and then removed and applied to the ground after the spring runoff would eliminate much of the phosphorus input to the lakes from manured agricultural lands. In addition, more of the nutrients would be retained in the soil where they would be available as additional fertilizer for plant growth during the summer months.

Cost estimates for this plan element are based on providing concrete holding tanks with sufficient volume to store five to six months' production of manure at all farms within the watershed area tributary to the lake under consideration. The cost of construction and installation of each tank was estimated to be $5,000 for an average size farm in the watershed. This element would involve a relatively large initial capital investment for construction of the tanks, but there would be little annual cost involved in maintaining the tanks. The cost of spreading the manure would be incurred both with or without the holding tanks, although the methods used would differ.

The use of the holding tanks, however, presents certain problems to the farmer. The period of time available for spreading manure when the ground is not frozen coincides with the time of maximum demand for farm labor. Consequently, the adoption of this system of phosphorus control on a voluntary basis by farmers can be expected to be limited. Furthermore, this is not a completely satisfactory type of control, since it does not prevent soil erosion and consequent movement of phosphorus from sloping lands. For complete elimination of agricultural phosphorus contribution to lakes, erosion must be controlled.

Bench Terraces: The construction of bench terraces on land subject to erosion will furnish almost complete erosion control and thereby effectively retain nutrients on the agricultural lands. Bench terraces would be capable of trapping over 95 percent of the sediment runoff from cultivated fields and essentially all of the phosphorus associated with such sediment. Bench terraces would eliminate the need for grassed waterways, permit parallel terraces with relatively straight alignments, put more water into the soil, retain the nutrients on the land to improve crop production, and eliminate the need for manure holding tanks. Therefore, the use of bench terraces is recommended for the control of nutrient inputs to lakes contributed by agricultural lands having slopes in excess of 2 percent.

To be acceptable to farmers, erosion and runoff control measures must maintain or improve the "farmability" of the land. Vegetative and mechanical measures, such as stripcropping, contouring, grassed waterways, and conventional terracing, because they do not contribute to such "farmability" utilizing present methods and machinery, have had limited acceptance in modern farming. Bench terracing provides a system of erosion and runoff control that is finding increasing acceptance by farmers because only minimal land areas are lost to cultivation, and conventional cultivation methods and machinery can be used.

On slopes of 6 percent or less, permanently maintained rows lead runoff water to storage areas constructed by placing earthfills across natural draws and drainageways. These fills are constructed so as to provide storage for about two inches of runoff from the tributary drainage area. On steeper slopes runoff would overtop the rows so that a continuous fill must be provided across the slopes.

The fills are constructed by pushing up earth borrowed from the downhill side. The downhill sides of the fill slopes are usually constructed at a slope of one foot vertical to two feet horizontal and are seeded to grass. The uphill slope of the earthfill is proportioned to fit modern farming

---

[32] *The term "bench terraces" is herein defined as a small earthfill constructed across a field slope to store runoff and release it slowly through underground drainage tiles. Such bench terraces are also known as blind tile outlet terraces.*

equipment. A typical cross section of a bench-terraced slope is shown in Figure 24, and the spacings recommended for various land slopes are given in Table 70. It should be noted that the Technical Guide used by the U. S. Soil Conservation Service recommends somewhat narrower spacing for tile outlet bench terraces than those set forth in the accompanying table. The width used will determine the number of terraces required for any given application and, therefore, the cost.

Table 70

RECOMMENDED TERRACE SPACING

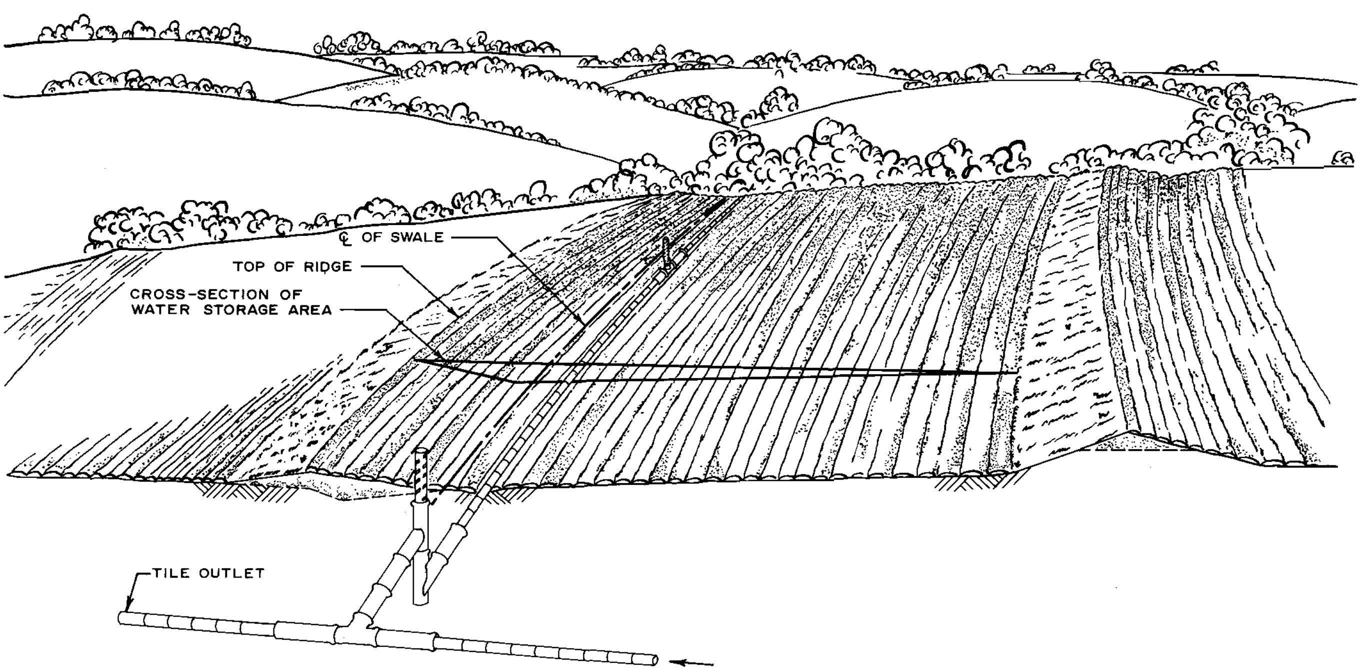
SLOPE PERCENT	SPACING (IN FEET)	INITIAL NUMBER OF 40-INCH ROWS	NUMBER OF ROWS AFTER BENCHING			FINAL BENCH WIDTH (IN FEET)
			40-INCH	30-INCH	20-INCH	
2	245	72	72	96	144	240
4	247	72	72	96	144	240
6	250	72	72	96	144	240
	171	48	48	64	96	160
8	132[a]	36	36	48	72	120
10	134[a]	36	36	48	72	120

[a]THESE SPACINGS SHOULD BE INCREASED IF SOILS WILL PERMIT BENCHING THE LAND.

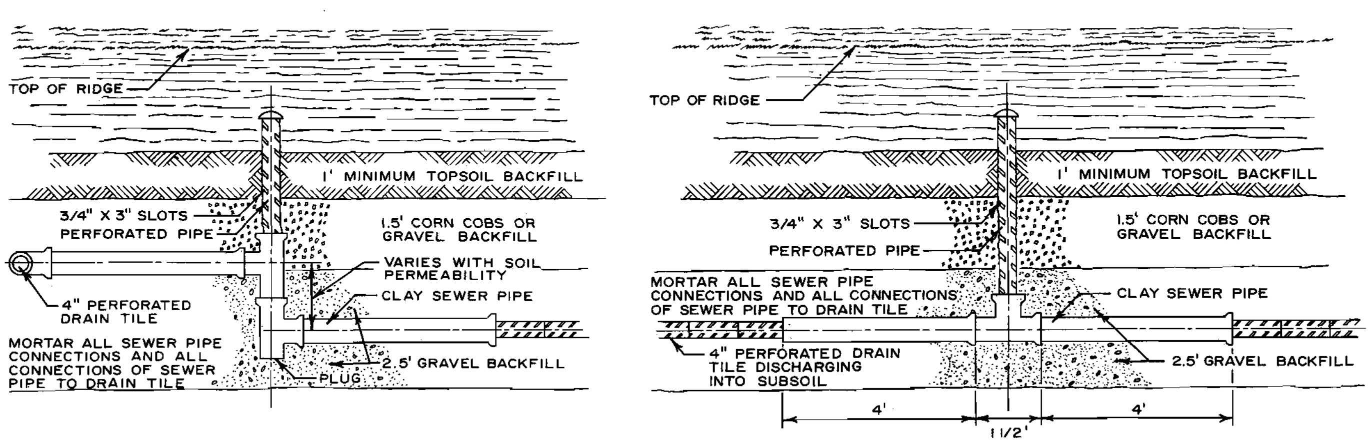
SOURCE- HARZA ENGINEERING COMPANY.

Figure 24

TYPICAL BENCH TERRACE CROSS-SECTION



BLIND TILE OUTLETS FOR BENCH TERRACES



Source: U. S. Soil Conservation Service and SEWRPC.

Originally, this type of control was used only for deep soils where exposure of subsoils in the construction of the terraces was not a problem. The earthfill provides a barrier for collecting the eroded soil so that the combination of soil pushed into the earthfill and the collected soil produces a flattened slope—thus, the name "bench terrace."

Farmers working with shallower soils, as in north central Iowa and New Brunswick, Canada, realized the advantages of the more nearly straight rows and wider terrace spacing offered by the bench terrace system.[33] Here, where exposed subsoil might seriously depress yields, a system of construction is being used which provides for the replacement of topsoil on nearly all borrow areas. A 40 to 50 foot section of a terrace is constructed by pushing up earth from the downhill side. This procedure leaves the subsoil exposed in the borrow area. Before constructing the adjacent 40 to 50 foot section of the same bench terrace, the topsoil from the adjacent area is removed and spread over the borrow area for the previously constructed section of the terrace. The subsoil in the second area is then pushed up to construct the terrace in the adjacent area. This procedure is continued for adjacent areas until the entire length of the terrace is completed. In this way the terrace is built primarily by pushing up subsoil, with topsoil being replaced on all borrow areas except the very last 40 to 50 foot length of the terrace.

Any excess water stored on the bench terraces is drained off through underground conduits usually made of field drain tile, as shown in Figure 24. The water enters the underground tile conduits through blind tile inlets so that all runoff is percolated or filtered through the soil, allowing absorption of organic phosphates. The tile inlets are sized to carry one inch of runoff in 24 hours, thus retarding peak inflows. This retardation allows sediment to settle out and, in so doing, traps about 95 percent of the sediment in the storage area while providing good agricultural drainage.

Research on blind inlets has been carried out by Iowa State University[34] in the Clarion-Webster Soil Association of north central Iowa. This soil association, of predominantly glacial origin, is similar to soils in the Milwaukee River watershed. The general conclusion of these tests was that corncob backfill of the trenches serving as blind inlets produced higher average discharge rates than backfill with soil or sand. The inlets filled with corncobs discharged a minimum flow of about 0.055 cfs per 100 feet of tile, therefore requiring about 100 feet of blind inlet per acre of drainage area to release one inch of runoff in 24 hours.

The storage fills or terraces are normally constructed with a bulldozer. although a carryall scraper is more efficient where extensive, long-distance, lateral movement of earth is required. Tile can be installed with conventional agricultural drainage equipment.

Terracing costs increase with slope, since the steeper slopes require higher earthfills for storage and the terraces must be spaced closer together. The cost of constructing the bench terraces may vary from $60 per acre on 2 percent slopes to $240 per acre on 12 percent slopes. The cost of installing drain tiles may vary from $10 to $50 per acre normally, depending upon the amount of existing tile and distance to outlets. As with all practices, initial construction costs may run 10 percent to 15 percent higher until construction operators become proficient. Based on the average slope of land and the probable amount of existing tile in the Milwaukee River watershed, the average cost of constructing bench terraces and drain tiles is estimated at $120 per acre.

The cost of the bench terrace system with tile outlets is usually justified by the improvements in farm operations and the more intensive cropping allowed by maintaining soil loss within permissible limits. Additional benefits accrue due to the erosion and runoff controlling features. Off-farm sediment and pollution damages are reduced, as are flood peaks. Manure can be spread in normal practice, and no manure holding tanks are required.

Other Land Management Practices: It should be emphasized that the foregoing discussion of the use of bench terraces with tile outlets to reduce lake nutrients by controlling agricultural runoff is not intended to preclude consideration of other farm management and soil conservation practices throughout all of the lake subwatersheds. In some cases application of bench terracing is not feasible

[33] *Paul Jacobson, E. A. Olafson, and J. A. Roberts, Erosion Control in New Brunswick, Canada, ASAE Paper No. 69-226.*

[34] *H. P. Johnson and D. P. Palmer, "Field Evaluation of Flow-Through Blind Inlets," Transactions of American Society of Agricultural Engineering, 1962.*

or appropriate because of landscape, soil, and cost considerations. Where the use of the more effective bench terraces is not feasible or appropriate, nutrient input to lakes can be reduced through the application of a variety of other soil and water conservation practices, including contour stripcropping, diversion of runoff, grassed waterways, detention dams to prevent manure runoff and to control sediment, minimum tillage, crop rotation, and feedlot and barnyard control practices. All of these practices have specific applications with varying benefits and varying costs of installation and maintenance. In the application of these soil and water conservation practices, therefore, expert technical advice should be sought from the U. S. Soil Conservation Service.

Weed Harvesting: Aquatic weed harvesting machines are capable of cutting aquatic weeds to a maximum depth of seven feet and loading them onto a barge for disposal on suitable nearby land areas. Cutting and removal eliminate the nuisance caused by excessive weed growths in a lake and remove from the lake a small amount of nutrients fixed in the plant tissues. The weed cutting must be done selectively at each lake to preserve major fish spawning areas. Although weed harvesting can do little to reduce the rapid rate of eutrophication of most of the lakes within the watershed, it can serve to reduce one of the nuisances accompanying such eutrophication.

Cost estimates for weed harvesting were based on two harvesting operations per lake per year—removal of weeds up to a depth of seven feet and disposal of the weeds on suitable nearby land areas. The initial cost of a large weed-harvesting machine is approximately $60,000, and operation and maintenance costs are estimated to be $150 per day. The harvesting machines could be rented from the manufacturer, or an areawide harvesting program could be organized, in which each lake community contributes a proportionate share of the cost of purchasing and operating the machines. Both initial investment cost and annual operation and maintenance costs for this plan element are relatively low.

Algae Control: Nuisance blooms of algae can be eliminated or controlled by the application of algicides. Several algicides are available for this purpose, but the one most commonly used, and the only one presently permitted by the Wisconsin Department of Natural Resources in Wisconsin, is copper sulfate. It can be applied to a lake either by the addition in crystal form or by spraying in solution form from a boat or a barge. The use of an algicide will control the nuisance caused by excessive growths of algae; but it will not result in any nutrient removal from the lake, since the dead algae will, upon decay, release nutrients back into the water.

Copper sulfate, if applied infrequently and in dosages just sufficient to control algal populations, should not produce any undesirable side effects. If used in excessive concentrations, however, it will poison fish and other aquatic life. Permits from the Wisconsin Department of Natural Resources, Division of Environmental Protection, are required for any chemical spraying operations on a lake. Copper sulfate has been used in the past for algae control on many of the lakes in the watershed. While copper sulfate, when used as recommended, has not been found to have adverse effects on animal life to date, it is possible that microorganisms may have the capacity to transform this chemical into a form that can enter the natural food chain. This possibility, as well as the possibility of unknown chronic effects from this inorganic form of copper compound, warrants careful surveillance of the effects of this form of algal control.

Cost estimates for algae control are based upon two control operations per lake per year and vary with the size of the lake to be treated and the dosage required to kill the majority of the algae. Cost estimates include the cost of the chemicals, at $1 per acre treated; a boat or barge and spraying apparatus, at an initial cost of $1,250; operation and maintenance costs of $50 per day, and state supervision and inspection costs of about $50 per day. Initial investment costs and annual operation and maintenance costs for algae control are relatively low compared to other plan elements for lake water quality management.

Lake Water Mixing: The use of pumps, compressed air diffusors, or other water recirculatory devices to mix lake waters will help to reduce stratification and thereby improve water quality in a lake. Such mixing will increase the dissolved oxygen in the deep portions of a lake, which generally contain little or no oxygen during the summer months. By providing oxygen to the deep portions of a lake, anaerobic conditions favorable for bringing certain nutrients into solution from the bottom muds will be limited. By adding oxygen and lowering surface water temperatures, mixing can also provide an improved and enlarged environment for fish production; and, if operated during the winter, it can reduce or eliminate winter fish kills in both shallow and deep lakes.

The effects of continuous mixing on algae growth in a lake are not well known. By lowering surface water temperatures and by carrying algae cells out of the zones of photosynthetic activity, mixing may limit algal growths. Mixing may, in some cases, however, bring additional nutrients into the upper waters and may actually cause an increase in the amount of algae being produced. Although the effect on algae is not highly predictive, certain studies have indicated that the nuisance algae are favored.

Cost estimates for providing continuous mixing of a lake are based on volume of the lake, the number of destratification devices and related facilities required, the power requirements of these devices, and the associated maintenance costs. These estimates have been prepared only for lakes having maximum depths in excess of 20 feet, since only such lakes are stratified. Provision of continuous lake mixing requires a relatively large initial investment for the required equipment, but annual operation and maintenance costs are low.

Other Elements: Several additional methods of lake water quality management were investigated but were eliminated as possible plan elements, either because the technology is not currently available to implement them or because the effects of the method are highly uncertain. These methods are briefly described below. Although these methods have not been sufficiently developed, tested, and evaluated to date for practical application, advances in knowledge and technology may make application of some of these desirable in the future.

Bottom Draw Devices: Devices can be installed, particularly in impoundment lakes, to draw water from the deep portions of the lake and discharge it downstream from the lake outlet. Nutrient-rich bottom waters would be discharged from the lake, reducing the amount of nutrients in the lake. The dissolved oxygen content of the remaining lake waters would be increased. This technique would be applicable only in stratified lakes and would be operated only while the lakes are stratified. The effects of this method on algae and weed growth in a lake are not presently known.

Water Replacement: Removing the water from nutrient-rich lakes by pumping and replacing such water with ground water is another technique being considered to improve lake water quality. Little data concerning the technique are as yet available, but both cost and replacement water limitations will probably limit application to relatively small lakes.

Nutrient Removal: The possibility of removing nitrogen and phosphorus from lake water by chemical and mechanical means was investigated. If part or all of the lake volume could be treated to remove or precipitate most of the nutrients present, algae and weed growth could be controlled.

There are several methods available for removing nutrients from sewage; but it is not presently known if these methods can be successfully applied to lake waters, which generally contain less than 1 percent as much nitrogen and phosphorus as municipal sewage. New techniques for this solution may prove to be an effective, although costly, method for halting, retarding, or even reversing eutrophication of a lake. The flow-through screening dissolved air flotation treatment system discussed in an earlier section of this chapter represents an example of such a new, rapidly developing technique. Such a technique might be especially applicable for the reduction of phosphorus in nutrient-enriched lake waters.

Dredging: Since the bottom sediments of a lake contain relatively large quantities of nutrients, some of which may be released to the lake water, dredging to effect a removal of the nutrients was considered. While the technology of dredging is well developed, the results in terms of nutrient removal are uncertain, primarily because it is not known how much nutrients are contributed to the lakes from bottom sediments. Moreover, the sediments immediately below those removed may be just as rich and contribute just as much nutrients as the sediments removed. The costs of dredging for nutrient removal are very high for the level of uncertainty involved. Dredging may, however, have a signficant value in some lakes as a means of deepening portions of a lake to reduce winter fish kills and to improve the potential for recreational use.

Fish Harvesting: Since fish concentrate nutrients in their body structures, the possibility of removing nutrients by harvesting fish was considered. The total quantity of nutrients that could be removed by this method, however, is very small in relation to the total quantity of nutrients in a lake. If species of algae-eating fish could be cultivated in a lake, the controlled removal of these fish could help to control nuisances caused by excessive algae growths. At present, however, there are no such species of fish in the lakes of the Milwaukee River watershed.

Aquatic biologists in Illinois are experimenting with a species of fish known as tilapias, originally from Africa, that feed on weeds and algae and can be used to keep ponds and lakes free of excessive weed and algae growths. This species cannot survive at temperatures below 50°F, however, and must be removed to warm waters for the winter. It is possible that, in the future, these fish could be raised commercially and stocked in lakes every spring to assist in controlling algae and weeds throughout the growing season.

Algae Harvesting: Removal of algae from a lake by harvesting would have two desirable results. First, the physical removal of algae would reduce or eliminate the nuisances caused by excessive algae growths; and second, algae removal would result in the removal of large quantities of nutrients contained in the algal cells. The very high costs entailed, however, presently eliminate algae harvesting as an economically feasible method of lake water quality control.

Application of the Potential Plan Elements to the Major Lakes in the Watershed

As already noted, various water quality management plans were investigated for each of the 19 major natural lakes within the watershed and are described in this section. The first table referenced under the discussion for each lake presents a summary of the pertinent characteristics of the lake, including lake surface area, present lake-oriented resident population,[35] present lake-oriented seasonal resident population,[36] forecast 1990 seasonal peak population,[37] major nutrient sources, and existing water quality problems.

---

[35] *The existing (1967) lake-oriented resident population was defined for the purposes of the watershed study as the population residing year-round in residences located within the watershed area tributary to the lake so as to capitalize upon the recreational and environmental amenities provided by the lake. This population was determined through field surveys conducted during the summer season at all major lakes in the watershed. These surveys served to update prior SEWRPC population estimates by enumerating the number of housing units located in the lake-oriented area and estimating the number of those units that were occupied on a year-round, as opposed to a seasonal or occasional, use basis. A person-per-housing-unit factor was then applied to the total estimated number of year-round housing units to arrive at an estimate of the total year-round resident population. The factors so applied were derived from regional population studies and varied from lake to lake, ranging from a high of 4.03 persons per housing unit for Green Lake and Lake Twelve to a low of 3.14 persons per housing unit for Random Lake. The lake-oriented population normally would not include the families residing in farm housing or in residences located more than one-quarter of a mile away from the lake. For evaluation of the per capita costs of proposed sanitary sewerage facilities, the lake-oriented resident population included only that portion of the year-round resident population that was not presently served by public sanitary sewerage facilities. For evaluation of the costs of all other water quality management plan elements considered, the lake-oriented resident population included all of the year-round resident population defined above. It is important to note that, while the unit cost of the facilities was computed using only the year-round resident population data, all sewerage facilities were sized to carry and treat the hydraulic and waste loadings generated by the seasonal peak lake-oriented population.*

[36] *The existing (1967) seasonal lake-oriented resident population was defined for the purposes of the watershed study as the lake-oriented year-round resident population plus the population residing on a seasonal basis in residences located within the watershed area tributary to the lake so as to capitalize upon the recreational and environmental amenities provided by the lake. As noted above, the number of seasonal dwelling units was determined by field surveys. The same person-per-housing-unit factor was applied to the seasonal housing unit as was applied to the year-round housing unit for a given lake in order to obtain the total seasonal lake-oriented resident population. As in the case of the year-round lake-oriented resident population, the seasonal lake-oriented resident population normally would not include families residing in farm housing or in residences located more than one-quarter of a mile away from the lake.*

[37] *The estimated future (1990) seasonal peak lake-oriented population was defined for the purposes of the watershed study as the lake-oriented seasonal resident population plus the estimated peak visitation at the year-round and seasonal residences located within the lake-oriented area. To derive the estimated seasonal peak population, factors derived from surveys of seasonal peak population conducted for the Commission under the watershed study by the Wisconsin Department of Natural Resources were applied to each housing unit comprising the total number of units within the lake-oriented area. These factors varied from lake to lake, ranging from a high of 11.6 persons per housing unit for Ellen Lake to a low of 4.6 persons per housing unit for Wallace Lake, and are on file at the SEWRPC offices. With two exceptions, the seasonal peak population for each lake does not include any person utilizing public or private*

water-related recreational facilities, either on a daily commuter basis or on an overnight basis utilizing portable shelters, such as tents, travel trailers, or campers. The two exceptions are Mauthe Lake and Long Lake, where estimates of seasonal peak population include that day visitation and camper population accommodated at the major state outdoor recreation areas located on these two lakes.

The second table referenced under the discussion of the lakes presents a summary of the alternative means considered for managing the water quality of the lake, the anticipated performance of each alternative, and the estimated costs of each alternative. The alternatives considered were selected on the basis of an analysis of the existing and probable future sources of pollution of each of the 19 major natural lakes within the watershed and constitute the most feasible water quality management plan alternatives under the existing state-of-the-art. The costs shown in the alternative plan table include estimated initial capital costs; annual operation and maintenance costs; present worth; total annual cost, including capital recovery; and average annual per capita cost, based on the present (1967) lake-oriented population.

Auburn (Fifteen) Lake: Auburn Lake is an elongated lake comprised of two "kettle" basins. The entire lake lies within the official project boundaries of the Northern Unit of the Kettle Moraine State Forest, as established by the Wisconsin Department of Natural Resources. There are 71 private homes presently located around the shoreline of the lake, which does not receive extensive public use. Water quality is generally suitable for all present uses of the lake; however, the lake evidences a moderate growth of weeds. Nutrient concentrations, based on spring phosphate levels, are lower than the average level for lakes within the Milwaukee River watershed. The major nutrient source is spring runoff from manured agricultural land, which is estimated to contribute about 57 percent of the total annual phosphorus input of 338 pounds per year (see Table 71).

Three alternative water quality management plan elements were considered for Auburn Lake. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake (see Table 72). While suppressing a symptom of eutrophication, this alternative would not significantly reduce the nutrient content of the lake or in any way reduce the nutrient input.

Table 71

SELECTED CHARACTERISTICS OF AUBURN (FIFTEEN) LAKE, FOND DU LAC COUNTY: 1967

CHARACTERISTICS	DESCRIPTION		
TRIBUTARY DRAINAGE AREA	5.5	SQUARE MILES	
SURFACE AREA	107	ACRES	
SHORELINE	2.4	MILES	
DEPTH			
UNDER 3 FEET	14	PERCENT	
OVER 20 FEET	32	PERCENT	
VOLUME	1,474	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION	220		
SEASONAL RESIDENT POPULATION	220		
SEASONAL PEAK POPULATION	220		
PHOSPHORUS SOURCES	MANURED LAND	190 LBS.[a]	57%
	RURAL RUNOFF	70	20
	SEPTIC TANKS	45	14
	OTHER[b]	33	9
	TOTAL	338 LBS.	100%
GENERAL WATER QUALITY	MODERATE WEED GROWTHS LOW NUTRIENT CONCENTRATIONS WATER QUALITY GENERALLY SUITABLE FOR MOST USES		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

The second alternative considered was the construction of bench terraces on approximately 565 acres of agricultural land tributary to the lake. This alternative could be expected to reduce the total annual phosphorus input to the lake by up to 57 percent, or by 190 pounds per year. Detailed site investigations may indicate that land management practices other than bench terraces would be suitable for some of the agricultural land acreage, requiring the institution of good soil conservation practices. Weed harvesting would also be provided as in the first alternative.

The third alternative considered was the construction of a sanitary sewerage system and treatment facility to serve all of the 71 private homes which are presently located along the shoreline of the lake (see Map 49). The treatment plant would provide secondary waste treatment. This alternative would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges. Construction of the sanitary sewerage system may be expected to result in a reduction of the total annual phosphorus input to the lake by about 14 percent, or by 45 pounds per year. Weed harvesting and bench terracing would also be provided as in the first and second alternatives. This alternative could be expected to reduce the total annual phosphorus input to Auburn (Fifteen) Lake by up to 71 percent, or by 235 pounds per year.

Table 72

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS
AUBURN (FIFTEEN) LAKE, FOND DU LAC COUNTY

ALTERNATIVE PLAN ELEMENT		ESTIMATED COST							ANTICIPATED PERFORMANCE
					TOTAL ANNUAL		ANNUAL PER CAPITA[a]		
NUMBER DESIGNATION	DESCRIPTION	CAPITAL	ANNUAL OPERATION AND MAINTENANCE	PRESENT WORTH	1970-1985	1986-2020	1970-1985	1986-2020	
1	WEED HARVESTING.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 2.3	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	TOTAL	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ 2.3	$ --	
2	WEED HARVESTING.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 2.3	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	BENCH TERRACES[c]......	68,000	--	68,000	4,300	4,300	19.5	19.5	REDUCE PHOSPHORUS INPUT BY ABOUT 60 PERCENT
	TOTAL	$ 70,100	$ 300	$ 73,000	$ 4,800	$ 4,300	$ 21.8	$ 19.5	
3	WEED HARVESTING.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 2.3	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	BENCH TERRACES[c]......	68,000	--	68,000	4,300	4,300	19.5	19.5	REDUCE PHOSPHORUS INPUT BY ABOUT 75 PERCENT
	SANITARY SEWERAGE SYSTEM[d]...........	538,730	14,610	781,930	49,650	49,650	225.7	225.7	ELIMINATE PUBLIC HEALTH HAZARDS
	TOTAL	$608,830	$ 14,910	$854,930	$ 54,450	$ 53,950	$247.5	$245.2	

[a] A POPULATION OF 220 PERSONS, REPRESENTING THE EXISTING LAKE-ORIENTED RESIDENT POPULATION, WAS USED FOR PER CAPITA COST CALCULATIONS. THE ESTIMATED SEASONAL LAKE-ORIENTED RESIDENT POPULATION IS 220, THE ESTIMATED SEASON PEAK LAKE-ORIENTED USER POPULATION IS 220.

[b] PRESENT WORTH CALCULATED UTILIZING A 6 PERCENT RATE OF INTEREST AND A 15-YEAR LIFE. THE PRESENT WORTH OF ALL OTHER PLAN ELEMENTS WAS CALCULATED UTILIZING A 6 PERCENT RATE OF INTEREST AND A 50-YEAR PROJECT LIFE.

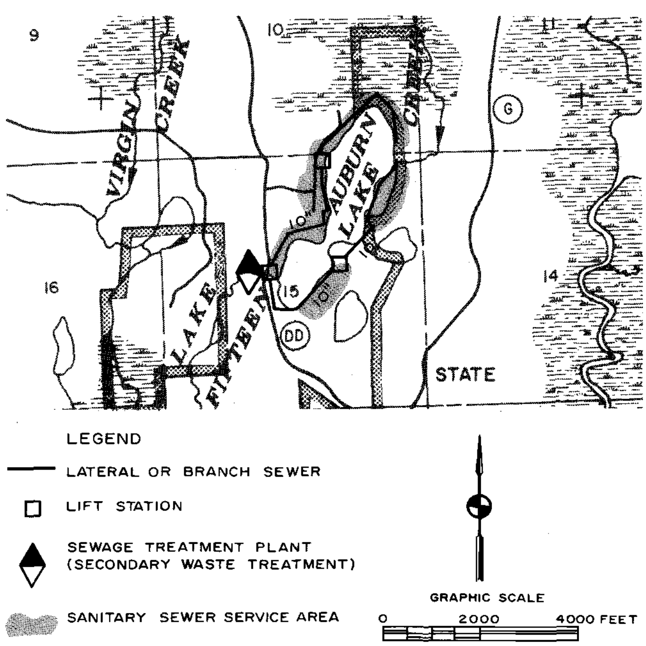
[c] INCLUDES THE CONSTRUCTION OF BENCH TERRACES OR THE INSTITUTION OF OTHER APPROPRIATE AGRICULTURAL LAND MANAGEMENT MEASURES ON APPROXIMATELY 565 ACRES OF AGRICULTURAL LAND TRIBUTARY TO THE LAKE.

[d] ENTIRE LAKE SERVED (220 PERSONS); SECONDARY TREATMENT PLANT AT LAKE OUTLET. THE COMPONENT CAPITAL COSTS OF THE SANITARY SEWERAGE SYSTEM ARE—TREATMENT PLANT (SECONDARY) $56,700; LATERAL, BRANCH, AND BUILDING SEWERS $482,030.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Map 49

PROPOSED SANITARY SEWERAGE SYSTEM FOR AUBURN (FIFTEEN) LAKE



Auburn Lake lies within the Northern Unit of the Kettle Moraine State Forest. There are, however, 71 private homes presently located along the shoreline of the lake. Construction of the indicated sanitary sewerage system would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal system to the lake and would also assist in maintaining good lake water quality for recreational uses by eliminating any potential public health hazard. Construction of the system was not considered essential, however, because less than 15 percent of the total nutrient input to the lake is contributed by existing septic tank systems.

Source: Harza Engineering Company and SEWRPC.

It is recommended that the second alternative plan element considered, including weed harvesting and bench terracing and other appropriate agricultural land management measures, be included in the recommended watershed plan. The provision of a sanitary sewerage system was not recommended because less than 15 percent of the total annual phosphorus input to the lake was estimated to be contributed by the septic tank systems serving the existing residential development around the lake and because the entire lake lies within the project boundaries of the Northern Unit of the Kettle Moraine State Forest. It is not expected, therefore, that the lake-oriented resident population will increase from its present level, but, on the contrary, that completion of the public acquisition of the Kettle Moraine State Forest would lead to the eventual removal of the private residences around Auburn Lake and eliminate the need for a sanitary sewerage system.

Big Cedar Lake: Big Cedar Lake is the largest natural lake within the Milwaukee River watershed and receives extensive recreational use by lake-oriented resident households occuping the extreme residential development surrounding the lake. Public use, however, is limited by lack of access. Big Cedar Lake is high in nutrient content, as measured by spring phosphate levels, a condition which could lead to algal blooms. The major nutrient sources are discharges from septic tank sewage disposal facilities serving the residential development around the lake, and agricultural runoff (see Table 73).

Table 73

SELECTED CHARACTERISTICS OF BIG CEDAR LAKE, WASHINGTON COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA............	12.1	SQUARE MILES	
SURFACE AREA.........................	932	ACRES	
SHORELINE............................	11.0	MILES	
DEPTH			
UNDER 3 FEET....................	7	PERCENT	
OVER 20 FEET....................	47	PERCENT	
VOLUME...............................	31,983	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION..	1,044		
SEASONAL RESIDENT POPULATION.......	2,680		
SEASONAL PEAK POPULATION...........	4,960		
PHOSPHORUS SOURCES.................	MANURED LAND	187 LBS.[a]	18%
	SEPTIC TANKS	458	44
	RURAL RUNOFF	250	24
	OTHER[b]	145	14
	TOTAL	1,040 LBS.	100%
GENERAL WATER QUALITY..............	MODERATE WEED AND ALGAE GROWTH		
	HIGH NUTRIENT CONCENTRATIONS		
	GENERALLY GOOD WATER QUALITY CONDITIONS		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATERS.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

The upland soils surrounding the lake are generally suitable for the use of on-site sewage disposal systems, but many residences are located immediately on the lakeshore, where high ground water conditions may interfere with proper operation of the septic tank systems. Additional intensive urban land use development, such as is now occurring at the south end of the lake, may be expected to further intensify waste disposal problems. The need to protect this large body of water against a potential hazard to public health makes the provision of a sanitary sewerage system around the lake desirable. The proximity of the City of West Bend, with its large central sewage treatment facility, presents an opportunity for the economical provision of sewage treatment.

Four alternative lake water quality management plan elements were considered for Big Cedar Lake. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake and the utilization of algicides to control algal growths that interfere with other recreational uses, as well as with the aesthetic enjoyment, of the lake (see Table 74).

Table 74

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS BIG CEDAR LAKE, WASHINGTON COUNTY

ALTERNATIVE PLAN ELEMENT		ESTIMATED COST							
					TOTAL ANNUAL		ANNUAL PER CAPITA[a]		ANTICIPATED PERFORMANCE
NUMBER DESIGNATION	DESCRIPTION	CAPITAL	ANNUAL OPERATION AND MAINTENANCE	PRESENT WORTH	1970-1985	1986-2020	1970-1985	1986-2020	
1	WEED HARVESTING.....	$ 7,250	$ 1,050	$ 17,450[b]	$ 1,800	$ --	$ 1.7	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	ALGAE CONTROL.......	1,250	2,100	21,650[b]	2,250	--	2.1	--	
	TOTAL	$ 8,500	$ 3,150	$ 39,100	$ 4,050	$ --	$ 3.8	$ --	
2	WEED HARVESTING.....	$ 7,250	$ 1,050	$ 17,450[b]	$ 1,800	$ --	$ 1.7	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	ALGAE CONTROL.......	1,250	2,100	21,650[b]	2,250	--	2.1	--	REDUCE PHOSPHORUS INPUT BY ABOUT 18 PERCENT
	BENCH TERRACES[c]......	240,000	--	240,000	14,000	14,000	13.4	13.4	
	TOTAL	$ 248,500	$ 3,150	$ 279,100	$ 18,050	$ 14,000	$ 17.2	$ 13.4	
3	WEED HARVESTING.....	$ 7,250	$ 1,050	$ 17,450[b]	$ 1,800	$ --	$ 1.7	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	ALGAE CONTROL.......	1,250	2,100	21,650[b]	2,250	--	2.1	--	ELIMINATE PUBLIC HEALTH HAZARDS
	BENCH TERRACES[c]......	240,000	--	240,000	14,000	14,000	13.4	13.4	REDUCE PHOSPHORUS INPUT BY ABOUT 62 PERCENT
	SANITARY SEWERAGE SYSTEM[d]...........	3,793,000	98,000	5,536,550	351,000	351,000	336.2	336.2	
	TOTAL	$4,041,500	$101,150	$5,815,650	$369,050	$365,000	$353.4	$349.6	
4	WEED HARVESTING.....	$ 7,250	$ 1,050	$ 17,450[b]	$ 1,800	$ --	$ 1.7	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	ALGAE CONTROL.......	1,250	2,100	21,650[b]	2,250	--	2.1	--	ELIMINATE PUBLIC HEALTH HAZARDS
	BENCH TERRACES[c]......	240,000	--	240,000	14,000	14,000	13.4	13.4	REDUCE PHOSPHORUS INPUT BY ABOUT 62 PERCENT
	SANITARY SEWERAGE SYSTEM[e]...........	3,810,480	84,440	5,323,980	337,440	337,440	323.2	323.2	
	TOTAL	$4,058,980	$ 87,590	$5,603,080	$355,490	$351,440	$340.4	$336.6	

[a]A POPULATION OF 1,044 PERSONS, REPRESENTING THE EXISTING LAKE-ORIENTED RESIDENT POPULATION, WAS USED FOR PER CAPITA COST CALCULATIONS. THE ESTIMATED SEASONAL LAKE-ORIENTED RESIDENT POPULATION IS 2,680; THE ESTIMATED SEASONAL PEAK LAKE-ORIENTED USER POPULATION IS 4,960.

[b]PRESENT WORTH CALCULATED UTILIZING A 6 PERCENT INTEREST RATE AND A 15-YEAR PROJECT LIFE. THE PRESENT WORTH OF ALL OTHER PLAN ELEMENTS WAS CALCULATED UTILIZING A 6 PERCENT RATE OF INTEREST AND A 50-YEAR PROJECT LIFE.

[c]INCLUDES THE CONSTRUCTION OF BENCH TERRACES OR THE INSTITUTION OF OTHER APPROPRIATE AGRICULTURAL LAND MANAGEMENT MEASURES ON APPROXIMATELY 2,000 ACRES OF AGRICULTURAL LAND TRIBUTARY TO THE LAKE.

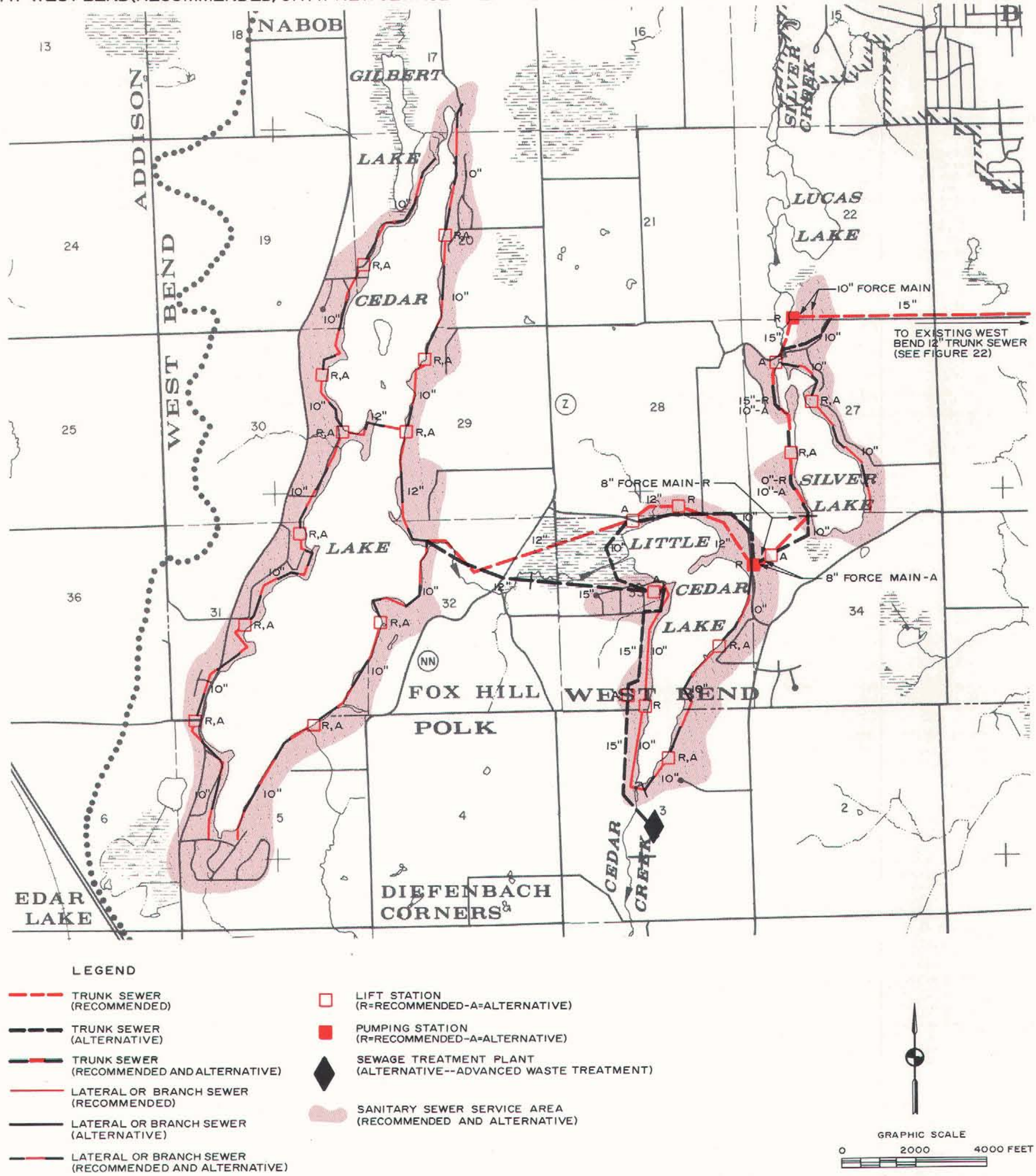
[d]ENTIRE LAKE SERVED (4,960 PERSONS); ADVANCED WASTE TREATMENT AT WEST BEND. THE COMPONENT CAPITAL COSTS OF THIS SANITARY SEWERAGE SYSTEM ARE- TREATMENT (ADVANCED) $309,700; TRUNK SEWERS $608,300; LATERAL AND BRANCH SEWERS $2,875,000.

[e]ENTIRE LAKE SERVED (4,960 PERSONS); ADVANCED WASTE TREATMENT AT NEW TRI-LAKES PLANT. THE COMPONENT CAPITAL COSTS OF THIS SANITARY SEWERAGE SYSTEM ARE- TREATMENT (ADVANCED) $557,000; TRUNK SEWERS $378,480; LATERAL, BRANCH, AND BUILDING SEWERS $2,875,000.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Map 50

RECOMMENDED AND ALTERNATIVE SANITARY SEWERAGE SYSTEMS FOR TRI-LAKES--ADVANCED WASTE TREATMENT AT WEST BEND (RECOMMENDED) OR AT NEW SEWAGE TREATMENT PLANT BELOW LITTLE CEDAR LAKE (ALTERNATIVE)



Two methods of providing sanitary sewer service to existing urban development ringing the shores of Big Cedar, Little Cedar, and Silver Lakes are shown on this map. The recommended method would provide for advanced waste treatment of the Tri-Lakes sewage at the City of West Bend sewage treatment plant. This method was found to be more economical than an alternate method under which a new sewage treatment plant providing advanced waste treatment would be constructed on Cedar Creek just below Little Cedar Lake to serve the Tri-Lakes area. In addition to being more economical, the recommended method would be in accord with the sound antiproliferation policy of the Wisconsin Department of Natural Resources with respect to sewage treatment plants.

Source: Harza Engineering Company and SEWRPC.

The second alternative considered was the construction of bench terraces on approximately 500 acres of agricultural land tributary to the lake. In addition, other appropriate agricultural land management practices would be applied on an additional 1,500 acres of agricultural land within the watershed area tributary to the lake. Weed harvesting and algae control would also be provided as in the first alternative. This alternative could be expected to reduce the total annual phosphorus input to Big Cedar Lake by up to 18 percent, or by 187 pounds per year.

The third alternative considered was the construction of a sanitary sewerage system to serve all of the 520 homes which are presently located along the entire shoreline of the lake (see Map 50). This alternative would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges. Treatment of the sanitary wastes under this alternative would be at an expanded plant providing advanced waste treatment in the City of West Bend. The sanitary wastes would be conveyed to the City of West Bend treatment plant by a system of trunk sewers which would also serve Little Cedar and Silver Lakes.[38] Construction of the sanitary sewerage system may be expected to result in a reduction of the total annual phosphorus input to the lake by about 44 percent, or by 458 pounds per year. Weed harvesting, algae control, and bench terracing and other appropriate agricultural land management measures would also be provided as in the first and second alternatives. This alternative could be expected to reduce the total annual phosphorus input to Big Cedar Lake by up to 62 percent, or by 645 pounds per year.

The fourth alternative considered also provides for the construction of a sanitary sewerage system to serve the existing urban development along the shoreline of Big Cedar Lake but provides for treatment of the sewage at a new sewage treatment plant constructed to serve only Big Cedar Lake, Little Cedar Lake, and Silver Lake (see Map 50). This proposed plant would provide advanced waste treatment for nutrient removal, as would the West Bend plant. In addition, this alternative would provide weed harvesting, algae control, and bench terracing. In terms of anticipated phosphorus reduction, this alternative would perform equally as well as the third alternative.

It is recommended that the third alternative plan element considered, including weed harvesting, algae control, bench terracing and other appropriate agricultural land management measures, and a sanitary sewerage system with advanced waste treatment provided at the City of West Bend sewage treatment plant, be included in the recommended watershed plan. The fourth alternative, while performing equally as well as the third alternative, was not recommended since treatment of sewage at a new sewage treatment facility to serve the Tri-Lakes area would be more costly than treating the wastes at the City of West Bend treatment facility.

Crooked Lake: Crooked Lake is an elongated, irregularly shaped lake with a large main basin and a smaller basin connected by a broad channel. The entire lake lies within the official project boundaries of the Northern Unit of the Kettle Moraine State Forest. There are 72 private homes presently located around the shoreline of the lake. Recreational use of the lake is severely restricted by dense weed growths. The lake is an important nesting and feeding area for waterfowl during the migratory period. The major nutrient sources are agricultural runoff and septic tank effluent (see Table 75).

Table 75

SELECTED CHARACTERISTICS OF CROOKED LAKE, SHEBOYGAN AND FOND DU LAC COUNTIES: 1967

CHARACTERISTIC	DESCRIPTION
TRIBUTARY DRAINAGE AREA	7.9 SQUARE MILES
SURFACE AREA	91.4 ACRES
SHORELINE	2.25 MILES
DEPTH	
UNDER 3 FEET	17 PERCENT
OVER 20 FEET	30 PERCENT
VOLUME	1,100 ACRE-FEET
LAKE-ORIENTED RESIDENT POPULATION	228
SEASONAL RESIDENT POPULATION	315
SEASONAL PEAK POPULATION	400
PHOSPHORUS SOURCES	MANURED LAND 81 LBS.[a] 31% RURAL RUNOFF 112 43 SEPTIC TANKS 36 14 OTHER[b] 31 12 TOTAL 260 LBS. 100%
GENERAL WATER QUALITY	HIGHEST WEED CONCENTRATION OF ALL MAJOR LAKES IN THE MILWAUKEE RIVER WATERSHED MODERATE NUTRIENT CONCENTRATIONS

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

[38]*Big Cedar Lake, Little Cedar Lake, and Silver Lake comprise the Tri-Lakes sewer service area referred to in an earlier section of this chapter dealing with alternative stream water quality management plan elements for the upper Milwaukee River watershed.*

Three alternative water quality management plan elements were considered for Crooked Lake. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake. The weed harvesting would have to be conducted in a carefully planned manner so that the excessive weed growths eliminated would not be replaced by algal blooms (see Table 76).

The second alternative considered was the construction of bench terraces on approximately 300 acres of agricultural land tributary to the lake. In addition, other appropriate agricultural land management practices would be applied on an additional 600 acres of agricultural land within the lake watershed. This alternative could be expected to reduce the total annual phosphorus input to the lake by up to 31 percent, or by 81 pounds per year. Weed harvesting would also be provided as in the first alternative.

The third alternative considered was the construction of a sanitary sewerage system and treatment facility to serve the 72 private homes which are presently located along the northeastern shoreline of the lake (see Map 51). The treatment plant would provide secondary waste treatment. This alternative would eliminate all discharge of waste from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges. Construction of the sanitary sewerage system may be expected to result in a reduction of the total annual phosphorus input to the lake by about 14 percent, or by 36 pounds per year. Weed harvesting and bench terracing would also be provided as in the first and second alternatives. This alternative could be expected to reduce the total annual phosphorus input to Crooked Lake by up to 45 percent, or by 117 pounds per year.

It is recommended that the second alternative plan element considered, including weed harvesting and bench terracing and other appropriate agricultural land management measures, be included in the recommended watershed plan. The provision of a sanitary sewerage system was not recommended because less than 14 percent of the total annual phosphorus input to the lake was estimated to be contributed by the septic tank systems serving the existing residential development around the lake and because the entire lake lies within the project boundaries of the Northern Unit of the Kettle Moraine State Forest. It is not expected, therefore, that the lake-oriented resident population will increase from its present level, but, on the contrary, that completion of the public acquisition of the Kettle Moraine State Forest would lead to the eventual removal of the private residences around Crooked Lake and eliminate the need for a sanitary sewerage system.

Table 76

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS
CROOKED LAKE, SHEBOYGAN AND FOND DU LAC COUNTIES

ALTERNATIVE PLAN ELEMENT		ESTIMATED COST								ANTICIPATED PERFORMANCE
NUMBER DESIGNATION	DESCRIPTION	CAPITAL	ANNUAL OPERATION AND MAINTENANCE	PRESENT WORTH	TOTAL ANNUAL 1970-1985	TOTAL ANNUAL 1986-2020	ANNUAL PER CAPITA[a] 1970-1985	ANNUAL PER CAPITA[a] 1986-2020		
1	WEED HARVESTING.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 2.2	$ --		CONTROL AQUATIC NUISANCE GROWTHS
	TOTAL	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ 2.2	$ --		
2	WEED HARVESTING.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 2.2	$ --		CONTROL AQUATIC NUISANCE GROWTHS
	BENCH TERRACES[c]......	110,000	--	110,000	7,000	7,000	31.1	31.1		REDUCE PHOSPHORUS INPUT BY ABOUT 31 PERCENT
	TOTAL	$112,100	$ 300	$115,000	$ 7,500	$ 7,000	$ 33.3	$ 31.1		
3	WEED HARVESTING.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 2.2	$ --		CONTROL AQUATIC NUISANCE GROWTHS
	BENCH TERRACES[c]......	110,000	--	110,000	7,000	7,000	31.1	31.1		REDUCE PHOSPHORUS INPUT BY ABOUT 45 PERCENT
	SANITARY SEWERAGE SYSTEM[d]...........	346,180	13,400	577,630	36,600	36,600	160.5	160.5		ELIMINATE PUBLIC HEALTH HAZARDS
	TOTAL	$458,280	$ 13,700	$692,630	$ 44,100	$ 43,600	$193.8	$191.6		

[a]A POPULATION OF 228 PERSONS, REPRESENTING THE EXISTING LAKE-ORIENTED RESIDENT POPULATION, WAS USED FOR PER CAPITA COST CALCULATIONS. THE ESTIMATED SEASONAL LAKE-ORIENTED RESIDENT POPULATION IS 315; THE ESTIMATED SEASONAL PEAK LAKE-ORIENTED USER POPULATION IS 400.

[b]PRESENT WORTH CALCULATED UTILIZING A 6 PERCENT INTEREST RATE AND A 15-YEAR PROJECT LIFE. THE PRESENT WORTH OF ALL OTHER PLAN ELEMENTS WAS CALCULATED UTILIZING A 6 PERCENT RATE OF INTEREST AND A 50-YEAR PROJECT LIFE.

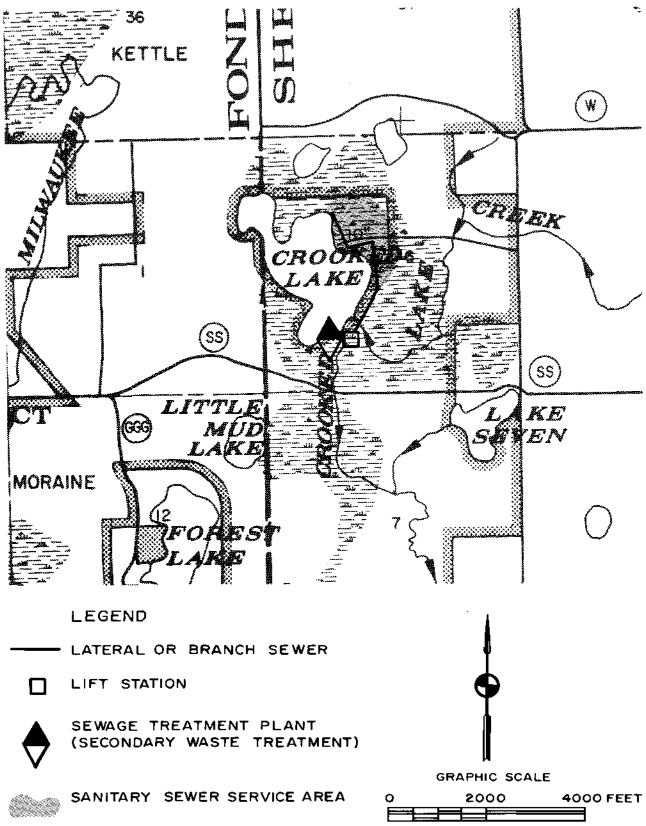
[c]INCLUDES THE CONSTRUCTION OF BENCH TERRACES OR THE INSTITUTION OF OTHER APPROPRIATE AGRICULTURAL LAND MANAGEMENT MEASURES ON APPROXIMATELY 900 ACRES OF AGRICULTURAL LAND TRIBUTARY TO THE LAKE.

[d]EAST SHORE OF LAKE SERVED (400 PERSONS); SECONDARY TREATMENT PLANT AT LAKE OUTLET. THE COMPONENT CAPITAL COSTS OF THE SANITARY SEWERAGE SYSTEM ARE- TREATMENT PLANT (SECONDARY) $87,750, LATERAL, BRANCH, AND BUILDING SEWERS $258,430.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Map 51

PROPOSED SANITARY SEWERAGE SYSTEM FOR CROOKED LAKE



Crooked Lake lies entirely within the official boundaries of the Northern Unit of the Kettle Moraine State Forest. There are, however, 72 private homes located along the shoreline of the lake. The sanitary sewerage system shown above was considered in the watershed study as an alternative plan element but was not recommended, since it was estimated that the phosphorus contribution to the lake from septic tank effluent constituted less than 15 percent of the total input from all sources. In addition, it is not expected that the lake-oriented population will increase from its present level because of its location in the Kettle Moraine State Forest.

Source: Harza Engineering Company and SEWRPC.

Ellen Lake: Lake Ellen is an elongated, single-basin "kettle" lake located in Sheboygan County. The lake is high in nutrient content during midsummer, a condition which could lead to algal blooms. Water quality for swimming and skin diving is usually good. The major nutrient sources are discharges from septic tank sewage disposal facilities serving the residential development around the lake and spring runoff from manured agricultural land (see Table 77).

Three alternative water quality management plan elements were considered for Lake Ellen. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake and the utilization of algicides to control algal growths that interfere with other recreational uses, as well as with the aesthetic enjoyment, of the lake (see Table 78).

The second alternative considered was the construction of bench terraces on approximately 100 acres of agricultural land tributary to the lake. In addition, other appropriate agricultural land management practices would be applied on an additional 100 acres of agricultural land within the watershed area tributary to the lake. Weed harvesting and algae control would be provided as in the first alternative. Under this second alternative, the total annual phosphorus input to Lake Ellen could be expected to be reduced by about 38 percent, or by 54 pounds per year.

The third alternative considered was the construction of a sanitary sewerage system to serve all of the 112 homes located along the northern, eastern, and southern shorelines of the lake (see Map 52). This alternative would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges.

Table 77

SELECTED CHARACTERISTICS OF ELLEN LAKE, SHEBOYGAN COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA	1.5	SQUARE MILES	
SURFACE AREA	121	ACRES	
SHORELINE	1.9	MILES	
DEPTH			
UNDER 3 FEET	15	PERCENT	
OVER 20 FEET	37	PERCENT	
VOLUME	1,689	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION	142		
SEASONAL RESIDENT POPULATION	380		
SEASONAL PEAK POPULATION	1,220		
PHOSPHORUS SOURCES	MANURED LAND	54 LBS.[a]	38%
	SEPTIC TANKS	46	32
	RURAL RUNOFF	24	17
	OTHER[b]	19	13
	TOTAL	143 LBS.	100%
GENERAL WATER QUALITY	MODERATE WEED AND ALGAE GROWTH; LOW NUTRIENT CONCENTRATIONS IN SPRING BUT RELATIVELY HIGH CONCENTRATIONS IN MID-SUMMER; EVIDENCE OF POLLUTION RELATED TO HIGH CONCENTRATIONS OF CHLORIDE AND SODIUM IONS		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Table 78

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS ELLEN LAKE, SHEBOYGAN COUNTY

Alternative Plan Element		Estimated Cost							Anticipated Performance
Number Designation	Description	Capital	Annual Operation and Maintenance	Present Worth	Total Annual 1970-1985	Total Annual 1986-2020	Annual per Capita[a] 1970-1985	Annual per Capita[a] 1986-2020	
1	Weed Harvesting.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 3.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	350	4,650[b]	500	--	3.5	--	
	Total	$ 3,350	$ 650	$ 9,650	$ 1,000	$ --	$ 7.0	$ --	
2	Weed Harvesting.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 3.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	350	4,650[b]	500	--	3.5	--	
	Bench Terraces[c]......	25,200	--	25,200	1,600	1,600	11.3	11.3	Reduce Phosphorus Inputs by About 38 Percent
	Total	$ 28,550	$ 650	$ 34,850	$ 2,600	$ 1,600	$ 18.3	$ 11.3	
3	Weed Harvesting.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 3.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	350	4,650[b]	500	--	3.5	--	
	Bench Terraces[c]......	25,200	--	25,200	1,600	1,600	11.3	11.3	Eliminate Public Health Hazards
	Sanitary Sewerage System[d]...........	735,800	47,300	907,000	104,800	104,800	738.0	738.0	Reduce Phosphorus Input by About 70 Percent
	Total	$ 764,350	$ 47,950	$ 941,850	$107,400	$106,400	$756.3	$749.3	

[a]A population of 142 persons, representing the existing lake-oriented resident population, was used for per capita cost calculations. The estimated seasonal lake-oriented resident population is 380, the estimated seasonal peak lake-oriented user population is 1,220.

[b]Present worth calculated utilizing a 6 percent interest rate and a 15-year project life. The present worth of all other plan elements was calculated utilizing a 6 percent rate of interest and a 50-year project life.

[c]Includes the construction of bench terraces or the institution of other appropriate agricultural land management measures on approximately 210 acres of agricultural land tributary to the lake.

[d]North, east, and south shores of lake served (1,200 persons); secondary treatment at proposed Cascade sewage treatment plant. The component capital costs of the sanitary sewerage system are- treatment (secondary) $179,000 (apportioned cost to lake-oriented residents); trunk sewers $118,400; lateral, branch, and building sewers $438,400.

Source- Harza Engineering Company and SEWRPC.

Treatment of the sanitary wastes under this alternative would be at a proposed sewage treatment plant in the Village of Cascade, which plant would provide secondary waste treatment. Construction of the sanitary sewerage system may be expected to result in the reduction of the total annual phosphorus input to the lake by about 32 percent, or by 46 pounds per year. Weed harvesting, algae control, and bench terracing would be provided as in the first and second alternatives. This alternative could be expected to reduce the total annual phosphorus input to Lake Ellen by up to 70 percent, or by 100 pounds per year.

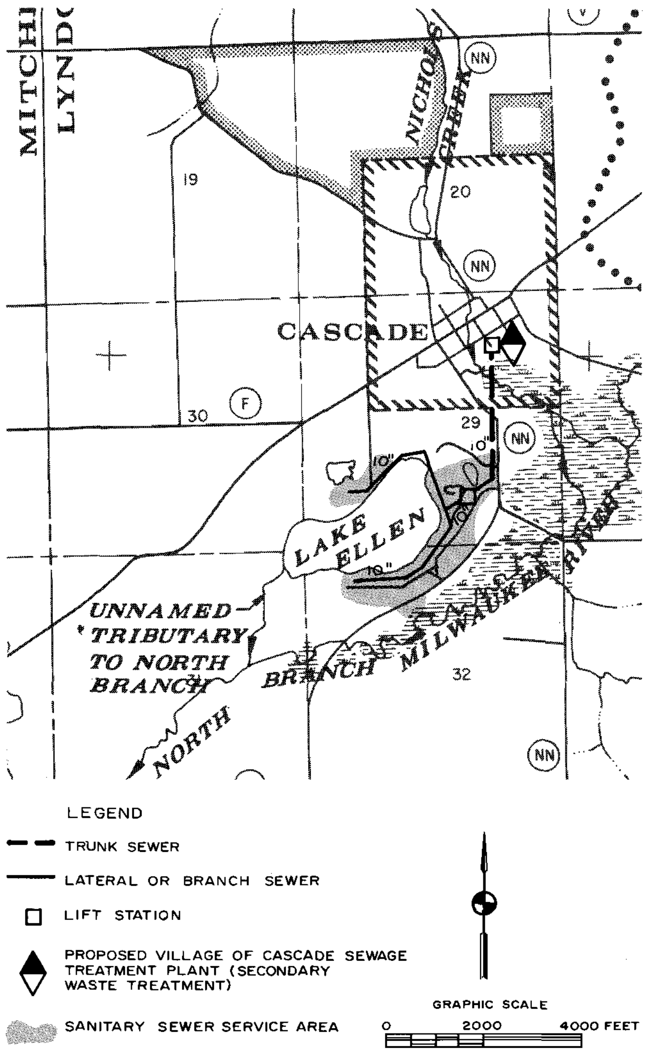
It is recommended that the third alternative plan element considered, including weed harvesting, algae control, bench terracing and other appropriate agricultural land management measures, and a sanitary sewerage system with secondary treatment of wastes at the proposed Village of Cascade sewage treatment plant, be included in the recommended watershed plan.

Forest Lake: Forest Lake is an elongated, single-basin "kettle" lake which has no stream outlet. The entire lake lies within the official project boundaries of the Northern Unit of the Kettle Moraine State Forest as established by the Wisconsin Department of Natural Resources. There are 49 private homes presently located around the shoreline of the lake, which receives extensive recreational use from the adjacent homeowners. Public use of the lake is limited by lack of access. Water quality, however, is generally suitable for all present uses of the lake (see Table 79). The Forest Lake watershed contributes to ground water flow and could contaminate the shallow ground water with discharges from individual septic tank sewage disposal systems. The major nutrient source is from septic tank sewage disposal facilities serving the residential development around the lake, which is estimated to contribute about 73 percent of the total annual phosphorus input of 62 pounds per year.

Two alternative water quality management plan elements were considered for Forest Lake. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake and the utilization of algicides to control algal growths that interfere with other recreational uses, as well as with the aesthetic enjoyment, of the lake (see Table 80).

Map 52

RECOMMENDED SANITARY SEWERAGE SYSTEM FOR ELLEN LAKE



The recommended construction of a sanitary sewerage system to serve Ellen Lake would serve to eliminate about one-third of the total annual phosphorus contribution to the lake and would, in addition, serve to eliminate any potential public health hazards. Sewage from the Lake Ellen area would be conveyed to a sewage treatment plant recommended in the plan to be constructed to serve the Village of Cascade for secondary treatment, with discharge of the treated effluent to an unnamed tributary of the North Branch of the Milwaukee River.

Source: Harza Engineering Company and SEWRPC.

The second alternative considered was the construction of a sanitary sewerage system and treatment facility to serve all of the 49 private homes which are presently located around the shoreline of the lake (see Map 53). The treatment plant, which would provide secondary waste treatment, would be located beyond the lake watershed and would discharge to a tributary of the East Branch of the Milwaukee River. This alternative would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges. Construction of the sanitary sewerage system may be expected to result in a reduction of the total annual phosphorus input to the lake by about 73 percent, or by 45 pounds per year. Weed harvesting and algae control would also be provided as in the first alternative.

Table 79

SELECTED CHARACTERISTICS OF FOREST LAKE, FOND DU LAC COUNTY: 1967

CHARACTERISTIC	DESCRIPTION
TRIBUTARY DRAINAGE AREA	C.3 SQUARE MILES
SURFACE AREA	50.5 ACRES
SHORELINE	1.3 MILES
DEPTH	
UNDER 3 FEET	12 PERCENT
OVER 20 FEET	18 PERCENT
VOLUME	552 ACRE-FEET
LAKE-ORIENTED RESIDENT POPULATION	80
SEASONAL RESIDENT POPULATION	265
SEASONAL PEAK POPULATION	580
PHOSPHORUS SOURCES	SEPTIC TANKS 45 LBS.[a] 73%
	MANURED LAND 8 13
	RURAL RUNOFF 2 3
	OTHER[b] 7 11
	TOTAL 62 LBS. 100%
GENERAL WATER QUALITY	MODERATE WEED GROWTH MODERATE NUTRIENT CONCENTRATIONS WATER QUALITY GENERALLY SUITABLE FOR MOST USES

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

It is recommended that the second alternative plan element considered, including weed harvesting, algae control, and a sanitary sewerage system with a sewage treatment plant discharging wastes beyond the lake watershed tributary area, be included in the comprehensive watershed plan, assuming that the private homes will remain on the lake. Completion of public acquisition of the Kettle Moraine State Forest would lead to the eventual removal of the private residences around Forest Lake and eliminate any need for a sanitary sewerage system.

Green Lake: Green Lake is an elongated, dual-basin "kettle" lake and is the second most heavily fished major lake in the Milwaukee River watershed. Sparse weed growths occur around the periphery, with greater concentrations along the

Table 80

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS
FOREST LAKE, FOND DU LAC COUNTY

Alternative Plan Element		Estimated Cost							Anticipated Performance
Number Designation	Description	Capital	Annual Operation and Maintenance	Present Worth	Total Annual 1970-1985	Total Annual 1986-2020	Annual per Capita[a] 1970-1985	Annual per Capita[a] 1986-2020	
1	Weed Harvesting.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 6.2	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	100	3,200[b]	350	--	4.4	--	
	Total	$ 3,350	$ 400	$ 8,200	$ 850	$ --	$ 10.6	$ --	
2	Weed Harvesting.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 6.2	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	100	3,200[b]	350	--	4.4	--	Eliminate Public Health Hazards
	Sanitary Sewerage System[c]...........	390,900	17,000	685,100	43,450	43,450	543.1	543.1	Reduce Phosphorus Input by About 70 Percent
	Total	$ 394,250	$ 17,400	$ 693,300	$ 44,300	$ 43,450	$553.7	$543.1	

[a]A population of 80 persons, representing the existing lake-oriented resident population, was used for per capita cost calculations. The estimated seasonal lake-oriented resident population is 265; the estimated seasonal peak lake-oriented user population is 580.

[b]Present worth calculated utilizing a 6 percent interest rate and a 15-year project life. The present worth of all other plan elements was calculated utilizing a 6 percent rate of interest and a 50-year project life.

[c]Entire lake served (580 persons); secondary treatment plant discharging to Crooked Lake Creek. The component capital costs of the sanitary sewerage system are- treatment plant (secondary) $112,300; trunk sewers $50,600; lateral, branch, and building sewers $228,000.

Source- Harza Engineering Company and SEWRPC.

northeast shore. These growths do not seriously restrict swimming activities at the private beaches. Green Lake is low in nutrient content, as measured by spring phosphate levels. The major nutrient source is from septic tank sewage disposal facilities serving the residential development around the lake (see Table 81). There are 85 private homes along the north, west, and south shorelines of the lake. These homes are generally located on small lots inadequate for the safe absorption of septic tank effluent. The lake-oriented population is expected to increase by about 20 percent from 1970 to 1990.

Only one water quality management plan alternative was considered for Green Lake. It is recommended that a sanitary sewerage system be provided for the entire lake, with a treatment plant discharging to a wetland area immediately southwest of the lake (see Map 54). The treatment plant would provide secondary waste treatment. The costs for this water quality management plan are shown in Table 82. Construction of the sanitary sewerage system may be expected to eliminate potential hazard to public health associated with individual sewage disposal systems. This alternative could be expected to reduce the total annual phosphorus input to Green Lake by up to 58 percent, or by 63 pounds per year.

Kettle Moraine Lake: Kettle Moraine Lake is located at the extreme headwater of the main stem of the Milwaukee River. There are 115 private homes presently located around nearly the entire shoreline of the lake which receives extensive private recreational use. Public use of the lake, however, is limited by lack of access. Recreational activities are limited by dense growths of weeds in the shallow areas of the lake. The lake has moderate nutrient concentrations based on spring phosphate levels. The major source of phosphorus is effluent from individual septic tank sewage disposal systems (see Table 83).

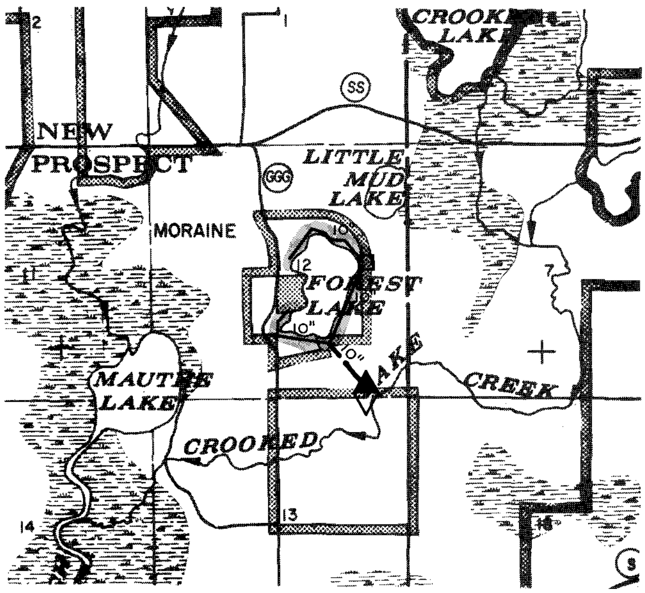
Two alternative water quality management plan elements were considered for Kettle Moraine Lake. The first alternative considered was the provision of weed harvesting to eliminate the excessive weed growths that interfere with certain recreational uses of the lake (see Table 84).

The second alternative considered was the construction of a sanitary sewerage system and treatment facility to serve the 115 private homes which are presently located around the entire shoreline of the lake (see Map 55). The treatment facility, which would provide secondary waste treatment, would be located downstream from nearby Mud Lake. Weed harvesting would also be provided as in the first alternative. This alternative could be expected to reduce the total annual phosphorus input to Kettle Moraine Lake by up to 33 percent, or by 38 pounds per year.

It is recommended that the second alternative plan element, including weed harvesting and sanitary sewerage system with a treatment facility discharging below the outlet of Mud Lake, be included in the recommended comprehensive watershed plan.

Map 53

RECOMMENDED SANITARY SEWERAGE SYSTEM FOR FOREST LAKE



LEGEND

TRUNK SEWER

LATERAL OR BRANCH SEWER

LIFT STATION

SEWAGE TREATMENT PLANT (SECONDARY WASTE TREATMENT)

SANITARY SEWER SERVICE AREA

GRAPHIC SCALE 0 2000 4000 FEET

It is estimated that over 70 percent of the total annual phosphorus input to Forest Lake is contributed by septic tank effluent from the 49 private homes located around the lake. Construction of the recommended sanitary sewerage system and treatment facility shown above would eliminate this major nutrient source, as well as eliminate any potential for public health hazards that may arise from malfunctioning septic tank sewage disposal systems. The treated wastes would receive secondary treatment prior to discharge to an unnamed tributary of the East Branch of the Milwaukee River. Since the entire lake lies within the project boundaries of the Kettle Moraine State Forest, it is not expected that the lake-oriented population will increase significantly in the next 20 years. Completion of the public acquisition of the Kettle Moraine State Forest would lead to the eventual removal of the private homes on Forest Lake and eliminate any need for a sanitary sewerage system.

Source: Harza Engineering Company and SEWRPC.

Table 81

SELECTED CHARACTERISTICS OF GREEN LAKE, WASHINGTON COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA	0.7 SQUARE MILES		
SURFACE AREA	71 ACRES		
SHORELINE	1.8 MILES		
DEPTH			
UNDER 3 FEET	11 PERCENT		
OVER 20 FEET	38 PERCENT		
VOLUME	1,195 ACRE-FEET		
LAKE-ORIENTED RESIDENT POPULATION	50		
SEASONAL RESIDENT POPULATION	340		
SEASONAL PEAK POPULATION	670		
PHOSPHORUS SOURCES	SEPTIC TANKS	63 LBS.[a]	58%
	MANURED LAND	26	24
	RURAL RUNOFF	10	9
	OTHER[b]	10	9
	TOTAL	109 LBS.	100%
GENERAL WATER QUALITY	SPARSE WEED GROWTH ALONG PERIPHERY LOW NUTRIENT CONCENTRATIONS *WATER QUALITY GENERALLY SUITABLE* FOR MOST USES		

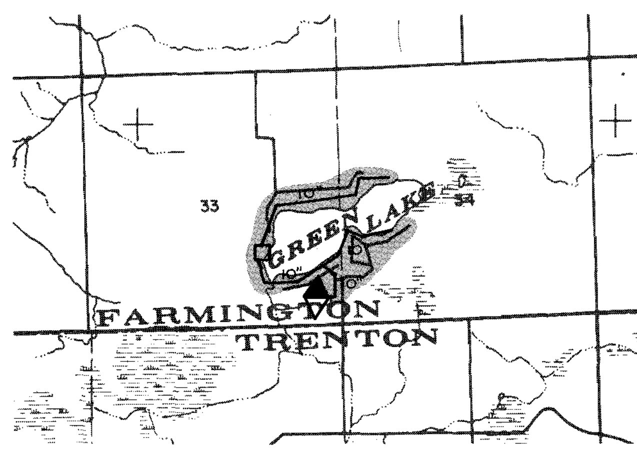
[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Map 54

RECOMMENDED SANITARY SEWERAGE SYSTEM FOR GREEN LAKE



LEGEND

LATERAL OR BRANCH SEWER

LIFT STATION

SEWAGE TREATMENT PLANT (SECONDARY WASTE TREATMENT)

SANITARY SEWER SERVICE AREA

GRAPHIC SCALE 0 2000 4000 FEET

The recommended sanitary sewerage system plan for Green Lake would provide sewerage service to the entire lake-oriented community. The sewage treatment plant would discharge to a seepage pond located in the wetland area south of the lake and would, therefore, not directly enter any surface watercourses. Construction of such a sanitary sewerage system would assist in maintaining good lake water quality for recreational uses by eliminating any potential public health hazards due to malfunctioning septic tank sewage disposal systems, as well as reducing the total nutrient input to the lake.

Source: Harza Engineering Company and SEWRPC.

Table 82

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS
GREEN LAKE, WASHINGTON COUNTY

Alternative Plan Element: Number Designation	Alternative Plan Element: Description	Estimated Cost: Capital	Estimated Cost: Annual Operation and Maintenance	Estimated Cost: Present Worth[a]	Total Annual: 1970-1985	Total Annual: 1986-2020	Annual Per Capita[b]: 1970-1985	Annual Per Capita[b]: 1986-2020	Anticipated Performance
1	Sanitary Sewerage System[c]...........	$ 524,800	$ 16,750	$ 819,700	$ 51,900	$ 51,900	$1,038.0	$1,038.0	Eliminate Public Health Hazards Reduce Phosphorus Input by 58 Percent
	Total	$ 524,800	$ 16,750	$ 819,700	$ 51,900	$ 51,900	$1,038.0	$1,038.0	

[a]Present worth calculated utilizing a 6 percent interest rate and a 50-year project life.

[b]A population of 50 persons, representing the existing lake-oriented resident population, was used for per capita cost calculations. The estimated seasonal lake-oriented resident population is 340; the estimated seasonal peak lake-oriented user population is 670.

[c]Entire lake served (670 persons), secondary treatment plant near lake outlet. The component capital costs of the sanitary sewerage system are- treatment plant (secondary) $132,800; lateral, branch, and building sewers $392,000.

Source- Harza Engineering Company and SEWRPC.

Table 83

SELECTED CHARACTERISTICS OF
KETTLE MORAINE LAKE,
FOND DU LAC COUNTY:
1967

Characteristic	Description
Tributary Drainage Area............	2.8 Square Miles
Surface Area........................	230 Acres
Shoreline............................	3.0 Miles
Depth	
Under 3 Feet....................	20 Percent
Over 20 Feet....................	1 Percent
Volume..............................	1,340 Acre-Feet
Lake-Oriented Resident Population..	56
Seasonal Resident Population.......	420
Seasonal Peak Population...........	790
Phosphorus Sources.................	Septic Tanks 38 Lbs.[a] 33% Manured Land 17 15 Rural Runoff 7 5 Other[b] 53 47 Total 115 Lbs. 100%
General Water Quality..............	Dense Weed Growth Attributed to Shallow Depth Moderate Nutrient Concentrations Turbid Water Conditions at Times Caused by Extensive Wetland Drainage

[a]Pounds of phosphorus contributed annually by the indicated sources.

[b]Precipitation and ground water.

Source- Harza Engineering Company and Wisconsin Department of Natural Resources.

Little Cedar Lake: Little Cedar Lake is the third largest natural lake within the Milwaukee River watershed and receives extensive recreational use by lake-oriented resident households occupying the extensive residential development surrounding the lake. Public use, however, is limited by lack of access. Little Cedar Lake is high in nutrient content, as measured by spring phosphate levels, a condition which could lead to algal blooms. The major nutrient sources are discharges from septic tank sewage disposal facilities serving the residential development around the lake and agricultural runoff (see Table 85).

The upland soils surrounding the lake are generally suitable for the use of on-site sewage disposal systems, but many residences are located immediately on the lakeshore, where high ground water conditions may interfere with proper operations of the septic tank systems. There is evidence of high coliform counts based on a survey

Table 84

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS
KETTLE MORAINE LAKE, FOND DU LAC COUNTY

Alternative Plan Element: Number Designation	Alternative Plan Element: Description	Estimated Cost: Capital	Estimated Cost: Annual Operation and Maintenance	Estimated Cost: Present Worth	Total Annual: 1970-1985	Total Annual: 1986-2020	Annual Per Capita[a]: 1970-1985	Annual Per Capita[a]: 1986-2020	Anticipated Performance
1	Weed Harvesting.....	$ 6,200	$ 900	$ 14,950[b]	$ 1,550	$ --	$ 27.7	$ --	Control Aquatic Nuisance Growths
	Total	$ 6,200	$ 900	$ 14,950	$ 1,550	$ --	$ 27.7	$ --	
2	Weed Harvesting.....	$ 6,200	$ 900	$ 14,950[b]	$ 1,550	$ --	$ 27.7	$ --	Control Aquatic Nuisance Growths
	Sanitary Sewerage System[c]............	934,100	23,200	1,332,700	84,500	84,500	1,508.9	1,508.9	Eliminate Public Health Hazards
	Total	$ 940,300	$ 24,100	$1,347,650	$ 86,050	$ 84,500	$1,536.6	$1,508.9	

[a]A population of 56 persons, representing the existing lake-oriented resident population, was used for per capita cost calculations. The estimated seasonal lake-oriented resident population is 420; the estimated seasonal peak lake-oriented user population is 790.

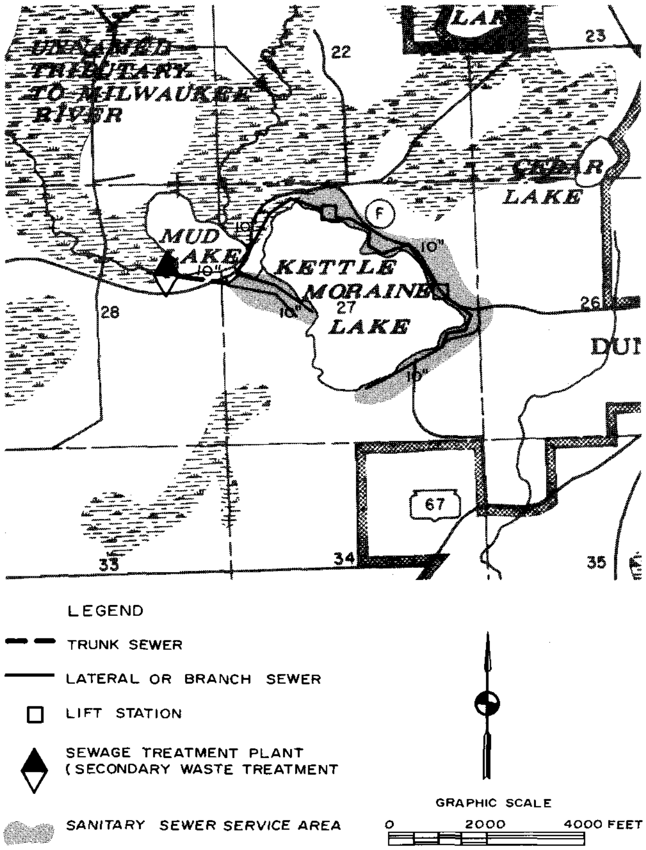
[b]Present worth calculated utilizing a 6 percent interest rate and a 15-year project life. The present worth for all other plan elements was calculated utilizing a 6 percent rate of interest and a 50-year project life.

[c]Entire lake served (790 persons); secondary treatment plant below outlet of Mud Lake. The component capital costs of the sanitary sewerage system are- treatment plant (secondary) $139,700; trunk sewers $94,700; lateral, branch, and building sewers $699,700.

Source- Harza Engineering Company and SEWRPC.

Map 55

RECOMMENDED SANITARY SEWERAGE SYSTEM FOR KETTLE MORAINE LAKE



The entire lake-oriented community, consisting of 115 homes located almost entirely surrounding the lake, would be served by the recommended sanitary sewerage system shown above. The secondary level sewage treatment facility would be located downstream from adjacent Mud Lake and would discharge to an unnamed tributary of the Milwaukee River main stem. The provision of a sanitary sewerage system would greatly assist in improving and maintaining the lake water quality for recreational uses by eliminating any potential public health hazards due to malfunctioning septic tank sewage disposal systems. It would also serve to reduce the nutrient input to the lake.

Source: Harza Engineering Company and SEWRPC.

made during the summer of 1968 by the Wisconsin Department of Natural Resources. The need to protect this large body of water against a potential hazard to public health makes the provision of a sanitary sewerage system around the lake highly desirable, especially since the urbanization around the lake is at a high density. The proximity of the City of West Bend, with its large central sewage treatment facility, presents an opportunity for the economical provision of sewage treatment.

Table 85

SELECTED CHARACTERISTICS OF LITTLE CEDAR LAKE, WASHINGTON COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA............	3.7	SQUARE MILES	
SURFACE AREA.......................	246	ACRES	
SHORELINE..........................	3.3	MILES	
DEPTH			
UNDER 3 FEET..................	17	PERCENT	
OVER 20 FEET..................	37	PERCENT	
VOLUME.............................	3,153	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION..	140		
SEASONAL RESIDENT POPULATION.......	610		
SEASONAL PEAK POPULATION...........	1,510		
PHOSPHORUS SOURCES.................	MANURED LAND	50 LBS.[a]	20%
	SEPTIC TANKS	105	42
	RURAL RUNOFF	63	25
	OTHER[b]	32	13
	TOTAL	250 LBS.	100%
GENERAL WATER QUALITY..............	MODERATE WEED AND ALGAE GROWTH HIGH NUTRIENT CONCENTRATIONS EVIDENCE OF HIGH COLIFORM BACTERIA COUNTS		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Four alternative lake water quality management plan elements were considered for Little Cedar Lake. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake and the utilization of algicides to control algal growths that interfere with other recreational uses, as well as with the aesthetic enjoyment, of the lake (see Table 86).

The second alternative considered was the institution of appropriate agricultural land management practices on about 525 acres of agricultural land tributary to Little Cedar Lake. Because of the undulating character of the land area around Little Cedar Lake, bench terraces would probably not be suitable for this particular lake watershed. Weed harvesting and algae control would also be provided as in the first alternative. This alternative could be expected to reduce the total annual phosphorus input to Little Cedar Lake by up to 20 percent, or 50 pounds per year.

The third alternative considered was the construction of a sanitary sewerage system to serve all of the 190 homes which are presently located along the entire shoreline of the lake (see Map 50). This alternative would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges.

Table 86

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENT LITTLE CEDAR LAKE, WASHINGTON COUNTY

Alternative Plan Element		Estimated Cost							
Number Designation	Description	Capital	Annual Operation and Maintenance	Present Worth	Total Annual		Annual per Capita[a]		Anticipated Performance
					1970-1985	1986-2020	1970-1985	1986-2020	
1	Weed Harvesting......	$ 4,150	$ 600	$ 10,000[b]	$ 1,050	$ --	$ 7.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	600	7,100[b]	750	--	5.3	--	
	Total	$ 5,400	$ 1,200	$ 17,100	$ 1,800	$ --	$ 12.8	$ --	
2	Weed Harvesting......	$ 4,150	$ 600	$ 10,000[b]	$ 1,050	$ --	$ 7.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	600	7,100[b]	750	--	5.3	--	
	Bench Terraces[c]......	63,000	--	63,000	4,000	4,000	28.6	28.6	Reduce Phosphorus Input by About 40 Percent
	Total	$ 68,400	$ 1,200	$ 80,100	$ 5,800	$ 4,000	$ 41.4	$ 28.6	
3	Weed Harvesting......	$ 4,150	$ 600	$ 10,000[b]	$ 1,050	$ --	$ 7.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	600	7,100[b]	750	--	5.3	--	
	Bench Terraces[c]......	63,000	--	63,000	4,000	4,000	28.6	28.6	Eliminate Public Health Hazards
	Sanitary Sewerage System[d]...........	1,362,700	28,720	1,875,320	118,720	118,720	848.0	848.0	Reduce Phosphorus Input by About 70 Percent
	Total	$1,431,100	$ 29,920	$1,955,420	$124,520	$122,720	$889.4	$876.6	
4	Weed Harvesting......	$ 4,150	$ 600	$ 10,000[b]	$ 1,050	$ --	$ 7.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	600	7,100[b]	750	--	5.3	--	
	Bench Terraces[c]......	63,000	--	63,000	4,000	4,000	28.6	28.6	Eliminate Public Health Hazards
	Sanitary Sewerage System[e]...........	1,315,900	24,720	1,760,250	111,520	111,520	796.6	796.6	Reduce Phosphorus Input by About 70 Percent
	Total	$1,384,300	$ 25,920	$1,840,350	$117,320	$115,520	$838.0	$825.2	

[a] A population of 140 persons, representing the existing lake-oriented resident population, was used for per capita cost calculations. The estimated seasonal lake-oriented resident population is 610; the estimated seasonal peak lake-oriented user population is 1,510.

[b] Present worth calculated utilizing a 6 percent interest rate and a 15-year project life. The present worth of all other plan elements was calculated utilizing a 6 percent rate of interest and a 50-year project life.

[c] Includes the construction of bench terraces or the institution of other appropriate agricultural land management measures on approximately 525 acres of agricultural land tributary to the lake.

[d] Entire lake served (1,510 persons); advanced waste treatment at West Bend. The component capital costs of this sanitary sewerage system are- treatment (advanced) $90,700; trunk sewers $328,000; lateral and branch sewers $944,000.

[e] Entire lake served (1,510 persons); advanced waste treatment at new Tri-Lakes plant. The component capital costs of this sanitary sewerage system are- treatment (advanced) $163,000; trunk sewers $208,900; lateral, branch, and building sewers $944,000.

Source- Harza Engineering Company and SEWRPC.

Treatment of the sanitary wastes under this alternative would be at an expanded plant providing advanced waste treatment in the City of West Bend. The sanitary wastes would be conveyed to the City of West Bend treatment plant by a system of trunk sewers which would also serve Big Cedar and Silver Lakes. Construction of the sanitary sewerage system may be expected to result in a reduction of the total annual phosphorus input to the lake by about 42 percent, or by 105 pounds per year. Weed harvesting, algae control, and bench terracing and other appropriate agricultural land management measures would also be provided as in the first and second alternatives. This alternative could be expected to reduce the total annual phosphorus input to Little Cedar Lake by up to 62 percent, or by 155 pounds per year.

The fourth alternative considered also provides for the construction of a sanitary sewerage system to serve the existing urban development along the shoreline of Little Cedar Lake but provides for treatment of the sewage at a new sewage treatment plant constructed to serve only Big Cedar Lake, Little Cedar Lake, and Silver Lake (see Map 50). This proposed plant would provide advanced waste treatment for nutrient removal, as would the West Bend plant. In addition, this alternative would provide weed harvesting, algae control, and bench terracing and other appropriate agricultural land management measures. In terms of phosphorus reduction, this alternative would perform equally as well as the third alternative.

It is recommended that the third alternative plan element considered, including weed harvesting, algae control, bench terracing and other appropriate agricultural land management measures, and a sanitary sewerage system with advanced waste treatment provided at the City of West Bend sewage treatment plant, be included in the recommended watershed plan. The fourth alternative, while performing equally as well as the third alternative, was not recommended since treatment of sewage at a new sewage treatment facility to serve the Tri-Lakes area would be more costly than treating the wastes at the City of West Bend treatment facility.

Long Lake: Long Lake is the second largest lake in the Milwaukee River watershed and is located in the extreme headwater region of the East Branch of the Milwaukee River. The lake is partially encompassed by the official project boundaries of the Northern Unit of the Kettle Moraine State Forest, as established by the Wisconsin Department of Natural Resources. The Long Lake State Recreation Area, a major regional public outdoor recreation area, is located along the eastern shore of the lake. There are 271 private homes presently located around the shoreline of the lake, which receives extensive recreational use from the private residences on the lake and from the public outdoor recreation area. Water quality is generally suitable for most present uses of the lake. Long Lake has moderate weed growths; however, algae growths have not reached nuisance levels. The major nutrient source is spring runoff from manured agricultural land (see Table 87).

Three alternative water quality management plan elements were considered for Long Lake. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake (see Table 88). Algae control is not required at this time.

The second alternative considered was the construction of bench terraces on approximately 500 acres of agricultural land tributary to the lake. In addition, other appropriate agricultural land management practices would be applied on an additional 1,050 acres of agricultural land within the lake watershed. Weed harvesting would also be provided as in the first alternative. This alternative could be expected to reduce the total annual phosphorus input to Long Lake by up to 58 percent, or 520 pounds per year.

Table 87

SELECTED CHARACTERISTICS OF LONG LAKE, FOND DU LAC COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA	14.6	SQUARE MILES	
SURFACE AREA	409	ACRES	
SHORELINE	6.4	MILES	
DEPTH			
UNDER 3 FEET	5	PERCENT	
OVER 20 FEET	42	PERCENT	
VOLUME	9,329	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION	744		
SEASONAL RESIDENT POPULATION	1,220		
SEASONAL PEAK POPULATION	2,240		
PHOSPHORUS SOURCES	MANURED LAND	520 LBS.[a]	58%
	RURAL RUNOFF	180	21
	SEPTIC TANKS	120	13
	OTHER[b]	74	8
	TOTAL	894 LBS.	100%
GENERAL WATER QUALITY	MODERATE WEED GROWTH MEDIUM NUTRIENT CONCENTRATIONS WATER QUALITY GENERALLY SUITABLE FOR MOST USES		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Table 88

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS LONG LAKE, FOND DU LAC COUNTY

ALTERNATIVE PLAN ELEMENT		ESTIMATED COST							
NUMBER DESIGNATION	DESCRIPTION	CAPITAL	ANNUAL OPERATION AND MAINTENANCE	PRESENT WORTH	TOTAL ANNUAL 1970-1985	TOTAL ANNUAL 1986-2020	ANNUAL PER CAPITA[a] 1970-1985	ANNUAL PER CAPITA[a] 1986-2020	ANTICIPATED PERFORMANCE
1	WEED HARVESTING	$ 4,150	$ 600	$ 10,000[b]	$ 1,050	$ --	$ 1.4	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	TOTAL	$ 4,150	$ 600	$ 10,000	$ 1,050	$ --	$ 1.4	$ --	
2	WEED HARVESTING	$ 4,150	$ 600	$ 10,000[b]	$ 1,050	$ --	$ 1.4	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	BENCH TERRACES[c]	186,000	--	186,000	11,800	11,800	15.9	15.9	REDUCE PHOSPHORUS INPUT BY ABOUT 60 PERCENT
	TOTAL	$ 190,150	$ 600	$ 196,000	$ 12,850	$ 11,800	$ 17.3	$ 15.9	
3	WEED HARVESTING	$ 4,150	$ 600	$ 10,000[b]	$ 1,050	$ --	$ 1.4	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	BENCH TERRACES[c]	186,000	--	186,000	11,800	11,800	15.9	15.9	ELIMINATE PUBLIC HEALTH HAZARDS
	SANITARY SEWERAGE SYSTEM[d]	1,800,300	53,000	2,738,900	173,800	173,800	233.6	233.6	REDUCE PHOSPHORUS INPUT BY ABOUT 70 PERCENT
	TOTAL	$1,990,450	$ 53,600	$2,934,900	$186,650	$185,600	$250.9	$249.5	

[a]A POPULATION OF 744 PERSONS, REPRESENTING THE EXISTING LAKE-ORIENTED RESIDENT POPULATION, WAS USED FOR PER CAPITA COST CALCULATIONS. THE ESTIMATED SEASONAL LAKE-ORIENTED RESIDENT POPULATION IS 1,220; THE ESTIMATED SEASONAL PEAK LAKE-ORIENTED USER POPULATION IS 2,240.

[b]PRESENT WORTH CALCULATED UTILIZING A 6 PERCENT INTEREST RATE AND A 15-YEAR PROJECT LIFE. THE PRESENT WORTH FOR ALL OTHER PLAN ELEMENTS WAS CALCULATED UTILIZING A 6 PERCENT RATE OF INTEREST AND A 50-YEAR PROJECT LIFE.

[c]INCLUDES THE CONSTRUCTION OF BENCH TERRACES OR THE INSTITUTION OF OTHER APPROPRIATE AGRICULTURAL LAND MANAGEMENT MEASURES ON APPROXIMATELY 1,550 ACRES OF AGRICULTURAL LAND TRIBUTARY TO THE LAKE.

[d]ENTIRE LAKE SERVED, INCLUDING LONG LAKE STATE RECREATION AREA AND THE UNINCORPORATED COMMUNITY OF DUNDEE (2,640 PERSONS); SECONDARY TREATMENT PLANT AT DUNDEE. THE COMPONENT CAPITAL COSTS OF THE SANITARY SEWERAGE SYSTEM ARE- TREATMENT PLANT (SECONDARY) $374,700; TRUNK SEWERS $140,600, LATERAL, BRANCH, AND BUILDING SEWERS $1,285,000.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

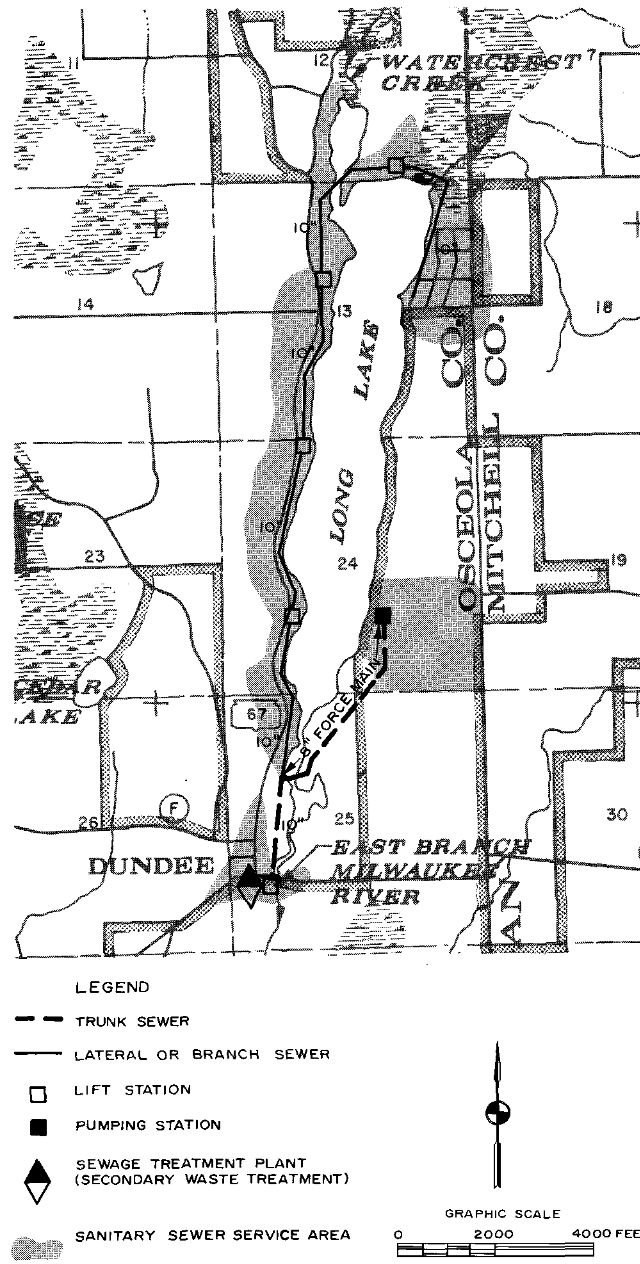
The third alternative considered was the construction of a sanitary sewerage system and treatment facility to serve all of the 271 private homes presently located along the shoreline of the lake, as well as the major state outdoor recreational area (see Map 56). The treatment facility would be located below the lake near the unincorporated community of Dundee and would be sized to serve the existing development in Dundee. This alternative would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges. Construction of the sanitary sewerage system may be expected to result in a reduction of the total annual phosphorus input to the lake by about 13 percent, or by 120 pounds per year. Weed harvesting and bench terracing would also be provided as in the first and second alternatives. This alternative could be expected to reduce the total annual phosphorus input to Long Lake by up to 71 percent, or by 640 pounds per year.

It is recommended that the second alternative plan element considered, including weed harvesting and bench terracing and other appropriate agricultural land management measures, be included in the recommended watershed plan. The provision of a sanitary sewerage system was not recommended because less than 15 percent of the phosphorus input to the lake was estimated to be contributed by the septic tank systems serving the existing residential development around the lake. Because of the high population concentrations around the lake, particularly during the summer season, it is recommended that a water quality monitoring program be pursued to determine whether or not, at some time in the future, a sanitary sewerage system should be constructed.

Lucas Lake: Lucas Lake is located on Silver Creek near the City of West Bend. There are only five private homes presently located around the shoreline of the lake, with the major development on the lakeshore being an organizational camp. The major recreational use during the summer season is pleasure boating by small, nonpowered craft. There is no public access to recreational use. Lucas Lake is low in nutrient content, as measured by spring phosphate levels. The major nutrient source is agricultural runoff (see Table 89).

Map 56

PROPOSED SANITARY SEWERAGE SYSTEM FOR LONG LAKE



Long Lake lies partially within the official project boundaries of the northern unit of the Kettle Moraine State Forest and serves as the principal attraction of the Long Lake State Recreation Area, one of the five existing major public outdoor recreation sites in the watershed. The western and northern shores of the lake are lined with 271 private homes. The sanitary sewerage system shown above would serve those homes, the Long Lake State Recreation Area, and the unincorporated community of Dundee. This sewerage system was not recommended for inclusion in the comprehensive watershed plan, since it was estimated that the phosphorus contribution to the lake from septic tank effluent constituted less than 15 percent of the total input from all sources.

Source: Harza Engineering Company and SEWRPC.

Two alternative water quality management plan elements were considered for Lucas Lake. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake (see Table 90). Algae control is not required at the present time.

The second alternative considered was the institution of appropriate agricultural land management practices on about 350 acres of agricultural land tributary to the lake. This alternative could be expected to reduce phosphorus input to the lake by at least 50 percent, or by 40 pounds per year. Weed harvesting would also be provided as in the first alternative.

Table 89

SELECTED CHARACTERISTICS OF LUCAS LAKE, WASHINGTON COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA............	3.6 SQUARE MILES		
SURFACE AREA........................	78 ACRES		
SHORELINE...........................	2.39 MILES		
DEPTH			
UNDER 3 FEET....................	8.1 PERCENT		
OVER 20 FEET....................	0 PERCENT		
VOLUME..............................	461 ACRE-FEET		
LAKE-ORIENTED RESIDENT POPULATION..	20		
SEASONAL RESIDENT POPULATION.......	20		
SEASONAL PEAK POPULATION...........	20		
PHOSPHORUS SOURCES.................	RURAL RUNOFF	55 LBS.[a]	67%
	SEPTIC TANKS	16	20
	OTHER[b]	11	13
	TOTAL	82 LBS.	100%
GENERAL WATER QUALITY..............	DENSE SUBMERGED WEED GROWTH ATTRIBUTED TO SHALLOW DEPTH LOW NUTRIENT CONCENTRATIONS CLEAR WATER ALLOWS PHOTOSYNTHESIS AT DEPTHS GREATER THAN IS NORMALLY THE CASE		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

It is recommended that the second alternative plan element, including weed harvesting and the institution of appropriate agricultural land management practices to control phosphorus input to the lake, be included in the comprehensive watershed plan.

Mauthe Lake: Mauthe Lake is a circular-shaped lake with a single basin. The entire lake lies within the official project boundaries of the Northern Unit of the Kettle Moraine State Forest, as established by the Wisconsin Department of Natural Resources; and, in fact, the entire shoreline is in public ownership. Mauthe Lake receives extensive summer recreational use at a public beach at the state recreation area on the east shore.[39] Water quality for swimming and skin diving is fair, being hindered by algal blooms. The major nutrient source is spring runoff from manured agricultural lands (see Table 91).

Two alternative water quality management plan elements were considered for Mauthe Lake. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake and the utilization of algicides to control algal growths that interfere with other recreational uses, as well as with the aesthetic enjoyment, of the lake (see Table 92).

---

[39]*Sanitary facilities for the Mauthe Lake State Recreation Area consist of concrete pit holding tanks which are pumped and discharged to a sand filtration sewage disposal facility located near the bathhouse. This sewage disposal facility discharges effluent below the lake outlet.*

Table 90

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS LUCAS LAKE, WASHINGTON COUNTY

ALTERNATIVE PLAN ELEMENT		ESTIMATED COST								ANTICIPATED PERFORMANCE
NUMBER DESIGNATION	DESCRIPTION	CAPITAL	ANNUAL OPERATION AND MAINTENANCE	PRESENT WORTH	TOTAL ANNUAL 1970-1985	TOTAL ANNUAL 1986-2020	ANNUAL PER CAPITA[a] 1970-1985	ANNUAL PER CAPITA[a] 1986-2020		
1	WEED HARVESTING.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 25.0	$ --		CONTROL AQUATIC NUISANCE GROWTHS
	TOTAL	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ 25.0	$ --		
2	WEED HARVESTING.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 25.0	$ --		CONTROL AQUATIC NUISANCE GROWTHS
	BENCH TERRACES[c]......	42,000	--	42,000	2,600	2,600	130.0	130.0		REDUCE PHOSPHORUS INPUT BY ABOUT 50 PERCENT
	TOTAL	$ 44,100	$ 300	$ 47,000	$ 3,100	$ 2,600	$155.0	$130.0		

[a]A POPULATION OF 20 PERSONS, REPRESENTING THE EXISTING LAKE-ORIENTED RESIDENT POPULATION, WAS USED FOR PER CAPITA COST CALCULATIONS. THE ESTIMATED SEASONAL LAKE-ORIENTED RESIDENT POPULATION IS 20 PERSONS; THE ESTIMATED SEASONAL PEAK LAKE-ORIENTED USER POPULATION, NOT INCLUDING CAMPERS AT AN ORGANIZATIONAL CAMP, IS 20 PERSONS.

[b]PRESENT WORTH CALCULATED AT A 6 PERCENT INTEREST RATE AND A 15-YEAR PROJECT LIFE. THE PRESENT WORTH FOR ALL OTHER PLAN ELEMENTS WAS CALCULATED AT A 6 PERCENT RATE OF INTEREST AND A 50-YEAR PROJECT LIFE.

[c]INCLUDES THE CONSTRUCTION OF BENCH TERRACES OR THE INSTITUTION OF OTHER APPROPRIATE AGRICULTURAL LAND MANAGEMENT MEASURES ON APPROXIMATELY 350 ACRES OF AGRICULTURAL LAND TRIBUTARY TO THE LAKE.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

The second alternative considered was the construction of bench terraces and the institution of other appropriate agricultural land management measures on about 330 acres of agricultural land tributary to the lake. This alternative could be expected to reduce phosphorus input to the lake by up to 55 percent, or by 124 pounds per year. Weed harvesting and algae control would also be provided as in the first alternative.

It is recommended that the second alternative plan element considered for Mauthe Lake, including weed harvesting, algae control, and bench terracing and other appropriate agricultural land management measures, be included in the recommended comprehensive watershed plan.

Table 91

SELECTED CHARACTERISTICS OF MAUTHE LAKE, FOND DU LAC COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA	25.7 SQUARE MILES		
SURFACE AREA	78 ACRES		
SHORELINE	1.55 MILES		
DEPTH			
UNDER 3 FEET	9 PERCENT		
OVER 20 FEET	25 PERCENT		
VOLUME	961 ACRE-FEET		
LAKE-ORIENTED RESIDENT POPULATION	--		
SEASONAL RESIDENT POPULATION	--		
SEASONAL PEAK POPULATION	3,200		
PHOSPHORUS SOURCES	MANURED LAND	124 LBS.[a]	55%
	RURAL RUNOFF	45	20
	OTHER[b]	55	25
	TOTAL	224 LBS.	100%
GENERAL WATER QUALITY	DENSE WEED AND ALGAE GROWTH HIGH NUTRIENT CONCENTRATIONS BY EARLY SUMMER WATER QUALITY SUITABLE FOR MOST USES BUT ALGAL BLOOMS INTERFERE WITH RECREATIONAL ACTIVITIES		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Mud Lake (Fond du Lac County): Mud Lake is an irregular, oval-shaped drainage lake located in the headwater region of the main stem of the Milwaukee River. The shoreland is nearly all lowland swamp, which is unsuitable for urban development. There are no cottages directly on the shore of Mud Lake, and the lake receives little recreational use. The dense growths of aquatic vegetation, the amount of private shoreline ownership, and the lack of public access are the main deterrents to public recreational use. The major nutrient source is ground water inflow, which accounts for about 42 percent of the total phosphorus input, or 25 pounds per year. Spring runoff from manured agricultural land is estimated to account for about 32 percent of the total phosphorus input, or 19 pounds per year (see Table 93).

There is little potential for permanent control of aquatic nuisance growths, since ground water inflow would remain a constant source of nutrient input. There is no potential for swimming, with turbid water conditions, muck bottom shoreline, and abundant vegetation in the shallow shore waters. The use of Mud Lake for fishing and wildlife observation could be made more feasible for the general public through the acquisition and development of a public access. Shoreland zoning to protect the lake from homesite development on unsuitable soils should also be enacted.

No water quality management plan elements are recommended for Mud Lake, since a lake-oriented population should not develop and since nutrient inputs could not be substantially reduced by the management of the surface runoff.

Table 92

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS MAUTHE LAKE, FOND DU LAC COUNTY

ALTERNATIVE PLAN ELEMENT		ESTIMATED COST							ANTICIPATED PERFORMANCE
NUMBER DESIGNATION	DESCRIPTION	CAPITAL	ANNUAL OPERATION AND MAINTENANCE	PRESENT WORTH	TOTAL ANNUAL 1970-1985	TOTAL ANNUAL 1986-2020	ANNUAL PER CAPITA[a] 1970-1985	ANNUAL PER CAPITA[a] 1986-2020	
1	WEED HARVESTING	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ --	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	ALGAE CONTROL	1,250	350	4,650	500	--	--	--	
	TOTAL	$ 3,350	$ 650	$ 9,650[b]	$ 1,000	$ --	$ --	$ --	
2	WEED HARVESTING	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ --	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	ALGAE CONTROL	1,250	350	4,650	500	--	--	--	REDUCE PHOSPHORUS INPUT BY ABOUT 55 PERCENT
	BENCH TERRACING[c]	40,000	--	40,000	2,500	2,500	--	--	
	TOTAL	$ 43,350	$ 650	$ 49,650	$ 3,500	$ 2,500	--	--	

[a]SINCE THE ENTIRE LAKE SHORELINE IS IN PUBLIC OWNERSHIP AS PART OF THE NORTHERN UNIT OF THE KETTLE MORAINE STATE FOREST, THERE IS NO LAKE-ORIENTED RESIDENT POPULATION UPON WHICH TO BASE PER CAPITA COSTS. THE ESTIMATED SEASONAL PEAK LAKE-ORIENTED USER POPULATION AT THE MAUTHE LAKE STATE RECREATION AREA IS 3,200 PERSONS.

[b]PRESENT WORTH CALCULATED UTILIZING A 6 PERCENT INTEREST RATE AND A 15-YEAR PROJECT LIFE. THE PRESENT WORTH OF ALL OTHER PLAN ELEMENTS WAS CALCULATED UTILIZING A 6 PERCENT RATE OF INTEREST AND A 50-YEAR PROJECT LIFE.

[c]INCLUDES THE CONSTRUCTION OF BENCH TERRACES OR THE INSTITUTION OF OTHER APPROPRIATE AGRICULTURAL LAND MANAGEMENT MEASURES ON APPROXIMATELY 330 ACRES OF AGRICULTURAL LAND TRIBUTARY TO THE LAKE.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table 93

SELECTED CHARACTERISTICS OF MUD LAKE, FOND DU LAC COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA............	4.4	SQUARE MILES	
SURFACE AREA........................	55	ACRES	
SHORELINE...........................	1.4	MILES	
DEPTH			
UNDER 3 FEET....................	11	PERCENT	
OVER 20 FEET....................	0	PERCENT	
VOLUME..............................	452	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION..	--		
SEASONAL RESIDENT POPULATION.......	--		
SEASONAL PEAK POPULATION...........	--		
PHOSPHORUS SOURCES..................	MANURED LAND	19 LBS.[a]	32%
	RURAL RUNOFF	7	12
	OTHER[b]	33	56
	TOTAL	59 LBS.	100%
GENERAL WATER QUALITY..............	DENSE WEED GROWTH ATRIBUTED TO SHALLOW DEPTH AND POTENTIAL FOR ALGAL BLOOMS HIGH NUTRIENT CONCENTRATION TURBID WATER CONDITIONS AT TIMES CAUSED BY EXTENSIVE WETLAND DRAINAGE		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Mud Lake (Ozaukee County): Mud Lake in Ozaukee County is located within the Cedarburg Bog environmental laboratory maintained by the Wisconsin Department of Natural Resources. There is no present, and there should be no future, lake-oriented population. There is no potential for public recreational activities. The use of Mud Lake as a controlled wildlife and conservation area is its most important value, and such use should be maintained and enhanced. Selected characteristics of Mud Lake are shown in Table 94. It is recommended that Mud Lake continue to be used as a conservation area in its natural state.

Table 94

SELECTED CHARACTERISTICS OF MUD LAKE, OZAUKEE COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA............	7.4	SQUARE MILES	
SURFACE AREA........................	245	ACRES	
SHORELINE...........................	3.15	MILES	
DEPTH			
UNDER 3 FEET....................	45	PERCENT	
OVER 20 FEET....................	0	PERCENT	
VOLUME..............................	644	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION..	--		
SEASONAL RESIDENT POPULATION.......	--		
SEASONAL PEAK POPULATION...........	--		
PHOSPHORUS SOURCES[a]................	MANURED LAND	110 LBS.[b]	59%
	RURAL RUNOFF	40	22
	OTHER[c]	33	19
	TOTAL	183 LBS.	100%
GENERAL WATER QUALITY..............	DENSE WEED GROWTHS ATTRIBUTED TO SHALLOW DEPTH HIGH NUTRIENT CONCENTRATION LOCATED ENTIRELY WITHIN CEDARBURG BOG WILDLIFE AREA		

[a]ENTIRE CEDARBURG BOG.

[b]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[c]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Random Lake: Random Lake is an irregularly shaped "kettle" lake located in the headwater area of Silver Creek in Sheboygan County. The Village of Random Lake is located on the west shore. Homes along the shoreline within the Village are served by a public sanitary sewerage system, with a sewage treatment plant discharging to Silver Creek downstream of the Random Lake outlet. There are 60 private homes presently located around the shoreline of the lake and not served by a public sanitary sewerage system. Random Lake receives extensive private recreational use, hindered, however, by dense aquatic growths along the shoreline and at the north end of the lake near its outlet to Silver Creek. There is evidence of a pollution hazard related to the high concentrations of chloride and sodium ions. The major nutrient source is spring runoff from manured agricultural land, which is estimated to contribute about 45 percent of the total phosphorus input of 510 pounds per year (see Table 95).

Three alternative water quality management plan elements were considered for Random Lake. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake. Control of algae is not required at this time (see Table 96).

The second alternative considered was the construction of bench terraces and other appropriate agricultural land management measures

Table 95

SELECTED CHARACTERISTICS OF RANDOM LAKE, SHEBOYGAN COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA............	4.4	SQUARE MILES	
SURFACE AREA........................	209	ACRES	
SHORELINE...........................	3.6	MILES	
DEPTH			
UNDER 3 FEET....................	14	PERCENT	
OVER 20 FEET....................	4	PERCENT	
VOLUME..............................	1,280	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION..	1,130		
SEASONAL RESIDENT POPULATION.......	1,410		
SEASONAL PEAK POPULATION...........	1,680		
PHOSPHORUS SOURCES..................	MANURED LAND	230 LBS.[a]	45%
	URBAN RUNOFF	125	25
	RURAL RUNOFF	85	16
	SEPTIC TANKS	40	8
	OTHER[b]	30	6
	TOTAL	510 LBS.	100%
GENERAL WATER QUALITY..............	DENSE WEED GROWTH MODERATE NUTRIENT CONCENTRATION EVIDENCE OF POLLUTION RELATED TO HIGH CONCENTRATIONS OF CHLORIDE AND SODIUM IONS		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Table 96

ALTERNATIVE WATER QUALITY MANAGEMENT PLAN ELEMENTS
RANDOM LAKE, SHEBOYGAN COUNTY

Alternative Plan Element: Number Designation	Alternative Plan Element: Description	Estimated Cost: Capital	Estimated Cost: Annual Operation and Maintenance	Estimated Cost: Present Worth	Estimated Cost: Total Annual 1970-1985	Estimated Cost: Total Annual 1986-2020	Estimated Cost: Annual Per Capita[a] 1970-1985	Estimated Cost: Annual Per Capita[a] 1986-2020	Anticipated Performance
1	Weed Harvesting.....	$ 6,200	$ 900	$ 14,950[b]	$ 1,550	$ --	$ 1.4	$ --	Control Aquatic Nuisance Growths
	Total	$ 6,200	$ 900	$ 14,950	$ 1,550	$ --	$ 1.4	$ --	
2	Weed Harvesting.....	$ 6,200	$ 900	$ 14,950[b]	$ 1,550	$ --	$ 1.4	$ --	Control Aquatic Nuisance Growths
	Bench Terraces[c]......	60,000	--	60,000	3,800	3,800	3.4	3.4	Reduce Phosphorus Input by About 45 Percent
	Total	$ 66,200	$ 900	$ 74,950	$ 5,350	$ 3,800	$ 4.8	$ 3.4	
3	Weed Harvesting.....	$ 6,200	$ 900	$ 14,950[b]	$ 1,550	$ --	$ 1.4	$ --	Control Aquatic Nuisance Growths
	Bench Terraces[c]......	60,000	--	60,000	3,800	3,800	3.4	3.4	Reduce Phosphorus Input by About 50 Percent
	Sanitary Sewerage System[d]...........	524,000	5,950	618,100	39,200	39,200	34.7	34.7	Eliminate Public Health Hazards
	Total	$ 590,200	$ 6,850	$ 693,050	$ 44,550	$ 43,000	$ 39.5	$ 38.1	

[a]A population of 1,130 persons, representing the existing lake-oriented resident population, was used for per capita cost calculations. The estimated seasonal lake-oriented resident population is 1,410; the estimated seasonal peak lake-oriented user population is 1,680; the estimated lake-oriented resident population of the area to be sewered is 240.

[b]Present worth calculated utilizing a 6 percent interest rate and a 15-year project life. The present worth of all other plan elements was calculated utilizing a 6 percent rate of interest and a 50-year project life.

[c]Includes the construction of bench terraces or the institution of other appropriate agricultural land management measures on approximately 500 acres of agricultural land tributary to the lake.

[d]North and east shores of lake served; secondary and tertiary treatment at existing Random Lake sewage treatment plant. The component capital costs of the sanitary sewerage system are- trunk sewers $67,500; lateral, branch, and building sewers $456,500. The treatment plant capacity was considered adequate at the Random Lake treatment plant to handle the increased loading.

Source- Harza Engineering Company and SEWRPC.

on approximately 500 acres of agricultural land tributary to the lake. This alternative could be expected to reduce phosphorus input to the lake by up to 45 percent, or by 230 pounds per year. Weed harvesting would also be provided as in the first alternative.

The third alternative considered was the construction of a sewage collection system for the 60 homes located on the north and east shores of Random Lake and not presently served by the Village of Random Lake sewage treatment plant (see Map 57). Treatment for sewage collected in this area would be provided at the existing Random Lake sewage treatment plant, which plant would provide secondary and tertiary waste treatment. This alternative would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges. Weed harvesting and bench terracing and other appropriate agricultural land management measures would also be provided as in the first and second alternatives. This alternative could be expected to reduce the total annual phosphorus input to Random Lake by up to 53 percent, or by 270 pounds per year.

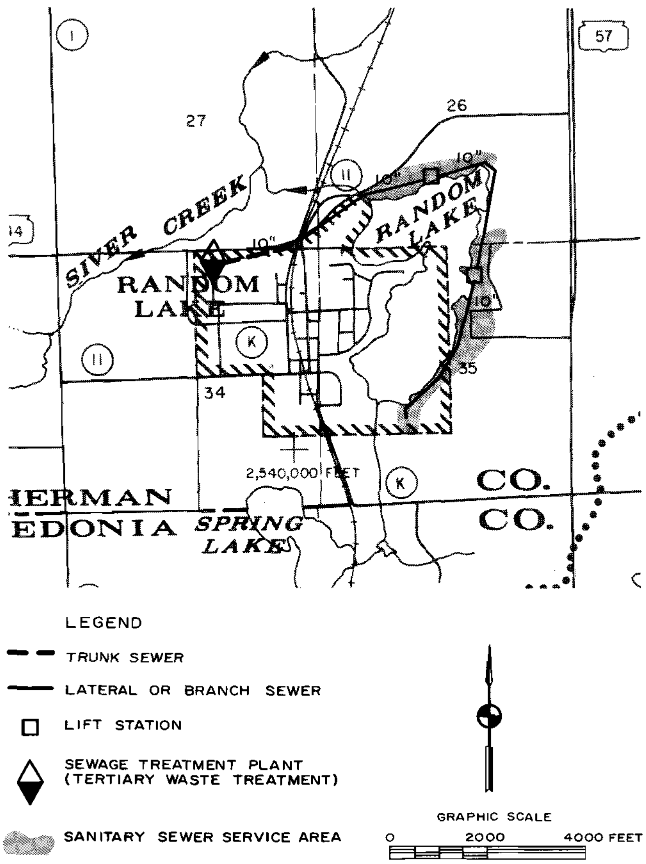
It is recommended that the third alternative plan element considered, including weed harvesting, bench terracing and other appropriate agricultural land management measures, and a sewage collection system for the north and east shores of Random Lake, with secondary and tertiary treatment to be provided at the existing Random Lake sewage treatment plant, be included in the recommended watershed plan.

Silver Lake: Silver Lake is located at the headwaters of Silver Creek near the City of West Bend. This lake receives extensive recreational use from private residents; public use, however, is limited by the lack of access. There are 195 private homes located along the shoreline of the lake, all of which are served by individual septic tank sewage disposal facilities. In general, these individual sewage disposal facilities are located on soils which are unsuitable for the safe absorption of septic tank effluent. The present water quality of Silver Lake is suitable for most uses, but a potential hazard to public health exists with the continued operation of septic tanks. The effluent from these individual septic tanks is estimated to contribute about 73 percent of the total annual phosphorus input of 167 pounds per year (see Table 97).

Two alternative water quality management plan elements were considered for Silver Lake (see Table 98). The first alternative considered was the construction of a sanitary sewerage system to serve all of the 195 homes which are presently located along the entire shoreline of the lake (see

Map 57

RECOMMENDED SANITARY SEWERAGE SYSTEM FOR RANDOM LAKE



There are about 60 private homes presently located around the shoreline of Random Lake not served by a public sanitary sewerage system. It is recommended, therefore, that service to this existing urban development be provided by an extension of the existing Village of Random Lake sewerage system. Implementation of this recommendation would eliminate all discharges of wastes from any malfunctioning private septic tank systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges.

Source: Harza Engineering Company and SEWRPC.

Map 50). This alternative would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges. Treatment of the sanitary wastes under this alternative would be at an expanded plant providing advanced waste treatment in the City of West Bend. The sanitary wastes would be conveyed to the City of West Bend treatment plant by a system of trunk sewers which would also serve Big Cedar and Little Cedar Lakes. Construction of the sanitary sewerage system may be expected to result

Table 97

SELECTED CHARACTERISTICS OF SILVER LAKE, WASHINGTON COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA............	1.4 SQUARE MILES		
SURFACE AREA........................	118 ACRES		
SHORELINE...........................	2.74 MILES		
DEPTH			
UNDER 3 FEET....................	12 PERCENT		
OVER 20 FEET....................	56 PERCENT		
VOLUME..............................	2,306 ACRE-FEET		
LAKE-ORIENTED RESIDENT POPULATION..	140		
SEASONAL RESIDENT POPULATION.......	410		
SEASONAL PEAK POPULATION...........	700		
PHOSPHORUS SOURCES..................	SEPTIC TANKS	122 LBS.[a]	73%
	RURAL RUNOFF	25	15
	OTHER[b]	20	12
	TOTAL	167 LBS.	100%
GENERAL WATER QUALITY...............	SPARSE WEED GROWTH MODERATE NUTRIENT CONCENTRATIONS WATER QUALITY GENERALLY SUITABLE FOR MOST USES		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- *HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.*

in a reduction of the total annual phosphorus input to the lake by about 73 percent, or by 122 pounds per year.

The second alternative considered also provides for the construction of a sanitary sewerage system to serve the existing urban development along the shoreline of Silver Lake but provides for treatment of the sewage at a new sewage treatment plant constructed to serve only Big Cedar Lake, Little Cedar Lake, and Silver Lake (see Map 50). This proposed plant would provide advanced waste treatment for nutrient removal, as would the West Bend plant. In terms of phosphorus reduction, this alternative would perform equally as well as the first alternative.

It is recommended that the first alternative plan element considered, consisting of the construction of a sanitary sewerage system with advanced waste treatment at the City of West Bend sewage treatment plant, be included in the recommended comprehensive watershed plan. The second alternative, while performing equally as well as the first alternative, was not recommended since treatment of sewage at a new sewage treatment plant to serve the Tri-Lakes area would be more costly than treating the wastes at the City of West Bend treatment facility.

<u>Smith Lake:</u> Smith Lake is a somewhat irregular, elongated lake of natural, glacial origin. The lake is very shallow, with a maximum depth of five feet. Except for limited fishing and swimming

Table 98

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS SILVER LAKE, WASHINGTON COUNTY

Alternative Plan Element		Estimated Cost							Anticipated Performance
Number Designation	Description	Capital	Annual Operation and Maintenance	Present Worth[a]	Total Annual 1970-1985	Total Annual 1986-2020	Annual per Capita[b] 1970-1985	Annual per Capita[b] 1986-2020	
1	Sanitary Sewerage System[c]	$ 666,900	$ 13,050	$ 896,860	$ 57,250	$ 57,250	$408.9	$408.9	Reduce Phosphorus Input by About 70 Percent Eliminate Public Health Hazards
	Total	$ 666,900	$ 13,050	$ 896,860	$ 57,250	$ 57,250	$408.9	$408.9	
2	Sanitary Sewerage System[d]	$1,067,220	$ 11,170	$1,276,100	$ 80,970	$ 80,970	$578.4	$578.4	Reduce Phosphorus Input by About 70 Percent Eliminate Public Health Hazards
	Total	$1,067,220	$ 11,170	$1,276,100	$ 80,970	$ 80,970	$578.4	$578.4	

[a] PRESENT WORTH CALCULATED USING A 6 PERCENT INTEREST RATE AND A 50-YEAR PROJECT LIFE.

[b] A POPULATION OF 140 PERSONS, REPRESENTING THE EXISTING LAKE-ORIENTED RESIDENT POPULATION, WAS USED FOR PER CAPITA COST CALCULATIONS. THE ESTIMATED SEASONAL LAKE-ORIENTED RESIDENT POPULATION IS 410; THE ESTIMATED SEASONAL PEAK LAKE-ORIENTED USER POPULATION IS 700.

[c] ENTIRE LAKE SERVED (700 PERSONS); ADVANCED WASTE TREATMENT AT WEST BEND. THE COMPONENT CAPITAL COSTS FOR THIS SANITARY SEWERAGE SYSTEM ARE- TREATMENT (ADVANCED) $42,000; TRUNK SEWERS $40,900; LATERAL, BRANCH, AND BUILDING SEWERS $584,000.

[d] ENTIRE LAKE SERVED (700 PERSONS); ADVANCED WASTE TREATMENT AT NEW TRI-LAKES PLANT. THE COMPONENT CAPITAL COSTS OF THIS SANITARY SEWERAGE SYSTEM ARE- TREATMENT (ADVANCED) $76,000; TRUNK SEWERS $407,220; LATERAL, BRANCH, AND BUILDING SEWERS $584,000.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

activities, the lake receives little recreational use from either the private residents or the general public. Swimming is limited by turbid water and an abundance of aquatic weeds. The major nutrient sources are spring runoff from manured agricultural and other rural land, which together account for up to 80 percent of the total annual phosphorus input of 123 pounds per year (see Table 99).

Two alternative water quality management plans were considered for Smith Lake. The first alternative considered was the provision of weed harvesting to remove excessive weed growths that interfere with certain recreational uses of the lake and the utilization of algicides to control algal growths that interfere with other recreational uses, as well as with the aesthetic enjoyment, of the lake (see Table 100).

The second alternative considered was the construction of bench terraces and the institution of other appropriate agricultural land management measures on approximately 170 acres of agricultural land tributary to the lake. Weed harvesting and algae control would also be provided as in the first alternative. This alternative could be expected to reduce the total annual phosphorus input to Smith Lake by up to 60 percent, or by 75 pounds per year.

It is recommended that the second alternative plan element considered, including weed harvesting, algae control, and bench terracing and other appropriate agricultural land management practices, be included in the recommended comprehensive watershed plan.

Table 99

SELECTED CHARACTERISTICS OF SMITH LAKE, WASHINGTON COUNTY: 1967

Characteristic	Description
Tributary Drainage Area	1.2 Square Miles
Surface Area	85.5 Acres
Shoreline	1.8 Miles
Depth	
Under 3 Feet	45 Percent
Over 20 Feet	0 Percent
Volume	252 Acre-Feet
Lake-Oriented Resident Population ..	58
Seasonal Resident Population	58
Seasonal Peak Population	90
Phosphorus Sources	Manured Land 75 Lbs.[a] 61% Rural Runoff 27 22 Septic Tanks 6 5 Other[b] 15 12 Total 123 Lbs. 100%
General Water Quality	Dense Weed Growth Attributed to Shallow Depth Algae Growth Possible in Mid-Summer Moderate Nutrient Concentrations Turbid Water Conditions and Muck-Bottomed Shoreline

[a] POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b] PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Spring Lake: Spring Lake is an elongated, sparsely populated "kettle" lake located at the headwaters of Silver Creek in Ozaukee County. Fishing is the main recreational activity. There are no public beaches, but some limited swimming activity does take place at a private beach. Spring Lake is low in nutrient content, as measured by spring phosphate levels; and water quality is generally suitable for most present uses of the lake. The major nutrient sources are spring runoff from manured agricultural land and septic tank discharges. The concentration of nutrients, however, is not considered to be a problem at Spring Lake (see Table 101).

Table 100

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS
SMITH LAKE, WASHINGTON COUNTY

ALTERNATIVE PLAN ELEMENT		ESTIMATED COST							ANTICIPATED PERFORMANCE
					TOTAL ANNUAL		ANNUAL PER CAPITA[a]		
NUMBER DESIGNATION	DESCRIPTION	CAPITAL	ANNUAL OPERATION AND MAINTENANCE	PRESENT WORTH	1970-1985	1986-2020	1970-1985	1986-2020	
1	WEED HARVESTING.....	$ 4,150	$ 600	$ 10,000[b]	$ 1,050	$ --	$ 18.1	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	ALGAE CONTROL.......	1,250	250	3,700[b]	400	--	6.9	--	
	TOTAL	$ 5,400	$ 850	$ 13,700	$ 1,450	$ --	$ 25.0	$ --	
2	WEED HARVESTING.....	$ 4,150	$ 600	$ 10,000[b]	$ 1,050	$ --	$ 18.1	$ --	CONTROL AQUATIC NUISANCE GROWTHS
	ALGAE CONTROL.......	1,250	250	3,700[b]	400	--	6.9	--	
	BENCH TERRACES[c]......	20,000	--	20,000	1,300	1,300	22.4	22.4	REDUCE PHOSPHORUS INPUT BY ABOUT 60 PERCENT
	TOTAL	$ 25,400	$ 850	$ 33,700	$ 2,750	$ 1,300	$ 47.4	$ 22.4	

[a]A POPULATION OF 58 PERSONS, REPRESENTING THE EXISTING LAKE-ORIENTED RESIDENT POPULATION, WAS USED FOR PER CAPITA COST CALCULATIONS. THE ESTIMATED SEASONAL LAKE-ORIENTED RESIDENT POPULATION IS 58; THE ESTIMATED SEASONAL PEAK LAKE-ORIENTED USER POPULATION IS 90.

[b]PRESENT WORTH CALCULATED AT A 6 PERCENT INTEREST RATE AND A 15-YEAR PROJECT LIFE. THE PRESENT WORTH OF ALL OTHER PLAN ELEMENTS WAS CALCULATED AT A 6 PERCENT RATE OF INTEREST AND A 50-YEAR PROJECT LIFE.

[c]INCLUDES THE CONSTRUCTION OF BENCH TERRACES OR THE INSTITUTION OF OTHER APPROPRIATE AGRICULTURAL LAND MANAGEMENT MEASURES ON APPROXIMATELY 170 ACRES OF AGRICULTURAL LAND TRIBUTARY TO THE LAKE.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table 101

SELECTED CHARACTERISTICS
OF SPRING LAKE,
OZAUKEE COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA............	C.5	SQUARE MILES	
SURFACE AREA........................	57	ACRES	
SHORELINE...........................	1.64	MILES	
DEPTH			
UNDER 3 FEET....................	21	PERCENT	
OVER 20 FEET....................	1	PERCENT	
VOLUME..............................	415	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION..	16		
SEASONAL RESIDENT POPULATION.......	16		
SEASONAL PEAK POPULATION...........	20		
PHOSPHORUS SOURCES.................	MANURED LAND	15 LBS.[a]	34%
	SEPTIC TANKS	14	32
	RURAL RUNOFF	6	14
	OTHER[b]	9	20
	TOTAL	44 LBS.	100%
GENERAL WATER QUALITY..............	SPARSE WEED GROWTH MODERATE NUTRIENT CONCENTRATIONS WATER QUALITY GENERALLY SUITABLE FOR MOST USES		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

No lake water quality management plan elements were considered for Spring Lake. Future development of homes around the lake should be restricted, since the soils around the lake generally have severe and very severe limitations for soil absorption sewage disposal systems.

Twelve Lake: Lake Twelve is a single-basin "kettle" lake surrounded by extensive wetlands on all but the south shore upland area. All development around the lake has been on these upland soils, which are generally suitable for the absorption of septic tank sewage effluent. Lake Twelve has high nutrient concentrations which create the potential for algal blooms. Moderate weed growths interfere with recreational activities. The major nutrient source is spring runoff from manured agricultural land (see Table 102). Although some of the nutrients may be intercepted by the extensive wetland area, there is considerable nutrient inflow from agricultural and other rural lands adjacent to the lake.

Three alternative water quality management plan elements were considered for Lake Twelve. The first alternative considered was the provision of weed harvesting to eliminate excessive weed growths that interfere with certain recreational uses of the lake and the utilization of algicides and control algal growths that interfere with other recreational uses, as well as with the aesthetic enjoyment, of the lake (see Table 103).

Table 102

SELECTED CHARACTERISTICS
OF TWELVE LAKE,
WASHINGTON COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA[a]...........	8.8	SQUARE MILES	
SURFACE AREA........................	53	ACRES	
SHORELINE...........................	1.3	MILES	
DEPTH			
UNDER 3 FEET....................	34	PERCENT	
OVER 20 FEET....................	C	PERCENT	
VOLUME..............................	340	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION..	90		
SEASONAL RESIDENT POPULATION.......	100		
SEASONAL PEAK POPULATION...........	185		
PHOSPHORUS SOURCES.................	MANURED LAND	420 LBS.[b]	73%
	RURAL RUNOFF	150	26
	OTHER[c]	5	1
	TOTAL	575 LBS.	100%
GENERAL WATER QUALITY..............	MODERATE WEED GROWTH AND POTENTIAL FOR ALGAL BLOOMS HIGH NUTRIENT CONCENTRATION TURBID WATER CONDITIONS AT TIMES CAUSED BY EXTENSIVE WETLAND DRAINAGE		

[a]INCLUDES WETLANDS ABOVE LAKE TWELVE.

[b]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[c]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Table 103

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS
TWELVE LAKE, WASHINGTON COUNTY

Alternative Plan Element		Estimated Cost							Anticipated Performance
					Total Annual		Annual Per Capita[a]		
Number Designation	Description	Capital	Annual Operation and Maintenance	Present Worth	1970-1985	1986-2020	1970-1985	1986-2020	
1	Weed Harvesting.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 5.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	200	3,200[b]	350	--	3.9	--	
	Total	$ 3,350	$ 500	$ 8,200	$ 850	$ --	$ 9.4	$ --	
2	Weed Harvesting.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 5.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	200	3,200[b]	350	--	3.9	--	Reduce Phosphorus Input by About 73 Percent
	Bench Terraces[c]......	38,400	--	38,400	2,400	2,400	26.7	26.7	
	Total	$ 41,750	$ 500	$ 46,600	$ 3,250	$ 2,400	$ 36.1	$ 26.7	
3	Weed Harvesting.....	$ 2,100	$ 300	$ 5,000[b]	$ 500	$ --	$ 5.5	$ --	Control Aquatic Nuisance Growths
	Algae Control.......	1,250	200	3,200[b]	350	--	3.9	--	Reduce Phosphorus Input by About 73 Percent
	Bench Terraces[c]......	38,400	--	38,400	2,400	2,400	26.7	26.7	
	Sanitary Sewerage System[d]...........	344,500	12,900	563,250	35,700	35,700	396.7	396.7	
	Total	$ 386,250	$ 13,400	$ 609,850	$ 38,950	$ 38,100	$432.8	$423.4	

[a]A population of 90 persons, representing the existing lake-oriented resident population, was used for per capita cost calculations. The estimated seasonal lake-oriented resident population is 100; the estimated seasonal peak lake-oriented user population is 185.

[b]Present worth calculated utilizing a 6 percent interest rate and a 15-year project life. The present worth for all other plan elements was calculated utilizing a 6 percent rate of interest and a 50-year project life.

[c]Includes the construction of bench terraces or the institution of other appropriate agricultural land management measures on approximately 320 acres of agricultural land tributary to the lake.

[d]South shore of lake served (260 persons, including Camp Awana); secondary treatment plant on North Branch of the Milwaukee River. The component capital costs of the sanitary sewerage system are- treatment plant (secondary) $63,500; trunk sewers $74,500; lateral, branch, and building sewers $206,500.

Source- Harza Engineering Company and SEWRPC.

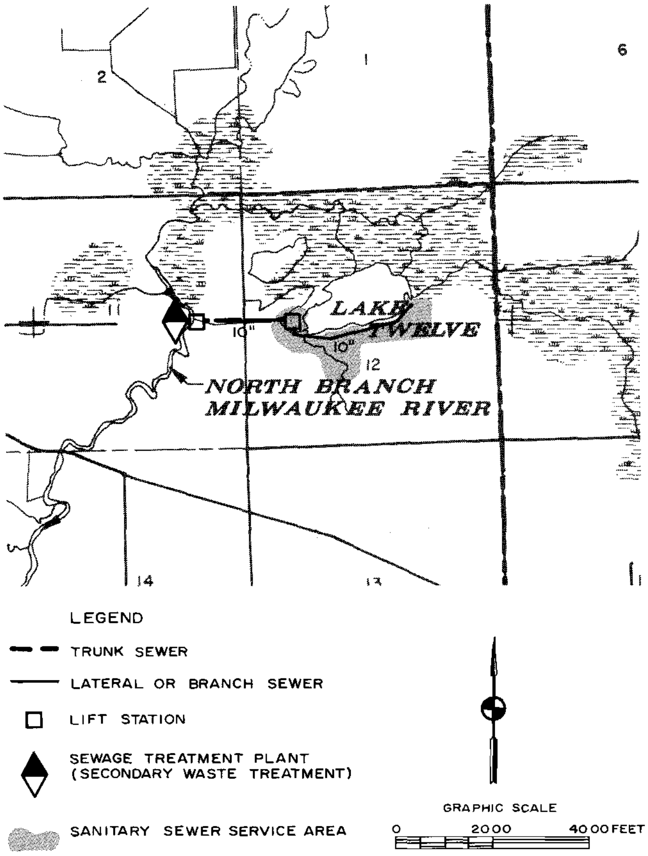
The second alternative considered was the construction of bench terraces and other appropriate agricultural land management measures on approximately 320 acres of agricultural land tributary to the south shore of the lake. This alternative could be expected to reduce phosphorus input to the lake by up to 73 percent, or by 420 pounds per year. Weed harvesting and algae control would also be provided as in the first alternative.

The third alternative considered was the construction of a sanitary sewerage system and secondary treatment facility to serve the 25 private homes located along the south shore of the lake (see Map 58). This alternative would eliminate all discharge of wastes from malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges. Treatment of the sanitary wastes would be at a new sewage treatment facility located on the North Branch of the Milwaukee River just west of Lake Twelve. Weed harvesting, algae control, and bench terracing and other appropriate agricultural land management measures would be provided as in the first and second alternatives. This alternative could be expected to reduce the total annual phosphorus input to Lake Twelve by up to 73 percent, or by 420 pounds per year.

It is recommended that the second alternative plan element considered, including weed harvesting, algae control, and bench terracing and other appropriate agricultural land management measures, be included in the recommended comprehensive watershed plan. The provision of a sanitary sewerage system was not recommended because the cost of the system was deemed to outweigh the water quality benefits, since a negligible amount of the phosphorus contributed to the lake was estimated to be from septic tank system discharges.

Wallace Lake: Wallace Lake is a single-basin "kettle" lake located just northeast of the City of West Bend in Washington County. There are 85 private homes presently located around the shoreline of the lake, with recreational activities on the lake normally restricted to private residents because of the very limited public access. Weed growths are found on the east and west shores of the lake, and submerged weeds can be found at depths up to 15 feet in the remainder of the lake. The submerged vegetation is a deterrent to recreational activities in only a few limited areas. Water quality is generally suitable for all uses. The major nutrient sources are spring runoff from manured agricultural land and effluent from individual septic tank sewage disposal systems (see Table 104).

Map 58
PROPOSED SANITARY SEWERAGE SYSTEM
FOR TWELVE LAKE



An alternative lake water quality management plan element considered for Lake Twelve was the construction of a sanitary sewerage system to serve the 25 private homes and the recreational camp located along the southern shoreline of the lake. Sewage treatment would be provided at a new treatment facility located on the North Branch of the Milwaukee River west of Lake Twelve. The provision of such a sanitary sewerage system was not included in the recommended watershed plan, however, since a relatively small amount of the phosphorus contributed to the lake annually was estimated to be contributed by septic tank system discharges.

Source: Harza Engineering Company and SEWRPC.

Two alternative water quality management plan elements were considered for Wallace Lake (see Table 105). The first alternative considered was the utilization of algicides to control algal growths that interfere with recreational uses, as well as with the aesthetic enjoyment, of the lake. In addition, the first alternative would provide for the construction of bench terraces and the institution of other appropriate agricultural land management measures on approximately 50 acres of agricultural land tributary to the lake. Under this first alternative, the annual phosphorus input to Wallace Lake may be expected to be reduced by about 40 percent, or by 40 pounds per year.

Table 104

SELECTED CHARACTERISTICS
OF WALLACE LAKE,
WASHINGTON COUNTY: 1967

CHARACTERISTIC	DESCRIPTION		
TRIBUTARY DRAINAGE AREA	0.6	SQUARE MILES	
SURFACE AREA	52	ACRES	
SHORELINE	1.5	MILES	
DEPTH			
UNDER 3 FEET	16	PERCENT	
OVER 20 FEET	17	PERCENT	
VOLUME	558	ACRE-FEET	
LAKE-ORIENTED RESIDENT POPULATION	330		
SEASONAL RESIDENT POPULATION	335		
SEASONAL PEAK POPULATION	410		
PHOSPHORUS SOURCES	MANURED LAND	40 LBS.[a]	40%
	SEPTIC TANKS	40	40
	RURAL RUNOFF	11	13
	OTHER[b]	6	7
	TOTAL	97 LBS.	100%
GENERAL WATER QUALITY	MODERATE WEED GROWTH MODERATE NUTRIENT CONCENTRATIONS CLEAR WATER ALLOWS PHOTOSYNTHESIS AT DEPTHS GREATER THAN IS NORMALLY THE CASE EVIDENCE OF POLLUTION RELATED TO HIGH CONCENTRATIONS OF CHLORIDE AND SODIUM IONS		

[a]POUNDS OF PHOSPHORUS CONTRIBUTED ANNUALLY BY THE INDICATED SOURCES.

[b]PRECIPITATION AND GROUND WATER.

SOURCE- HARZA ENGINEERING COMPANY AND WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

The second alternative considered was the construction of a sanitary sewerage system to serve all of the 85 homes which are presently located along the entire shoreline of the lake (see Map 59). Treatment of the sanitary wastes under this alternative would be at an expanded advanced waste treatment plant in the City of West Bend. This alternative would eliminate all discharge of wastes from any malfunctioning private soil absorption sewage disposal systems to the lake and thereby serve to eliminate any potential hazard to public health from such discharges. Algae control and bench terracing would also be provided as in the first alternative. This alternative could be expected to reduce the total annual phosphorus input to Wallace Lake by up to 80 percent, or by 80 pounds per year.

It is recommended that the second alternative plan element considered, including algae control, bench terracing and other appropriate agricultural land management measures, and a sanitary sewerage system, be included in the recommended watershed plan.

Concluding Remarks—Lake Water Quality Management Plan Elements

A number of alternative lake water quality management plan elements were investigated in the watershed study, including: installation of sanitary sewerage systems, agricultural runoff control, weed harvesting, and algae control. Utilizing

Table 105

ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS
WALLACE LAKE, WASHINGTON COUNTY

Alternative Plan Element		Estimated Cost							Anticipated Performance
Number Designation	Description	Capital	Annual Operation and Maintenance	Present Worth	Total Annual		Annual Per Capita[a]		
					1970-1985	1986-2020	1970-1985	1986-2020	
1	Algae Control.......	$ 1,250	$ 350	$ 4,650[b]	$ 500	$ --	$ 1.5	$ --	Control Aquatic Nuisance Growths
	Bench Terraces[c]......	6,700	--	6,700	400	400	1.2	1.2	Reduce Phosphorus Input by About 40 Percent
	Total	$ 7,950	$ 350	$ 11,350	$ 900	$ 400	$ 2.7	$ 1.2	
2	Algae Control.......	$ 1,250	$ 350	$ 4,650[b]	$ 500	$ --	$ 1.5	$ --	Control Aquatic Nuisance Growths
	Bench Terraces[c]......	6,700	--	6,700	400	400	1.2	1.2	Reduce Phosphorus Input by About 80 Percent
	Sanitary Sewerage System[d]...........	353,150	5,150	483,100	27,800	27,800	84.2	84.2	
	Total	$ 361,100	$ 5,500	$ 494,450	$ 28,700	$ 28,200	$ 86.9	$ 85.4	

[a] A population of 330 persons, representing the existing lake-oriented resident population, was used for per capita cost calculations. The estimated seasonal lake-oriented resident population is 335; the estimated seasonal peak lake-oriented user population is 410.

[b] Present worth calculated utilizing a 6 percent interest rate and a 15-year project life. The present worth of all other plan elements was calculated utilizing a 6 percent rate of interest and a 50-year project life.

[c] Includes the construction of bench terraces or the institution of other appropriate agricultural land management measures on approximately 50 acres of agricultural land tributary to the lake.

[d] Entire lake served (410 persons); advanced waste treatment at West Bend. The component capital costs of the sanitary sewerage system are- treatment (advanced) $16,450; lateral, branch, and building sewers $336,700. Existing and proposed trunk sewers in the City of West Bend were considered to have adequate capacity to serve the Wallace Lake area.

Source- Harza Engineering Company and SEWRPC.

these lake water quality management plan elements, alternative plans for the improvement of lake water quality were prepared for 16 of the 21 major lakes in the Milwaukee River watershed. These plans include some or all of the following elements: a sanitary sewerage system and a sewage treatment facility to serve developed areas around the lake in order to eliminate potential hazards to public health and reduce the nutrient input to the lake due to drainage from individual soil absorption sewage disposal (septic tank) facilities; provision of bench terracing or other appropriate agricultural land management practices on agricultural lands tributary to the lake that are subject to erosion and loss of soil and nutrients to reduce the nutrient and sediment input; weed harvesting to remove excessive growths of aquatic weeds that interfere with the recreational use of the lake; and algae control to reduce algae growths that interfere with recreation and with aesthetic uses of the lake. Based on the cost and anticipated performance of each alternative management plan element and on the present condition of each lake, it is recommended that the lake water quality management plan elements to be included in the recommended comprehensive watershed plan for the Milwaukee River watershed include the following:

1. Weed harvesting, as necessary, at Auburn, Big Cedar, Crooked, Ellen, Forest, Kettle Moraine, Little Cedar, Long, Lucas, Mauthe, Random, Smith, and Twelve Lakes.

2. Algae control, as necessary, at Big Cedar, Ellen, Forest, Little Cedar, Mauthe, Smith, Twelve, and Wallace Lakes.

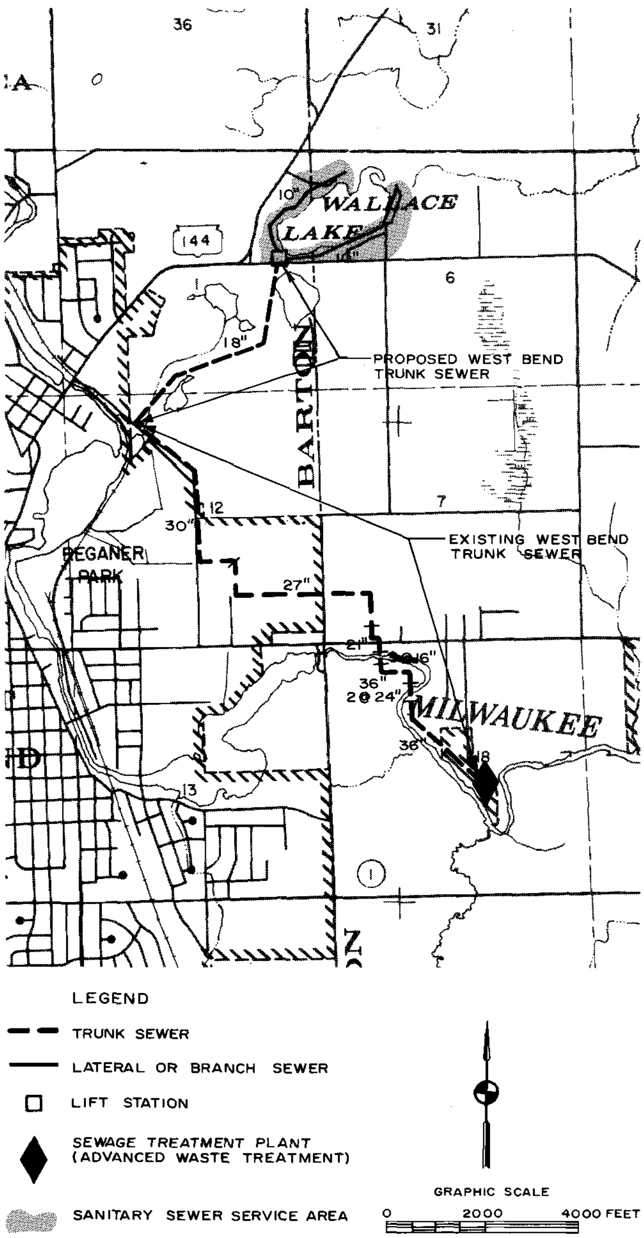
3. A long-term program of soil and water conservation through the construction of bench terraces and the institution of other appropriate agricultural land management measures on agricultural lands within the watersheds of Auburn, Big Cedar, Crooked, Ellen, Little Cedar, Long, Lucas, Mauthe, Random, Smith, Twelve, and Wallace Lakes.

4. Provision of sanitary sewerage systems for Big Cedar, Ellen, Forest, Green, Kettle Moraine, Little Cedar, Random, Silver, and Wallace Lakes.

Of the foregoing nine lake sanitary sewerage systems, three—Forest, Green, and Kettle Moraine—would include newly established sewage treatment facilities. Wastes from Big Cedar, Little Cedar, Silver, and Wallace Lakes are proposed to be conveyed to the existing sewage treatment plant in the City of West Bend. Wastes from the presently unsewered area of Random Lake would be conveyed to the existing sewage treatment plant in the Village of Random Lake, and wastes from Ellen Lake would be conveyed to a proposed new sewage treatment facility to serve the Village of Cascade.

Map 59

RECOMMENDED SANITARY SEWERAGE SYSTEM FOR WALLACE LAKE



The recommended construction of a sanitary sewerage system to serve Wallace Lake would serve to eliminate nearly one-half of the total annual phosphorus contribution to the lake and would, in addition, serve to eliminate any potential public health hazards. Because Wallace Lake is located in close proximity to the City of West Bend, it is recommended that sewage from the lake area be conveyed to the West Bend sewage treatment plant for advanced waste treatment prior to discharge of the treated effluent to the Milwaukee River.

Source: Harza Engineering Company and SEWRPC.

The capital cost of the recommended plan elements for these 16 major lakes in the Milwaukee River watershed is approximately $10 million; and the average annual cost, including capital recovery, operation, and maintenance, is $951,470. A summary of the costs for the recommended plan elements for each of the 16 major lakes considered is presented in Table 106.

Table 106

COST ESTIMATES OF THE RECOMMENDED LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS FOR THE MILWAUKEE RIVER WATERSHED

Name of Lake	Recommended Plan Elements	Estimated Cost						
		Capital	Annual Operation and Maintenance	Present[a] Worth	Total Annual		Annual Per Capita	
					1970-1985	1986-2020	1970-1985	1986-2020
AUBURN (FIFTEEN)	WEED HARVESTING......	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ 2.3	$ --
	BENCH TERRACES......	68,000	--	68,000	4,300	4,300	19.5	19.5
	TOTAL	$ 70,100	$ 300	$ 73,000	$ 4,800	$ 4,300	$ 21.8	$ 19.5
BIG CEDAR	WEED HARVESTING......	$ 7,250	$ 1,050	$ 17,450	$ 1,800	$ --	$ 1.7	$ --
	ALGAE CONTROL........	1,250	2,100	21,650	2,250	--	2.1	--
	BENCH TERRACES......	240,000	--	240,000	14,000	14,000	13.4	13.4
	SANITARY SEWERAGE SYSTEM............	3,793,000	98,000	5,536,550	351,000	351,000	336.2	336.2
	TOTAL	$4,041,500	$101,150	$5,815,650	$369,050	$365,000	$353.4	$349.6
CROOKED	WEED HARVESTING......	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ 2.2	$ --
	BENCH TERRACES......	110,000	--	110,000	7,000	7,000	31.1	31.1
	TOTAL	$ 112,100	$ 300	$ 115,000	$ 7,500	$ 7,000	$ 33.3	$ 31.1
ELLEN	WEED HARVESTING......	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ 3.5	$ --
	ALGAE CONTROL........	1,250	350	4,650	500	--	3.5	--
	BENCH TERRACES......	25,200	--	25,200	1,600	1,600	11.3	11.3
	SANITARY SEWERAGE SYSTEM............	735,800	47,300	907,000	104,800	104,800	738.0	738.0
	TOTAL	$ 764,350	$ 47,950	$ 941,850	$107,400	$106,400	$756.3	$749.3
FOREST	WEED HARVESTING......	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ 6.2	$ --
	ALGAE CONTROL........	1,250	100	3,200	350	--	4.4	--
	SANITARY SEWERAGE SYSTEM............	390,900	17,000	685,100	43,450	43,450	543.1	543.1
	TOTAL	$ 394,250	$ 17,400	$ 693,300	$ 44,300	$ 43,450	$553.7	$543.1
GREEN	SANITARY SEWERAGE SYSTEM............	$ 524,800	$ 16,750	$ 819,700	$ 51,900	$ 51,900	$1,038.0	$1,038.0
	TOTAL	$ 524,800	$ 16,750	$ 819,700	$ 51,900	$ 51,900	$1,038.0	$1,038.0
KETTLE MORAINE	WEED HARVESTING......	$ 6,200	$ 900	$ 14,950	$ 1,550	$ --	$ 27.7	$ --
	SANITARY SEWERAGE SYSTEM............	934,100	23,200	1,332,700	84,500	84,500	1,508.9	1,508.9
	TOTAL	$ 940,300	$ 24,100	$1,347,650	$ 86,050	$ 84,500	$1,536.6	$1,508.9
LITTLE CEDAR	WEED HARVESTING......	$ 4,150	$ 600	$ 10,000	$ 1,050	$ --	$ 7.5	$ --
	ALGAE CONTROL........	1,250	600	7,100	750	--	5.3	--
	BENCH TERRACES......	63,000	--	63,000	4,000	4,000	28.6	28.6
	SANITARY SEWERAGE SYSTEM............	1,362,700	28,720	1,875,320	118,720	118,720	848.0	848.0
	TOTAL	$1,431,100	$ 29,920	$1,955,420	$124,520	$122,720	$889.4	$876.6
LONG	WEED HARVESTING......	$ 4,150	$ 600	$ 10,000	$ 1,050	$ --	$ 1.4	$ --
	BENCH TERRACES......	186,000	--	186,000	11,800	11,800	15.9	15.9
	TOTAL	$ 190,150	$ 600	$ 196,000	$ 12,850	$ 11,800	$ 17.3	$ 15.9
LUCAS	WEED HARVESTING......	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ 25.0	$ --
	BENCH TERRACES......	42,000	--	42,000	2,600	2,600	130.0	130.0
	TOTAL	$ 44,100	$ 300	$ 47,000	$ 3,100	$ 2,600	$155.0	$130.0
MAUTHE	WEED HARVESTING......	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ --	$ --
	ALGAE CONTROL........	1,250	350	4,650	500	--	--	--
	BENCH TERRACES......	40,000	--	40,000	2,500	2,500	--	--
	TOTAL	$ 43,350	$ 650	$ 49,650	$ 3,500	$ 2,500	$ --	$ --
RANDOM	WEED HARVESTING......	$ 6,200	$ 900	$ 14,950	$ 1,550	$ --	$ 1.4	$ --
	BENCH TERRACES......	60,000	--	60,000	3,800	3,800	3.4	3.4
	SANITARY SEWERAGE SYSTEM............	524,000	5,950	618,100	39,200	39,200	34.7	34.7
	TOTAL	$ 590,200	$ 6,850	$ 693,050	$ 44,550	$ 43,000	$ 39.5	$ 38.1
SILVER (WASHINGTON COUNTY)	SANITARY SEWERAGE SYSTEM............	$ 666,900	$ 13,050	$ 896,860	$ 57,250	$ 57,250	$408.9	$408.9
	TOTAL	$ 666,900	$ 13,050	$ 896,860	$ 57,250	$ 57,250	$408.9	$408.9
SMITH	WEED HARVESTING......	$ 4,150	$ 600	$ 10,000	$ 1,050	$ --	$ 18.1	$ --
	ALGAE CONTROL........	1,250	250	3,700	400	--	6.9	--
	BENCH TERRACES......	20,000	--	20,000	1,300	1,300	22.4	22.4
	TOTAL	$ 25,400	$ 850	$ 33,700	$ 2,750	$ 1,300	$ 47.4	$ 22.4
TWELVE	WEED HARVESTING......	$ 2,100	$ 300	$ 5,000	$ 500	$ --	$ 5.5	$ --
	ALGAE CONTROL........	1,250	200	3,200	350	--	3.9	--
	BENCH TERRACES......	38,400	--	38,400	2,400	2,400	26.7	26.7
	TOTAL	$ 41,750	$ 500	$ 46,600	$ 3,250	$ 2,400	$ 36.1	$ 26.7
WALLACE	ALGAE CONTROL........	$ 1,250	$ 350	$ 4,650	$ 500	$ --	$ 1.5	$ --
	BENCH TERRACES......	6,700	--	6,700	400	400	1.2	1.2
	SANITARY SEWERAGE SYSTEM............	353,150	5,150	483,100	27,800	27,800	84.2	84.2
	TOTAL	$ 361,100	$ 5,500	$ 494,450	$ 28,700	$ 28,200	$ 86.9	$ 85.4
TOTAL		$10,241,450	$266,170	$14,218,880	$951,470	$934,320	--	--

[a]FOR ASSUMPTIONS UNDERLYING THE PRESENT WORTH AND PER CAPITA COST CALCULATIONS, SEE THE PRECEDING SERIES OF TABLES IN THIS CHAPTER REGARDING ALTERNATIVE LAKE WATER QUALITY MANAGEMENT PLAN ELEMENTS.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

(This page intentionally left blank)

Chapter VI

ALTERNATIVE WATER SUPPLY PLAN ELEMENTS

INTRODUCTION

Lake Michigan and the three ground water aquifers which underlie the Milwaukee River watershed comprise one of the most valuable natural resources within, and adjacent to, the watershed. These resources not only constitute the principal sources of water supply within the watershed but, if properly used and managed, also constitute a renewable water resource which can serve the watershed for all time to come.

The data and analyses presented in Chapter XI of Volume 1 of this report indicate that these resources constitute the principal sources of water supply now being used within the watershed, that these resources will continue to be used at an increasing rate in the future, and that these resources are capable of providing large additional quantities of water. Lake Michigan is the source of municipal water supply for the most heavily urbanized portion of the watershed, that is, for all that portion of the watershed lying within Milwaukee County, with the exception of the Villages of Bayside and River Hills. Local pollution of the two interconnected shallow aquifers, which constitute the most important source of water available to meet small, highly dispersed demands, such as those generated by farmsteads and by highly dispersed low-density residential development, may, in the absence of a sound water resource management program, be expected to become a serious problem within the watershed. Potential sources of pollution of the two shallow aquifers include septic tank disposal systems, dumps and improperly located and managed sanitary land fills, and both urban and agricultural runoff. The deep aquifer is less readily subject to pollution and, therefore, may be expected to remain a reliable source of supply of generally high-quality water throughout most, but not all of, the watershed.

The data and analyses presented in Chapter XI of Volume 1 of this report also indicated that the quantity of water present in both the shallow and deep aquifers can be expected to be adequate to meet forecast water supply needs within the upper and middle reaches of the watershed through the plan design year of 1990, even though total ground water use within the watershed may be expected to more than double by that year, reaching a total pumping rate of almost 25 million gallons per day, or 9 billion gallons per year.[1] Because of its ready availability, ground water may be expected to remain the only practical large-scale source of water supply within the upper reaches of the watershed through the plan design year.

Lake Michigan may be expected to be the major source of water supply within the lower reaches of the watershed, including supplies for all of the Milwaukee County and the Mequon-Thiensville portions of the watershed. Total Lake Michigan water use within the watershed is expected to reach 78 million gallons per day, or 29 billion gallons per year by 1990, an increase of 45 percent over present pumpage. The use of Lake Michigan water for the remainder of the watershed is restricted only by economic and engineering considerations, but a very large unanticipated water requirement would have to develop to justify the cost of treating and transporting lake water to serve the entire watershed.

This chapter presents recommendations for the development on a sustained basis of large water supplies from the ground water reservoirs and Lake Michigan, principally for municipal and industrial use. Small quantities, sufficient for individual domestic supply, are available from the shallow ground water reservoirs throughout the watershed and require only limited planning and management for protection of the quality of the supply, which is determined largely by local conditions. The specific ground water sources available to each existing and probable future major pumping center within the watershed are described

---

[1] *This total forecast pumping rate of 25 mgd is composed of approximately 15 mgd for municipal and subdivision public utility use, approximately 4 mgd for self-supplied industrial and commercial use, approximately 4 mgd for self-supplied domestic use, and approximately 2 mgd for agricultural use. See Chapter XI of Volume 1 of this report for forecast pumping rates by aquifer (see Table 95).*

and recommendations made concerning the development of the best available source of supply. Because the ground water resources of the watershed can be developed as a source of supply by wells located in, or close to, the areas to be served, the need for extensive transmission mains and pumping stations is minimized within the upper watershed. For this reason the alternative water supply plans presented in this report for the upper watershed are more general than such plans for portions of the lower watershed, being related primarily to desirable well field locations. Pertinent data concerning the ground water resources used by or available for use by local areas of concentrated pumping within the Milwaukee River watershed are summarized in Tables 107 through 110.

Many factors must be considered in choosing the source of water supply. In broad categories these include: the quantity and quality of water required, the cost of developing the facilities necessary to obtain and treat the water, the cost of operation and maintenance, the probable availability of increased supplies from the same source, the effect of the proposed development of the source of supply upon other water users, and the effect of other water users on the source of supply. In order to assist local communities within the watershed in considering these factors, information necessary to estimate the yield of, and effects of, development on each aquifer and to estimate the cost of well drilling and pumping are provided herein.

Table 107

EXISTING AND FORECAST GROUND WATER PUMPAGES FOR SELECTED URBAN AREAS IN THE MILWAUKEE RIVER WATERSHED

URBAN AREA	EXISTING PUMPAGE 1967 (MGD)	FORECAST PUMPAGE 1990		AQUIFERS USED		
		(MGD)	(GPM)	SAND AND GRAVEL	DOLOMITE	SANDSTONE
FOND DU LAC COUNTY						
CAMPBELLSPORT	0.22	0.48	332			X
MILWAUKEE COUNTY						
BAYSIDE	0.17	0.20	139		X	
RIVER HILLS	0.10	0.22	153		X	
OZAUKEE COUNTY						
CEDARBURG	1.40	2.68	1,860			X
FREDONIA	0.10	0.18	125		X	
GRAFTON	0.69	1.53	1,060		X	X
MEQUON	0.67	4.38	3,040		X	X
SAUKVILLE	0.28	0.59	340		X	
THIENSVILLE	0.24	0.36	250		X	
WAUBEKA	0.02	0.05	35		X	
SHEBOYGAN COUNTY						
ADELL	0.03	0.07	49		X	
CASCADE	0.02	0.04	28		X	
RANDOM LAKE	0.28	0.37	256		X	
WASHINGTON COUNTY						
JACKSON	0.07	0.17	118		X	
KEWASKUM	0.52	0.84	580		X	
NEWBURG	0.02	0.09	62		X	
WEST BEND	2.21	4.61	3,200	X	X	

SOURCE- U.S. GEOLOGICAL SURVEY AND SEWRPC.

For the lower urbanized reaches of the watershed, Lake Michigan is by far the most dependable supply of water, both in terms of quantity and quality, but will require the development of lake water intakes, as well as of water treatment facilities and transmission lines to the communities to be served. The preparation of a detailed municipal water supply system plan for the lower reaches of the watershed was beyond the scope of the comprehensive areawide watershed study, being more properly the responsibility of the municipalities concerned. The depth and detail of the water supply system planning for the lower watershed was accordingly limited to that required to delineate required service areas; to determine the approximate location and capacity of intakes or wells, and of necessary treatment, pumping, and transmission facilities; and to permit comparative cost analyses to be made of alternative ground and surface water supply systems.

SURFACE WATER SUPPLY

As was indicated in Chapter XI of Volume 1 of this report, surface water sources accounted for 90 percent of the total municipally supplied water use within the watershed during 1967 and are expected to account for about 87 percent of the municipally supplied water use by 1990, a slight decrease in relative importance. Lake Michigan was the only surface water source used for municipal supply within the watershed in 1967, and this fact is expected to remain unchanged to 1990. Lake Michigan has an enormous potential as a high-quality water supply, provided that future surface water intakes are properly located with respect to industrial and municipal waste discharges and provided the overall quality of the lake water is protected from further deterioration. Historic and forecast fluctuations in the lake level are not a factor in the future use of the lake as a water supply source. Continued discharge of partially treated wastes into the lake, however, may be detrimental to the quality of the lake water and may necessitate application of more advanced methods of water treatment before distribution than presently in use.

For the purpose of forecasting total water use in 1990, all major sources of supply in use in 1967 were assumed to remain in use through 1990. Therefore, anticipated water use within the City of Mequon and the Villages of Bayside, River Hills, and Thiensville was included in the total forecast ground water consumption for 1990,

Table 108

GROUND WATER AVAILABILITY AND ESTIMATED HYDROLOGIC CHARACTERISTICS FOR THE SAND AND GRAVEL AQUIFER IN THE MILWAUKEE RIVER WATERSHED

URBAN AREA	SAND AND GRAVEL AQUIFER				
	SATURATED THICKNESS OF GLACIAL DEPOSITS[a] (FEET)	WATER YIELDING POTENTIAL	DOES THIS AQUIFER MEET 1990 NEEDS FOR		AQUIFER DESCRIPTION
			QUANTITY	QUALITY	
FOND DU LAC COUNTY					
CAMPBELLSPORT.......	40	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL; NOT SUITABLE FOR LARGE SCALE DEVELOPMENT.
MILWAUKEE COUNTY					
BAYSIDE.............	40	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL; NOT SUITABLE FOR LARGE SCALE DEVELOPMENT. THIN GRAVEL LAYER MAY BE PRESENT LOCALLY JUST ABOVE BEDROCK.
RIVER HILLS.........	40	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL; NOT SUITABLE FOR LARGE SCALE DEVELOPMENT. THIN GRAVEL LAYER MAY BE PRESENT LOCALLY JUST ABOVE BEDROCK.
OZAUKEE COUNTY					
CEDARBURG...........	25	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL; NOT SUITABLE FOR LARGE SCALE DEVELOPMENT. THIN GRAVEL LAYER MAY BE PRESENT LOCALLY JUST ABOVE BEDROCK.
FREDONIA............	50	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL; NOT SUITABLE FOR LARGE SCALE DEVELOPMENT. THIN GRAVEL LAYER MAY BE PRESENT LOCALLY JUST ABOVE BEDROCK.
GRAFTON.............	30	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL; NOT SUITABLE FOR LARGE SCALE DEVELOPMENT. THIN GRAVEL LAYER MAY BE PRESENT LOCALLY JUST ABOVE BEDROCK.
MEQUON..............	48	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL; NOT SUITABLE FOR LARGE SCALE DEVELOPMENT. THIN GRAVEL LAYER MAY BE PRESENT LOCALLY JUST ABOVE BEDROCK.
SAUKVILLE...........	30	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL; NOT SUITABLE FOR LARGE SCALE DEVELOPMENT. THIN GRAVEL LAYER MAY BE PRESENT LOCALLY JUST ABOVE BEDROCK.
THIENSVILLE.........	48	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL; NOT SUITABLE FOR LARGE SCALE DEVELOPMENT. THIN GRAVEL LAYER MAY BE PRESENT LOCALLY JUST ABOVE BEDROCK.
WAUBEKA.............	70	POOR	NO	YES	GLACIAL DEPOSITS CHIEFLY CLAY AND TILL WITH SOME THIN SAND AND GRAVEL BEDS. NOT GENERALLY SUITABLE FOR LARGE SCALE DEVELOPMENT.
SHEBOYGAN COUNTY					
ADELL...............	90	GOOD	YES	YES	UP TO 100 FEET OF SATURATED SAND AND GRAVEL REPORTED BUT DEPOSITS ARE COMPLEX AND CONSIST CHIEFLY OF CLAY AND TILL. TEST DRILLING REQUIRED TO LOCATE FAVORABLE SITES.
CASCADE.............	60	GOOD	YES	YES	UP TO 80 FEET OF SATURATED SAND AND GRAVEL REPORTED BUT DEPOSITS ARE COMPLEX AND CONSIST CHIEFLY OF CLAY AND TILL. TEST DRILLING IS REQUIRED TO LOCATE FAVORABLE SITES.
RANDOM LAKE.........	95	FAIR	YES	YES	UP TO 95 FEET OF SATURATED FINE SAND REPORTED BUT DEPOSITS ARE CHIEFLY CLAY AND TILL.
WASHINGTON COUNTY					
JACKSON.............	95	POOR TO FAIR	NO	YES	GLACIAL DEPOSITS ARE COMPLEX AND CONSIST OF INTERLAYERED TILL, CLAY, SAND, AND GRAVEL. SATURATED THICKNESS RANGES BETWEEN 75 AND 120 FEET, THICKEST TO THE WEST.
KEWASKUM............	70	FAIR	NO	YES	UP TO 50 TO 70 FEET OF SATURATED SAND OR GRAVEL REPORTED PRESENT IN ADDITION TO CLAY AND TILL. TEST DRILLING REQUIRED TO LOCATE FAVORABLE SITES.
NEWBURG.............	80	POOR	NO	YES	GLACIAL DEPOSITS CONSIST CHIEFLY OF CLAY AND TILL, NOT SUITABLE FOR LARGE SCALE DEVELOPMENT.
WEST BEND...........	148	EXCELLENT	YES	YES	UP TO 177 FEET OF SATURATED SAND AND GRAVEL REPORTED PRESENT. ALSO MUCH TILL AND CLAY. TEST DRILLING REQUIRED TO LOCATE FAVORABLE SITES.

[a]THESE FIGURES REPRESENT AVERAGE CONDITIONS FOR THE COMMUNITY.

SOURCE- U. S. GEOLOGICAL SURVEY.

Table 109

GROUND WATER AVAILABILITY AND ESTIMATED HYDROLOGIC CHARACTERISTICS FOR THE DOLOMITE AQUIFER IN THE MILWAUKEE RIVER WATERSHED

URBAN AREA	DOLOMITE AQUIFER: THICKNESS[a] (FEET)	AVAILABLE HEAD[a] (FEET)	ESTIMATED TRANSMISSIVITY (GPD/FT)	ESTIMATED PERMEABILITY OF OVERLYING GLACIAL DEPOSITS (GPD/FT^2)	TOTAL DISSOLVED SOLIDS (MG/L)	DOES THIS AQUIFER MEET 1990 NEEDS FOR: QUANTITY	QUALITY	AQUIFER DESCRIPTION
FOND DU LAC COUNTY								
CAMPBELLSPORT........	275	312	3,000	0.01	400-500	YES	YES	ALTITUDE OF TOP OF DOLOMITE RANGES BETWEEN 930 AND 1,100 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS IS BETWEEN 250 AND 300 FEET. THE SATURATED THICKNESS OF OVERLYING GLACIAL DEPOSITS RANGES FROM 30 TO 55 FEET.
MILWAUKEE COUNTY								
BAYSIDE.............	450	500	5,000	0.01	400-600	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 590 AND 650 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS IS BETWEEN 450 AND 600 FEET. THE SATURATED THICKNESS OF OVERLYING GLACIAL DEPOSITS RANGES FROM 0 TO 100 FEET.
RIVER HILLS..........	450	500	5,000	0.01	400-600	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 525 AND 630 FEET ABOVE SEA LEVEL DATUM. THE SATURATED THICKNESS OF OVERLYING GLACIAL DEPOSITS RANGES FROM 25 TO 75 FEET.
OZAUKEE COUNTY								
CEDARBURG............	488	525	5,000	0.01	400	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 680 AND 805 FEET ABOVE SEA LEVEL DATUM DECREASING EASTWARD. THICKNESS RANGES BETWEEN 425 AND 500 FEET. THE SATURATED THICKNESS OF THE GLACIAL DEPOSITS RANGE FROM 0 TO 25 FEET.
FREDONIA.............	500	558	5,000	0.01	500-1,000	YES	YES[b]	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 725 AND 740 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS IS BETWEEN 480 AND 525 FEET. THE SATURATED THICKNESS OF THE GLACIAL DEPOSITS RANGE FROM 25 TO 50 FEET.
GRAFTON..............	520	540	5,000	0.01	400	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 680 AND 740 FEET ABOVE SEA LEVEL DATUM DECREASING EASTWARD. ITS THICKNESS IS BETWEEN 505 AND 550 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS AVERAGES ABOUT 30 FEET.
MEQUON...............	450	498	5,000	0.01	400-600	YES[c]	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 480 AND 800 FEET ABOVE SEA LEVEL DATUM, DECREASING SOUTHEASTWARD. ITS THICKNESS RANGES BETWEEN 450 AND 500 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGE BETWEEN 0 - 125 FEET. THEY AVERAGE 50 FEET THICK IN THE NORTHERN HALF AND 75 FEET IN THE SOUTHERN HALF.
SAUKVILLE............	560	572	5,000	0.01	350	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 710 AND 755 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS IS BETWEEN 550 AND 580 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGES BETWEEN 25 AND 50 FEET.
THIENSVILLE..........	450	498	5,000	0.01	400-600	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 450 AND 500 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS IS BETWEEN 450 AND 500 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS AVERAGE ABOUT 50 FEET.
WAUBEKA..............	500	525	5,000	0.01	400-500	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 740 AND 750 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS IS BETWEEN 490 AND 510 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGE FROM 50 TO 75 FEET.
SHEBOYGAN COUNTY								
ADELL................	575	660	5,000	1.00	500	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 740 AND 810 FEET AND ITS THICKNESS IS FROM 550 TO 610 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGES FROM 75 TO 100 FEET.
CASCADE..............	400	568	10,000	1.00	400	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 640 AND 770 FEET ABOVE SEA LEVEL DATUM DECREASING SOUTHEASTWARD. ITS THICKNESS IS BETWEEN 300 AND 400 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGES FROM 90 TO 200 FEET. VILLAGE OVERLIES STEEP WEST WALL OF MAJOR BURIED PREGLACIAL VALLEY.
RANDOM LAKE..........	575	665	5,000	1.00	500-1,000	YES	YES	ALTITUDE OF TOP OF THE DOLOMITE RANGES BETWEEN 740 TO 810 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS RANGES BETWEEN 550 AND 600 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGE FROM 75 TO 125 FEET.
WASHINGTON COUNTY								
JACKSON..............	212	312	10,000	1.00	400	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 740 AND 790 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS RANGES BETWEEN 175 AND 220 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGE FROM 75 TO 125 FEET.
KEWASKUM.............	350	410	10,000	1.00	400-500	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 875 AND 890 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS RANGES BETWEEN 300 AND 385 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGE FROM 60 TO 90 FEET.
NEWBURG..............	482	510	5,000	0.01	400	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 840 AND 855 FEET ABOVE SEA LEVEL DATUM AND ITS THICKNESS RANGES BETWEEN 475-500 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGES FROM 25 TO 40 FEET.
WEST BEND............	162	315	10,000	1.00	300-500	YES	YES	ALTITUDE OF THE TOP OF THE DOLOMITE RANGES BETWEEN 650 AND 855 FEET DECREASING EASTWARD. ITS THICKNESS RANGES BETWEEN 115 AND 262 FEET. THE SATURATED THICKNESS OF THE OVERLYING GLACIAL DEPOSITS RANGE FROM 75 TO 200 FEET. CITY OVERLIES WEST WALL OF MAJOR BURIED PREGLACIAL VALLEY.

[a] THESE FIGURES REPRESENT AVERAGE CONDITIONS FOR THE COMMUNITY.

[b] MAY NEED TREATMENT DUE TO HIGH LEVELS OF DISSOLVED SOLIDS.

[c] CAN BE ACCOMPLISHED UNDER A GROUND WATER MANAGEMENT PROGRAM WHERE WELLS ARE SPACED AT LEAST 5,000 FEET PUMPING AT A RATE OF 300 GPM.

SOURCE- U. S. GEOLOGICAL SURVEY.

despite the fact that Lake Michigan may, if the recommendations contained in this report are implemented, become the major source of supply for these communities by 1990. This would mean that the 1990 forecast ground water pumpage within the watershed of 25 mgd would be reduced by 3.6 mgd to 21.4 mgd if Mequon, Bayside, River Hills, and Thiensville began using Lake Michigan as a source of supply.

GROUND WATER SUPPLY

The three major aquifers underlying the Milwaukee River watershed are the shallow sand and

Table 110

GROUND WATER AVAILABILITY AND ESTIMATED HYDROLOGIC CHARACTERISTICS FOR THE SANDSTONE AQUIFER IN THE MILWAUKEE RIVER WATERSHED

	SANDSTONE AQUIFER							
						DOES THIS AQUIFER MEET 1990 NEEDS FOR		
URBAN AREA	THICKNESS[a] (FEET)	AVAILABLE HEAD[b] (FEET)	ESTIMATED TRANSMISSIVITY (GPD/FT)	ALLOWABLE DRAWDOWN[c] (FEET)	TOTAL DISSOLVED SOLIDS (MG/L)	QUANTITY	QUALITY	AQUIFER DESCRIPTION
FOND DU LAC COUNTY								
CAMPBELLSPORT........	532	610-620	10,000	610-620	400-500	YES	YES	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 190 AND 210 FEET ABOVE MEAN SEA LEVEL DATUM.
MILWAUKEE COUNTY								
BAYSIDE..............	>700	915	23,800	915	600-6,000	YES	NO	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 375 TO 395 FEET BELOW SEA LEVEL DATUM. VERY HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER.
RIVER HILLS..........	>700	875-890	23,800	875-890	600-6,000	YES	NO	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 320 AND 390 FEET BELOW SEA LEVEL DATUM. HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER.
OZAUKEE COUNTY								
CEDARBURG............	538	800-850	23,800	800-850	400-2,500	YES	YES[d]	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 100 AND 150 FEET BELOW SEA LEVEL DATUM. HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER.
FREDONIA.............	372	1,020-1,075	15,000	1,020-1,075	1,000	YES	YES[d]	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES 250 AND 275 FEET BELOW SEA LEVEL DATUM. HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER. NOT PRESENTLY USED AS A SOURCE OF SUPPLY IN AREA.
GRAFTON..............	532	850-950	23,800	850-950	1,000-2,000	YES	YES[d]	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 180 AND 275 FEET BELOW SEA LEVEL DATUM. HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER.
MEQUON...............	>700	675-970	23,800	675-970	500-2,000	YES	NO	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 30 FEET ABOVE AND 410 FEET BELOW SEA LEVEL DATUM, DECREASING EASTWARD. HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER IN EASTERN HALF OF CITY.
SAUKVILLE............	460	985-1,055	20,000	985-1,055	700-1,000	YES	YES[d]	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 260 AND 340 FEET BELOW SEA LEVEL DATUM. HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER. NOT PRESENTLY USED AS A SOURCE OF SUPPLY.
THIENSVILLE..........	>700	775-890	23,800	775-890	500-2,000	YES	YES[d]	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 150 AND 300 FEET BELOW SEA LEVEL DATUM. HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER. NOT PRESENTLY USED AS A SOURCE OF SUPPLY.
WAUBEKA..............	310	975	15,000	975	1,000	YES	YES[d]	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 220 AND 250 FEET BELOW SEA LEVEL DATUM. SOME PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER. NOT PRESENTLY USED AS A SOURCE OF SUPPLY IN THIS AREA.
SHEBOYGAN COUNTY								
ADELL................	450	1,000	15,000	1,000	1,000	YES	YES	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 240 AND 250 FEET BELOW SEA LEVEL DATUM. HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER. NOT PRESENTLY USED AS A SOURCE OF SUPPLY IN AREA.
CASCADE..............	450	875	15,000	875	1,000	YES	YES	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 80 AND 110 FEET BELOW SEA LEVEL DATUM. NOT PRESENTLY USED AS A SOURCE OF SUPPLY IN AREA.
RANDOM LAKE..........	365	1,035	10,000	1,035	1,000	YES	YES[d]	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 260 AND 280 FEET BELOW SEA LEVEL DATUM. HIGH PROBABILITY OF OBTAINING SALINE WATER FROM AQUIFER. NOT PRESENTLY USED AS A SOURCE OF SUPPLY IN AREA.
WASHINGTON COUNTY								
JACKSON..............	270	975	5,000	975	500	YES	YES	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES FROM 180 TO 200 FEET ABOVE SEA LEVEL DATUM. NOT PRESENTLY USED AS A SOURCE OF SUPPLY IN AREA.
KEWASKUM.............	115	660-710	3,000	660-710	500	YES	YES	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 110 AND 150 FEET ABOVE SEA LEVEL DATUM. NOT PRESENTLY USED AS A SOURCE OF SUPPLY.
NEWBURG..............	268	900	5,000	900	500	YES	YES	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 110 AND 130 FEET BELOW SEA LEVEL DATUM. NOT PRESENTLY USED AS A SOURCE OF SUPPLY IN AREA.
WEST BEND............	108	635-710	3,000	635-710	500	NO	YES	ALTITUDE OF THE TOP OF THE ST. PETER SANDSTONE RANGES BETWEEN 90 AND 180 FEET ABOVE SEA LEVEL DATUM. NOT PRESENTLY USED AS A SOURCE OF SUPPLY IN AREA.

[a] THESE FIGURES REPRESENT AVERAGE CONDITIONS FOR THE COMMUNITY.

[b] DIFFERENCE BETWEEN ELEVATION OF THE POTENTIOMETRIC SURFACE AND ELEVATION OF THE TOP OF THE ST. PETER SANDSTONE.

[c] ARBITRARILY BASED ON DRAWING THE WATER LEVEL DOWN TO THE TOP OF THE ST. PETER SANDSTONE.

[d] MAY NEED TREATMENT DUE TO HIGH LEVELS OF DISSOLVED SOLIDS.

SOURCE- U. S. GEOLOGICAL SURVEY.

gravel aquifer, the shallow dolomite aquifer, and the deep sandstone aquifer. The sand and gravel aquifer consists of isolated deposits of saturated sand and gravel within the glacial drift covering the watershed. The dolomite aquifer consists primarily of dolomitic bedrock that underlies the entire watershed except for a very small area of about two square miles in extent located northeast of Slinger in Washington County. The sandstone aquifer consists primarily of sandstone and some dolomitic rock, which underlie the entire watershed and extends several thousand square miles beyond its boundaries. The shallow aquifers are separated from the deep aquifer by a layer of relatively impervious shale. Table 107 sets forth the existing and probable future municipal water supply needs for the major urban communities within the upper watershed, and indicates the aquifer presently used as the source of supply.

The sand and gravel aquifer is capable of yielding large amounts of water to wells where its saturated thickness exceeds 30 feet, and it underlies an area of more than one-half a square mile in extent. Deposits of this size or larger are common in the interlobate moraine area of the watershed and in areas of glacial outwash. They may also occur in major bedrock valleys filled with glacial drift. Because there has been very little development of the sand and gravel aquifer in this watershed, relatively little is known about its aerial distribution, thickness, or permeability. Recharge to this aquifer occurs locally by direct infiltration of precipitation and is relatively large compared to the deep aquifers.

High capacity wells (yield greater than 70 gpm) can be developed in the dolomite aquifer in most areas of the watershed. Water quality is generally good, but highly dissolved solids contents occur locally in this aquifer as it underlies the easterly portion of the watershed. Permeability of the dolomite aquifer is due largely to fractures, crevices, and solution channels. Recharge is primarily from vertical leakage through the overlying glacial deposits.

The sandstone aquifer is capable of yielding large amounts of water to wells in all parts of the watershed. Water quality is generally good, but highly dissolved solids contents also occur in this aquifer as it underlies the easterly portion of the watershed. Its permeability is due to both intergranular porosity and fractures. The aquifer receives recharge from an area west of the watershed where the overlying Maquoketa shale is absent. Some recharge also occurs as leakage through the shale and through wells open to both the dolomite and sandstone aquifers.

In Chapter XI, Volume 1, of this report, it was indicated that in 1967 about 32 percent of the municipal and private utility supply, averaging 2.1 million gallons per day, and about 50 percent of the self-supplied commercial and industrial supply, averaging 0.9 million gallons per day, were obtained from the deep aquifer. Total pumpage from this aquifer may be expected to increase only slightly from this present level of about 3 million gallons per average day.

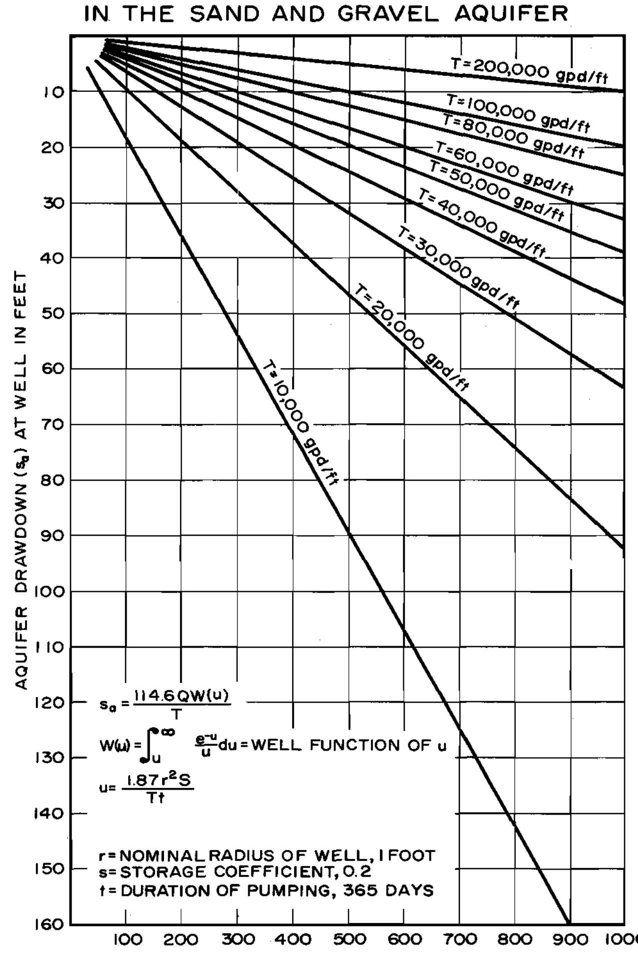
Aquifer performance is determined by the ability of the aquifer to store and transmit water and by recharge capabilities. Tables 108, 109, and 110 summarize the estimated hydraulic characteristics of the three aquifers underlying the principal population centers of the watershed. The following discussion details design criteria for use in planning large ground water supplies in each of the watershed aquifers.

<u>Sand and Gravel Aquifer</u>

The sand and gravel aquifer generally exists under water table conditions in the Milwaukee River watershed. Its ground water availability and estimated hydrologic characteristics are shown in Table 108. Transmissivity of the aquifer ranges from about 10,000 to as much as 200,000 gallons per day (gpd) per foot. This range is represented on the discharge-drawdown and distance-drawdown curves, shown in Figures 25 and 26, which may be used in planning water supply development within the watershed. The graphs are based on the conservative assumption that the well will be pumped for one year without benefit of recharge, so that all water pumped from the aquifer is assumed to be derived from storage. A storage coefficient, (S), of 0.2, which is representative of water table conditions, was used in the computation of these graphs. The graphs in Figure 26 are drawn for a pumping rate of 1,000 gallons per minute (gpm). Aquifer drawdown, (s_a), however,

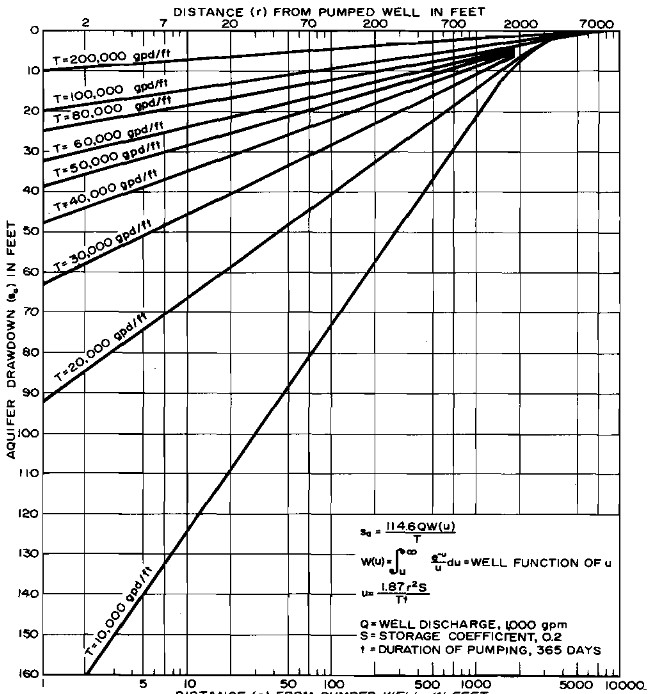
Figure 25

RELATION OF WELL DISCHARGE TO DRAWDOWN IN THE SAND AND GRAVEL AQUIFER



Source: U. S. Geological Survey.

Figure 26
RELATION OF DISTANCE FROM PUMPED WELL TO DRAWDOWN IN THE SAND AND GRAVEL AQUIFER



NOTE: DRAWDOWN AT ANY DISTANCE IS PROPORTIONAL TO THE WELL DISCHARGE (Q)

Source: U. S. Geological Survey.

is directly proportional to the pumping rate, (Q); and, therefore, Figure 26 can be used for pumping rates other than 1,000 gpm simply by multiplying the drawdown at any given distance from the well by the pumping rate in thousands of gpm.

The discharge-drawdown and the distance-drawdown graphs shown in Figures 25 and 26 assume a drawdown due to pumping under ideal conditions. To estimate the total drawdown in a pumping well in the sand and gravel aquifer for preliminary planning purposes, consideration must also be given to the effects of aquifer dewatering, partial penetration of the aquifer by the well, well losses, boundary conditions, and interference from other pumping wells.

The drawdown, s_a, determined from Figure 25 or 26, may be adjusted for the effects of dewatering by adding to it the factor, s_d, which may be computed from the expression:

$$s_d = s_a^2/2\underline{m}$$

where m = the initial saturated thickness of the aquifer in feet.

Drawdown in a pumping well caused by the partial penetration of the aquifer by the well may be assumed to be about 50 percent greater than the drawdown from Figure 25 or 26 after adjustment for aquifer dewatering is made. This adjustment for partial penetration, s_{pp}, is approximately correct, provided at least 30 percent of the saturated thickness of the aquifer is screened in the pumping well. If more than 30 percent of the aquifer is screened, the partial penetration adjustment is smaller, whereas if less than 30 percent is screened, the adjustment is larger. High-capacity wells in the sand and gravel aquifer in the watershed typically have between 20 and 40 percent of their saturated thickness screened and have an effective radius of about one foot.

Drawdowns due to well losses, s_{wl}, vary approximately as the square of the well discharge, (Q), and may be computed from the expression:

$$s_{wl} = 0.000025Q^2$$

where Q = the well discharge expressed in gpm.

The effects of boundary conditions, if they are known, can be simulated by use of the image well technique. This graphical procedure reproduces the hydraulic effect of an impermeable boundary or of a recharge zone, such as a river, through the use of carefully positioned hypothetical wells pumping in conjunction with, and at the same rate as, the actual well. The resulting potentiometric surface for this combination of actual and hypothetical, or image, wells is identical to that which would occur when the actual well responds to the hydraulic conditions imposed by the impermeable, or recharge, boundary. The effects of other pumping wells in the aquifer may be determined directly from Figure 26, provided the wells are spaced more than two times the aquifer thickness, (m), apart. At a distance greater than 2m, the effects due to partial penetration are negligible. To take advantage of most of the potential production capabilities of the aquifer, total drawdown in the pumping well should be limited to approximately two-thirds of the initial saturated thickness of the aquifer. The following example illustrates the application of Figures 25 and 26 in well location.

Example

A water user within the watershed requires 1,000 gpm and plans to obtain it by developing two wells in the shallow *sand and gravel aquifer, each 1 foot in diameter and pumping 500 gpm, 500 feet apart, in an area of known transmissivity, T, and saturated thickness.*

Requirement: 1,000 gpm from two wells 500 feet apart.

Transmissivity: 60,000 gpd per foot.

Saturated thickness: 100 feet.

Drawdown in well pumping 500 gpm from Figure 25

$s_a = 16$ *feet*

The correction factor for dewatering:

$s_d = (16^2)/200 = 1.28$ *feet, or approximately 1.3 feet.*

Drawdown caused by partial penetration:

s_{pp} - $(0.5)(16+1.3) = 8.65$ *feet, or approximately 8.6 feet.*

Drawdown caused by well losses:

$s_{wl} = (0.000025)(500)^2 = 6.2$ *feet.*

For drawdown caused by interference from the second well, s_i*, check for* $r/m > 2.0$*. Space wells 500 feet apart so that* $r/m = 500/100 = 5$*. This satisfies the requirement,* $r/m > 2.0$*, so Figure 26 may be used.*

From Figure 26, for $r = 500$ *feet,* $s_i = 9.00$ *feet.*

This is for $Q = 1,000$ *gpm. Then, for 500 gpm:*

$s_i = (500/1,000)(9.0) = 4.5$ *feet.*

The total drawdown in the aquifer is then:

$s_{total} = s_a + s_d + s_{pp} + s_{wl} + s$

$s_{total} = 16+1.3+8.6+6.2+4.5 = 36.6$ *feet.*

The allowable drawdown in the aquifer is $2\underline{m}/3$*, or*

$s = (2/3)(100) = 66.6$ *feet.*

Therefore, the aquifer is adequate to meet the user's needs. No boundary constraints were assumed to effect the aquifer in this example.

As already noted, because of its lack of development very little is known about the areal distribution and hydraulic properties of the sand and gravel aquifer. Therefore, wherever development of this aquifer is planned, aquifer performance tests should be carried out. Transmissivity values of the aquifer for use in Figures 25 and 26 may be obtained from such testing. Of equal importance, unknown boundary conditions may be discovered which may greatly alter the expected drawdown in a pumping well and, in some cases, may make development of a well unfeasible, whereas in other cases, such conditions will allow greater withdrawals.

Estimating the transmissivity (coefficient of transmissibility) of the coarse-grained materials in the glacial deposits during the progress of test drilling enables the hydrologist or planner to make a preliminary evaluation of the water supply potential of the materials at the site. The tabulation of permeability values for various materials (see Table 111) allows the planner to make these preliminary evaluations.

Each layer of clean sand or gravel that is penetrated by the test well below the water table is given an appropriate permeability value from the tabulation. Since transmissivity, (T), is the product of permeability, (P), and saturated thickness, (m), (T = P x m), the sum of the transmissivities of individual layers is the approximate total transmissivity of the aquifer at the site. A transmissivity in excess of 10,000 gpd per foot at the site probably justifies test pumping, but this depends upon water requirements. An example of the use of the permeability values and computations is given below.

Example

A test well is drilled 100 feet through the following sequence of unconsolidated glacial deposits, with the water table at a depth of 15 feet. What is the approximate transmissivity of the materials at this site?

Description	*Thickness (feet)*	*Saturated Thickness (m) (feet)*	*Coefficient of Permeability (P) (gpd/ft^2)*	*Coefficient of Transmissivity (T) (gpd/ft)*
Soil, sand loam	1	--	--	--
Sand, medium	19	6	400	2,400
Gravel, sandy	10	10	1,200	12,000
Sand, coarse	20	20	1,000	20,000
Sand, silty[a]	30	--	low	--
Silt, sand, and boulders[a] *(till)*	20	--	low	--
Total	100	36	--	34,400

[a]*Silt is assumed present in quantities sufficient to make the permeability negligible.*

Therefore, the approximate transmissivity (T) is 34,000 gpd per foot.

Table III

COEFFICIENT OF PERMEABILITY FOR VARIOUS COARSE-GRAINED MATERIALS

MATERIAL	COEFFICIENT OF PERMEABILITY (COEFFICIENT OF HYDRAULIC CONDUCTIVITY) (GPD/FT)
SAND (FINE)................	150
SAND (GRAVEL).............	400
SAND (COARSE)..............	1,000
SAND AND GRAVEL............	1,200
GRAVEL.....................	>2,000

SOURCE- U. S. GEOLOGICAL SURVEY.

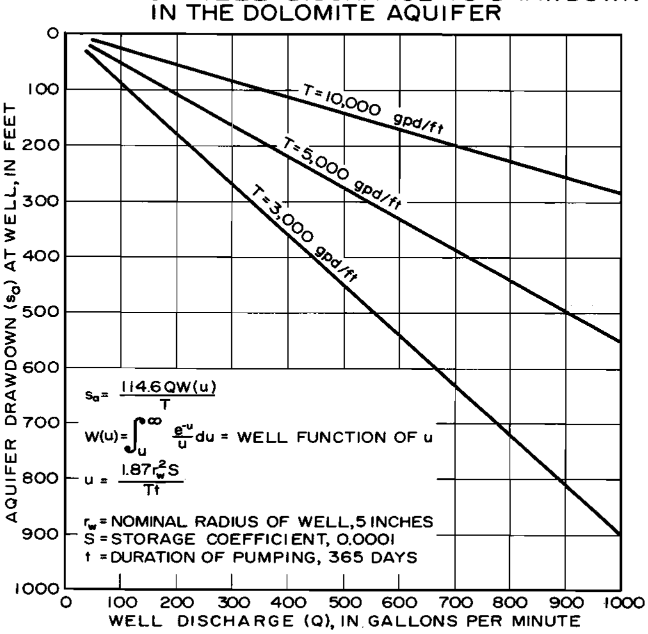
Dolomite Aquifer

The performance of the dolomite aquifer is determined by its pattern of fractures and solution channels and by the availability of recharge through the overlying glacial drift (see Table 109). Although this pattern may cause large differences in the yields of individual wells, the response of the aquifer to development will be determined by its average properties. The dolomite aquifer, when pumped for periods of time long enough to establish steady-state conditions, generally behaves as a water table aquifer. It is recharged mainly by vertical leakage from the overlying glacial deposits. Transmissivity of the aquifer is believed to range from about 2,000 to 10,000 gpd per foot in the watershed but generally lies between 3,000 and 10,000 gpd per foot. This range is represented on the discharge-drawdown and distance-drawdown curves, shown in Figures 27 and 28, which may be used in planning water supply development within the watershed.

The curves in Figure 28 are based on the assumption that the volume of water discharged by a well is balanced by the volume of leakage captured within the cone of depression created by pumping. Storage need not be considered in this situation. Each graph shows the drawdown to be expected in the dolomite aquifer for a given transmissivity, (T), when overlain by a leaky confining bed with the stated vertical permeabilities, (P'), and thicknesses, (m'). The result of recharge from vertical leakage is a reduction in extent of the cone of depression and the drawdown due to well interference within the cone. Drawdown, (s_a),

Figure 27

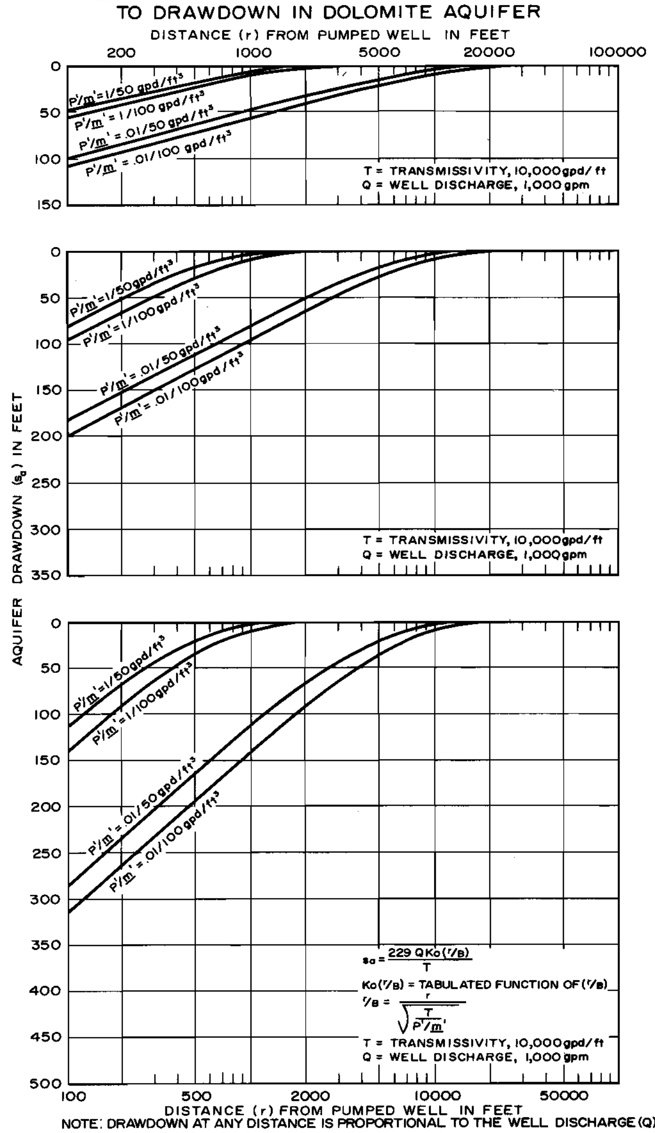
RELATION OF WELL DISCHARGE TO DRAWDOWN IN THE DOLOMITE AQUIFER



Source: U. S. Geological Survey.

Figure 28

RELATION OF DISTANCE FROM PUMPED WELL TO DRAWDOWN IN DOLOMITE AQUIFER



Source: U. S. Geological Survey.

is directly proportional to the pumping rate, (Q). This fact allows the use of Figure 28 for pumping rates other than the 1,000 gpm for which it is drawn.

The distance-drawdown curves assume a drawdown due to pumping under ideal artesian conditions. Although the dolomite aquifer is under artesian pressure presently in most areas of the watershed, any drawdown caused by pumping may draw the water level below the top of the dolomite, at least locally. The aquifer then would begin to behave as a water table aquifer close to the well while still under artesian pressure away from the well. With this understanding, these curves may be used to estimate roughly the drawdown in a pumping well and in the aquifer. Drawdown in the pumping well should be limited to approximately two-thirds of the available head in order to take advantage of most of the potential production of the aquifer.

Available head in the dolomite aquifer (see Table 109) is defined as the difference between the elevation of the potentiometric (piezometric) surface of the dolomite aquifer and the elevation of the top of the Maquoketa shale. The structure contours of the top of the Maquoketa shale are shown on Map 60.

Considering the approximation of Figure 27, the corrections to calculate drawdown in the well for the effects of well losses and dewatering are small enough to be neglected. Because the aquifer is continuous throughout most of the area, the effect of boundary conditions generally need not be considered. Also, supply wells in the dolomite aquifer generally should penetrate the full aquifer thickness as a matter of practice. This avoids additional drawdown in the well caused by partial penetration. The approximate effects of other pumping wells may be determined directly from Figure 28.

Curves for the coefficient of vertical permeability, (P'), of 0.01 gpd per square foot should be used for areas along the eastern side and northwest corner of the watershed (see Table 109). These are areas overlain by predominantly fine-grained clay tills. Curves for a vertical permeability of 1 gpd per square foot should be used for the rest of the watershed. The average thickness of the leaky glacial deposits, m, presented in Table 108, were determined from the saturated thickness map. Saturated thickness for other areas of the basin can also be estimated from this map.

It should be emphasized that Table 109 and Figures 27 and 28 are for use in planning and preliminary engineering studies. Because of the variable nature of this aquifer, aquifer performance tests should be conducted before development is actually committed.

Sandstone Aquifer

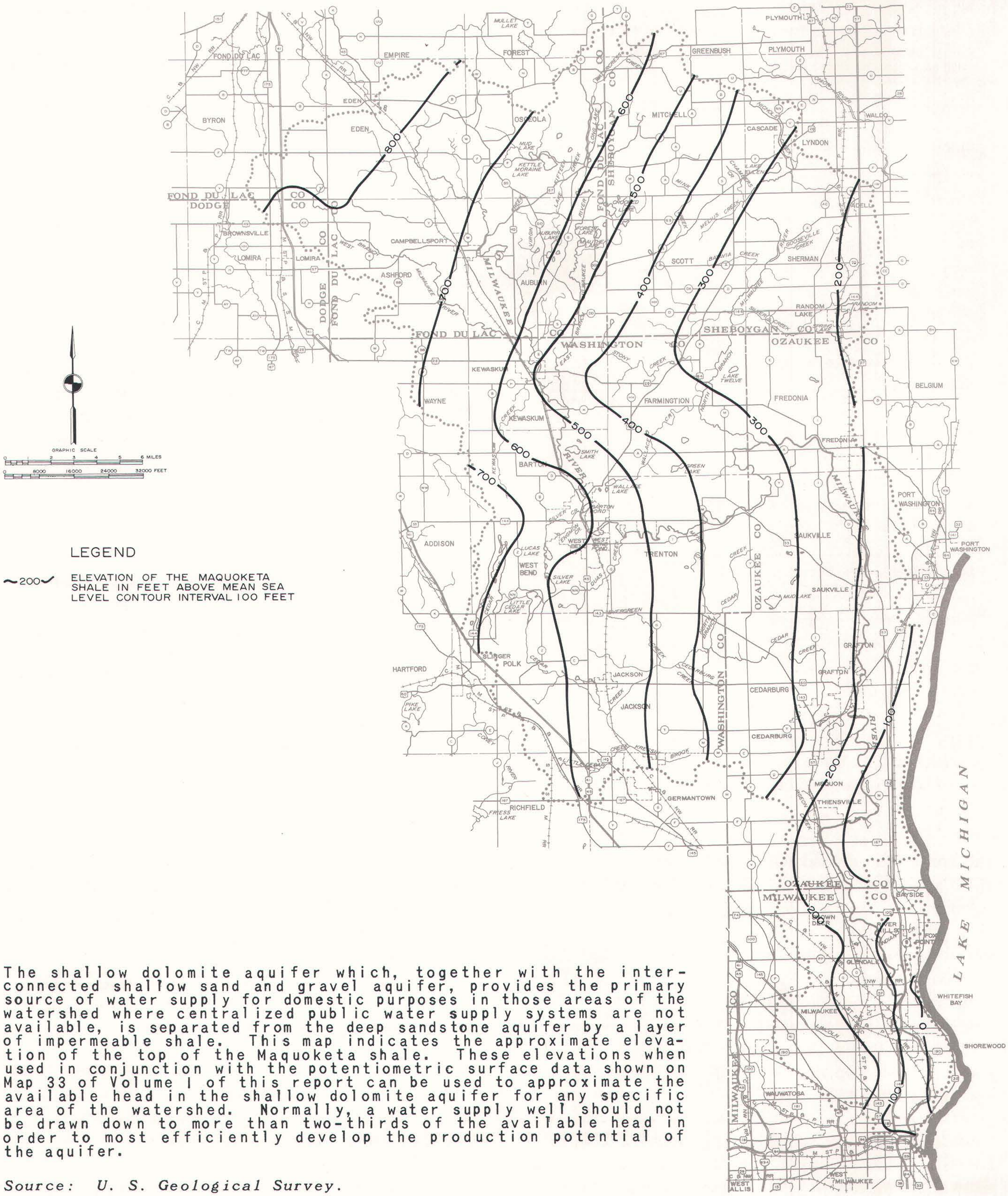
The sandstone aquifer is the most extensive aquifer in the Region and underlies the entire Milwaukee River watershed. Its performance generally depends on its thickness. Large individual well yields result from very large available drawdown and large saturated thickness, since the permeability of the aquifer is not high (see Table 110). Recharge to this artesian aquifer is very small, and present pumpage rates have caused a continuous regional decline in the potentiometric surface. This is especially true in the southern portion of the watershed. Water levels in the deep aquifer have declined by more than 300 feet at Milwaukee and 700 feet at Chicago during the past 100 years. Present pumpage from this aquifer is causing the water level to continue to decline at the rate of less than one foot to as much as four feet per year in the Milwaukee and Ozaukee County portions of the watershed, one to two feet per year in the Washington County portion of the watershed, and less than one foot per year in the Fond du Lac and Sheboygan County portion of the watershed.

The declines in the water level within this aquifer result from two related causes: regional pumpage located outside the Milwaukee River watershed, primarily in the Chicago and Milwaukee urbanized areas, and local pumpage within the watershed, concentrated primarily in Milwaukee and Ozaukee Counties. The greatest declines due to regional pumpage alone are expected to occur along the southern edges of the watershed. Although the regional declines may be expected to be small in Fond du Lac and Sheboygan Counties, they may be expected to exceed 100 feet by 1990 in central Milwaukee County. With the added effects of continued trends in local pumpage, total declines in central Milwaukee County may be expected to approximate 200 feet.

Transmissivity of the sandstone aquifer ranges from about 3,000 to 23,800 gpd per foot in the watershed, depending mainly on aquifer thickness. The expected range of transmissivity is represented on the discharge-drawdown, distance-drawdown, and time-drawdown curves shown in Figures 29 through 31. Figure 31 allows for consideration of

Map 60

STRUCTURE CONTOUR MAP OF THE TOP OF THE MAQUOKETA SHALE



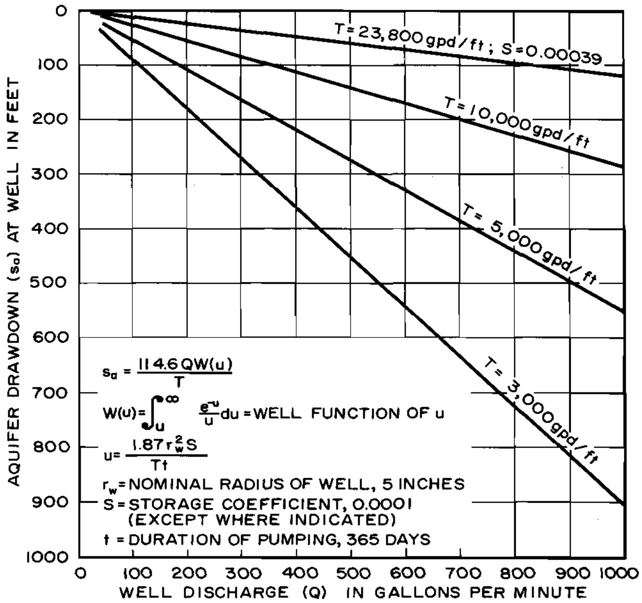
LEGEND

~200~ ELEVATION OF THE MAQUOKETA SHALE IN FEET ABOVE MEAN SEA LEVEL CONTOUR INTERVAL 100 FEET

The shallow dolomite aquifer which, together with the interconnected shallow sand and gravel aquifer, provides the primary source of water supply for domestic purposes in those areas of the watershed where centralized public water supply systems are not available, is separated from the deep sandstone aquifer by a layer of impermeable shale. This map indicates the approximate elevation of the top of the Maquoketa shale. These elevations when used in conjunction with the potentiometric surface data shown on Map 33 of Volume I of this report can be used to approximate the available head in the shallow dolomite aquifer for any specific area of the watershed. Normally, a water supply well should not be drawn down to more than two-thirds of the available head in order to most efficiently develop the production potential of the aquifer.

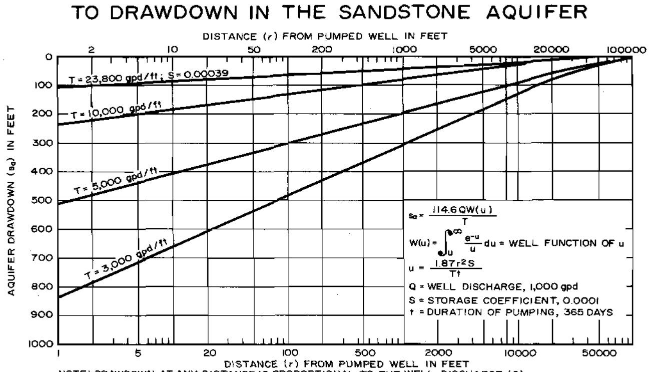
Source: U. S. Geological Survey.

Figure 29
RELATION OF WELL DISCHARGE TO DRAWDOWN IN THE SANDSTONE AQUIFER



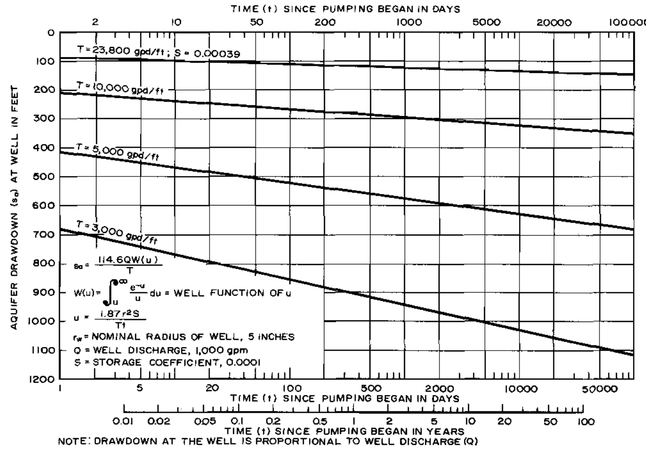
Source: U. S. Geological Survey.

Figure 30
RELATION OF DISTANCE FROM PUMPED WELL TO DRAWDOWN IN THE SANDSTONE AQUIFER



Source: U. S. Geological Survey.

Figure 31
RELATION OF TIME SINCE PUMPING BEGAN TO DRAWDOWN IN THE SANDSTONE AQUIFER



Source: U. S. Geological Survey.

the continuing drawdown brought about by pumping this aquifer. Again, drawdown, (s), is directly proportional to the pumping rate, (Q); and this fact allows the use of Figures 30 and 31 for pumping rates other than 1,000 gpm for which they are drawn. Available head in the sandstone aquifer is defined here as the difference in elevation between its potentiometric surface and the top of the St. Peter sandstone. The structure contours of the top of the St. Peter sandstone are shown on Map 61.

The discharge-drawdown, distance-drawdown, and time-drawdown graphs may be used to estimate drawdown either in the well or in the aquifer if consideration is given to other planned pumping wells and to the regional drawdown trend existing throughout the aquifer. The drawdown in the well and aquifer after any period of pumping may be determined from Figure 31. A nominal radius of the well of five inches is used in the computation of these curves, consistent with standard practice in the area.

The effects of other pumping wells after any period of pumping and at most distances may also be approximated from Figures 30 and 31, because pumping the aquifer for a sufficient period of time will bring about a state of equilibrium. When equilibrium is reached, drawdown in all but the extreme parts of the cone of depression is a constant value and allows the use of Figure 31 for most distances. Additional drawdown resulting from regional drawdown trends may be estimated from long-term observation well data.

Well losses in open holes, such as those in the sandstone aquifer, are generally small enough to be neglected. Because the aquifer is continuous throughout the area, the effect of boundary conditions need not be considered. Also, wells in the sandstone aquifer generally penetrate it sufficiently to avoid any significant additional drawdown caused by partial penetration.

The adopted regional land use plan provides a basis for estimating the spatial distribution of wells required to meet the future water supply demand. The land use plan is based, in part, upon the premise that the water resources of the Region can be better managed and future water

Map 61

STRUCTURE CONTOUR MAP OF THE TOP OF THE ST. PETER SANDSTONE

LEGEND

~200~ ELEVATION OF THE TOP OF ST. PETER SANDSTONE IN FEET ABOVE OR BELOW MEAN SEA LEVEL CONTOUR INTERVAL 100 FEET

The deep sandstone aquifer is separated from the shallow sand and gravel and dolomite aquifers by a thick layer of impermeable shale. The top of the sandstone aquifer is indicated by the contours shown on this map. These elevations when used in conjunction with the potentiometric surface data shown on Map 32 of Volume I of this report can be used to approximate the available head in the sandstone aquifer for any specific area of the watershed. Well drawdown effects in the sandstone aquifer can be determined from the data presented in Figures 29, 39, and 31 of this volume. As available aquifer head decreases, drawdown increases, requiring greater pumping heads for longer periods of time and resulting in significant increased power costs.

Source: U. S. Geological Survey.

supply problems avoided if the urban population of the Region is concentrated in areas which can be readily served by public water utilities. Public water utilities in 1967 served 15 areas of the watershed: Adell, Brown Deer, Campbellsport, Cedarburg, Fox Point, Fredonia, Glendale, Grafton, Kewaskum, Milwaukee, Random Lake, Saukville, Shorewood, West Bend, and Whitefish Bay. Local pumpage by 1990 may be expected to be heaviest in central Milwaukee and southern Ozaukee Counties where the greatest declines in water levels may also be expected. The effects of the increased demand for, and pumping of water from, the Milwaukee and Mequon-Thiensville areas, when added to the effects of the increased regional pumpage, if continued, may cause water level declines of more than 200 feet between 1967 and 1990.

This relatively rapid decline in the water level of the deep aquifer provides a warning of the need for a sound water resource management program and the development of alternative supply sources. Although an adequate supply of ground water is available to meet the anticipated needs, the water supply premises, upon which the regional land use plan was in part based, will be met only if this source of supply is carefully managed. In the absence of good water management practices, concentration of population and wells in major pumping centers will result in local water supply problems, an accelerated decline in water levels, continued poor water quality in a portion of the aquifer, and increased pumpage costs. In addition to careful attention to the proper location and spacing of wells tapping the ground water aquifers, contamination of the aquifers will have to be carefully guarded against in any sound management program.

Relative Costs of Well Drilling and Aquifer Development

In the Milwaukee River watershed, wells may be finished in either one or both bedrock aquifers or in the sand and gravel aquifer. Wells in the sand and gravel aquifer are constructed with an open bottom or with a well screen. In cases where this aquifer is fine-grained or where a greater yield is desired, a more costly gravel-packed well may be installed outside the well screen or perforated casing. Wells in the dolomite aquifer are cased a short distance into the rock but are open below this. Wells in the sandstone aquifer normally have the Maquoketa shale section cased but may be open above in the dolomite, as well as below in the sandstone.

The actual cost of a well depends on its depth, its diameter, the material it penetrates, and current economic conditions. The tabulation below and the curves provided in Figure 32 can be used to estimate the cost of wells within the Milwaukee River watershed because geologic, hydrologic, and economic conditions within the area studied by Ackermann[2] are similar to those in southeastern Wisconsin. The figures are based on 1966 costs and should be adjusted upward to reflect current cost levels. The tabulation compares the desired pumping rate with needed well diameter.

Pumping Rate (gpm)	Diameter of Well (inches)
125	6
300	8
600	10
1,200	12
2,000	14
3,000	16

For example, if a well capable of pumping 600 gpm is needed in an area where a fully penetrating well in the dolomite aquifer (a 400-foot well) will probably produce this amount, it can be determined from the tabulation and Figure 32 that a 10-inch well, 400 feet deep, has an average 1966 cost of $5,000. The mean plus one standard deviation line provide an estimate that can be expected to be exceeded only 16 percent of the time. The well cost so determined is for drilling and casing only and excludes the cost of pumping equipment. The cost of the pumping equipment can be estimated by determining the pump size required to provide the necessary peak rate of flow at the required head.

Pumping Cost

The continuing cost of pumping the water depends on the rate of pumping, duration of pumping, the total pumping head, the cost of energy, and the wire-to-water efficiency (pump and motor efficiency). The actual energy required in kilowatt hours is:

$$\text{Kw-hr} = \frac{(1.88 \times 10^{-4})}{E} Qht^{3}$$

where:

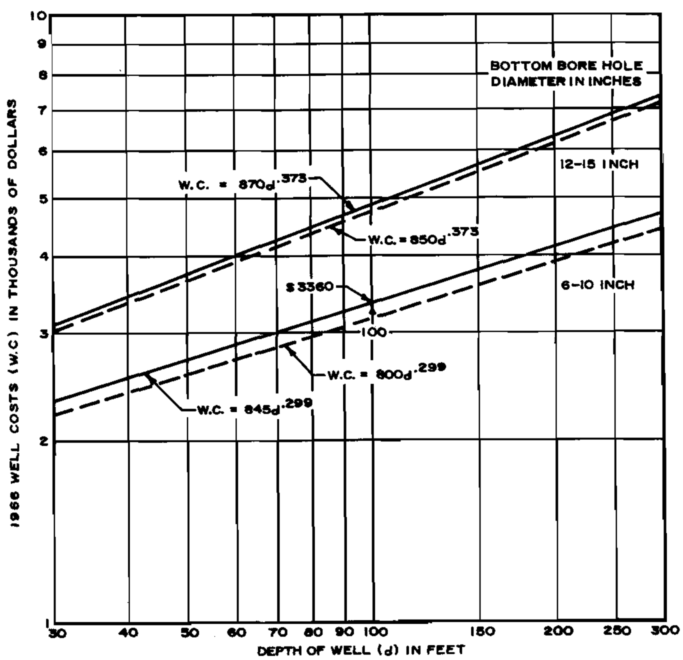
Q = flow in gpm.
h = total pumping head in feet.
t = time in hours.
E = wire-to-water efficiency in percent.

---

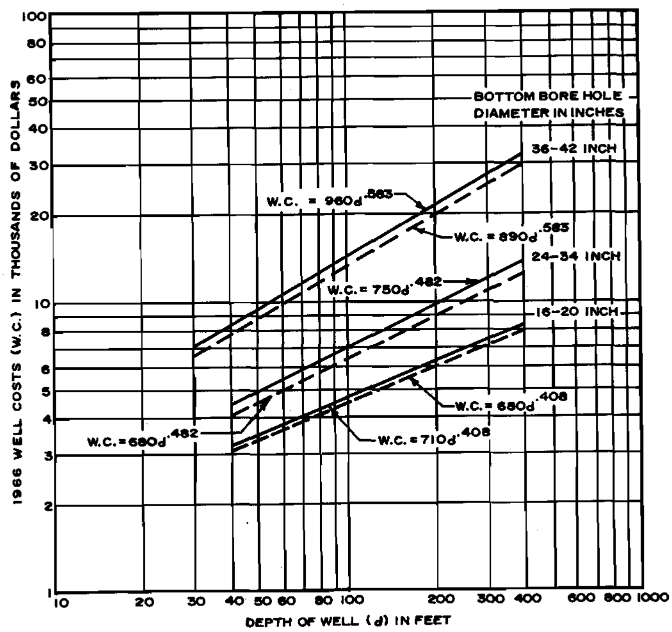
[2] *W. C. Ackermann, "Cost of Pumping Water," Ground Water, Vol. 7, No. 1, p. 38, 1969.*

[3] *Ibid., Footnote 2.*

Figure 32
GRAPHS FOR ESTIMATING THE COST OF DRILLING WELLS

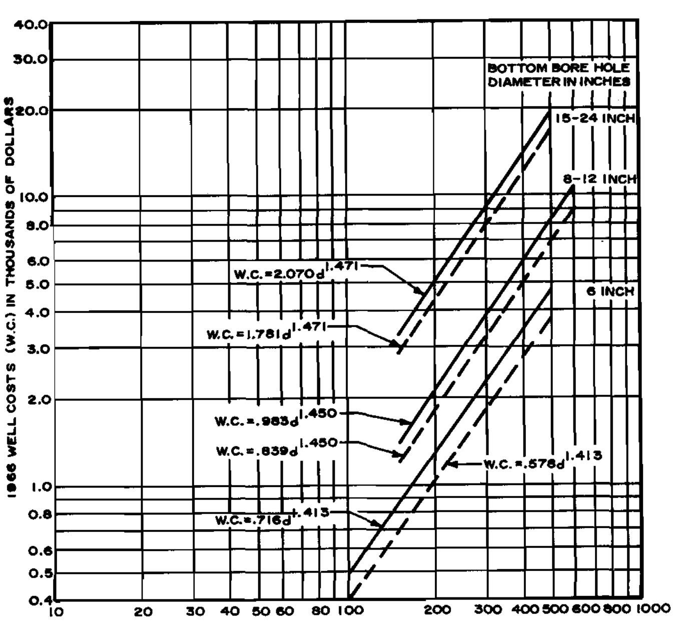


COST OF TUBULAR WELLS
FINISHED IN SAND AND GRAVEL

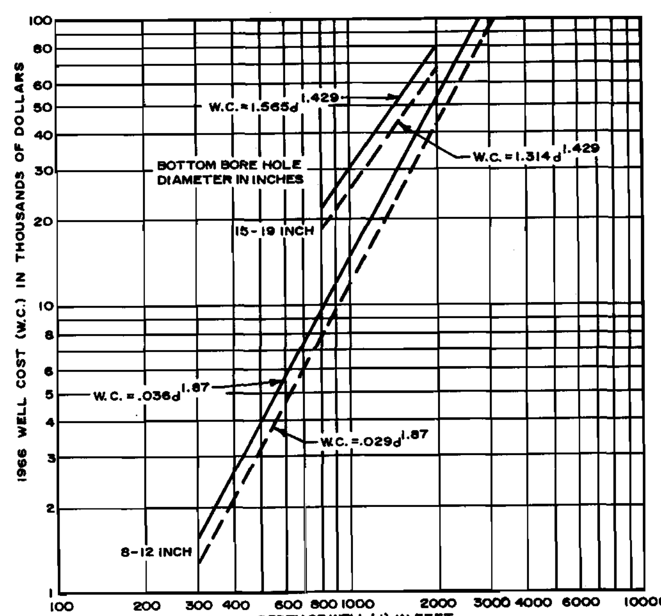


COST OF GRAVEL
PACKED WELLS

LEGEND
—— MEAN LINE
– – MEAN PLUS ONE STANDARD DEVIATION



COST OF SHALLOW SANDSTONE,
LIMESTONE, OR DOLOMITE



COST OF DEEP SANDSTONE WELLS

Source: U. S. Geological Survey.

From a sampling of pumping statistics in Wisconsin,[4] E was found to range between 43 and 50 percent and averaged 47.5 percent for ground water supplies, pumping less than 800 million gallons per year (2.2 mgd). Using this average percentage and the above formula, pumping costs can be estimated as follows:

Example

Required: approximate annual cost of pumping

Pumping rate: 500 gpm.

Time in hours: 12 hours per day x 365 days per year = 4,380 hours per year.

Water-to-wire efficiency: 47.5 percent.

Pumping head: 100 feet.

Cost of electricity: $0.02 per Kw-hr.

$$\text{Kw-hr} = \frac{(1.88 \times 10^{-4}) \times 500 \times 100 \times 4{,}380}{0.475}$$

$$\text{Kw-hr} = 86{,}600$$

at $0.02 per Kw-hr = $1,732 per year.

The user can estimate the cost of the well, exclusive of pumping equipment, and the continuing cost of pumping, knowing the depth and diameter of the well required and the pumping head. These can be estimated by use of appropriate available topographic maps in conjunction with the geologic and hydrologic maps and the graphs reproduced herein as Figures 25 through 32.

ALTERNATIVE WATER SUPPLY PLAN ELEMENTS

As already noted, there were 15 municipalities in the Milwaukee River watershed which operated municipal water utilities in 1967. One such community, the City of West Bend, used both the sand and gravel and the dolomite aquifers as sources of supply; five such communities, including the Villages of Adell, Fredonia, Kewaskum, Random Lake, and Saukville, used the dolomite aquifer; one such community, the Village of Grafton, used both the dolomite and sandstone aquifers; two such communities, the Village of Campbellsport and the City of Cedarburg, used the sandstone aquifer; and six such communities, the Villages of Brown Deer, Fox Point, Shorewood, and Whitefish Bay and the Cities of Glendale, and Milwaukee, used Lake Michigan as the source of supply. All of these 15 communities should be able to utilize essentially the same sources of supply used in 1967 through the design year of the watershed plan, provided that a good management program is implemented in any future expansion of the existing water supply facilities (see Tables 108 through 110).

Eight other urban communities in the watershed did not operate a municipal water utility in 1967. These are: the Villages of Bayside and River Hills in Milwaukee County; the City of Mequon, the Village of Thiensville, and the unincorporated community of Waubeka in Ozaukee County; the Village of Cascade in Sheboygan County; and the Village of Jackson[5] and the unincorporated community of Newburg in Washington County. Because the communities with existing public water supplies could be expected to be able to utilize the present sources of supply through at least the year 1990, alternative water supply plans were considered for only those urban communities which did not currently have a public water supply system.

Fond du Lac County

Within Fond du Lac County, there was only one community—the Village of Campbellsport—which operated a municipal water utility in 1967. All residents of the Fond du Lac County portion of the watershed outside of Campbellsport were served by individual wells tapping the dolomite aquifer.

Milwaukee County

There were only two communities in the Milwaukee County portion of the watershed which did not, in 1967, operate a municipal water supply system: the Villages of Bayside and River Hills. The total combined area of these villages within the watershed is 4.77 square miles.[6] In 1967 approximately 3,380 persons resided in this 4.77 square

[4] *Electric Power Pumping Statistics for Selected Water Utilities in Wisconsin*, *Wisconsin Public Service Commission, Bulletin No. 56, August 1968.*

[5] *It should be noted that the Village of Jackson, in October 1969, began operation of a total municipal water supply system, converting its previously existing limited fire protection water supply system.*

[6] *Of the total 1.77 square mile area of the Village of Bayside, 0.09 square mile is located in Ozaukee County. This fact does not, however, affect the total area of the Village within the watershed since the Ozaukee County portion of the Village lies in an area which drains directly to Lake Michigan.*

mile area and used an estimated 98.6 million gallons of water. This water was supplied solely from the shallow dolomite aquifer and delivered through private domestic and private cooperative water supply systems. By 1990 approximately 4,300 persons may be expected to reside in this same area, an increase over 1967 population levels of 27 percent, and to utilize 155.5 million gallons of water annually, an increase over 1967 water use of 58 percent.

Village of Bayside: In 1967 about 2,080 persons resided in the 0.63 square mile incorporated area of the Village of Bayside lying within the Milwaukee River watershed. These 2,080 persons used approximately 0.166 mgd of water drawn from the shallow dolomite aquifer. The population of this portion of the Village of Bayside may be expected to increase to approximately 2,100 persons by 1990, and water use may be expected to increase to 0.201 mgd. The shallow dolomite aquifer is adequate to meet this increase in demand due to the low anticipated population levels and densities. Although the shallow aquifer is subject to contamination, this danger is minimized within the Village of Bayside by virtue of the fact that the Village is served by a sanitary sewerage system and by virtue of the soil and depth to bedrock conditions existing within the Village.

Water levels in the shallow ground water aquifer underlying the Village of Bayside, which aquifer is recharged locally from rainfall, are subject to fluctuations in elevation of up to 11 feet, depending upon weather conditions and water utilization. As was indicated in Chapter XI of Volume 1 of this report, certain residences located within the Village of Bayside have, as a result of these fluctuations in ground water levels, been without water for periods of up to several days in length during very hot, dry periods of summer weather. This lack of water is probably due not to the complete depletion of the supply present in the dolomite aquifer but, rather, to the shallow depth to which the wells serving these residences have been drilled in relation to the full vertical extent of the dolomite aquifer, which approximates 450 feet in this area. The need to reconstruct these private wells if a more reliable water supply is to be provided, the relatively high dissolved solids content of the ground water in this area, and the desirability of providing better fire protection, combine to warrant careful consideration of the provision of a public water supply system for the Village. Such a public water supply system should, in light of declining water levels in the deep aquifer underlying this area, coupled with the potential intrusion of saline waters into the deep aquifer, utilize Lake Michigan as the source of supply.

Four alternative means were investigated whereby the Village of Bayside could obtain access to Lake Michigan as a source of water supply. The first alternative is for the Village to construct and develop its own municipal surface water supply system, including the necessary lake water intakes, treatment plant, pumping stations, and transmission, as well as distribution, mains.

The second alternative is for the Village to seek to obtain the necessary treated water from the North Shore water utility, which presently serves the adjacent Village of Fox Point, as well as the Village of Whitefish Bay and the City of Glendale.

A third alternative is for the Village to join with other municipalities within the area requiring a public water supply system in the cooperative provision of the necessary lake intake, treatment facilities, pumping station, and transmission mains. Potential members of such a cooperative arrangement would include, in addition to the Village of Bayside, the City of Mequon and the Villages of Thiensville and River Hills.

The fourth alternative is for the Village of Bayside to seek to obtain the necessary treated water from the City of Milwaukee municipal water utility. This alternative would be contingent upon, and become practical only if, either the Village of River Hills or the City of Mequon also elected to utilize the Milwaukee municipal water utility as the source of its supply.

A fifth alternative exists, similar to the third, but would involve the joint development of the dolomite aquifer as a source of supply, rather than Lake Michigan.

Village of River Hills: In 1967 about 1,300 persons resided in the 4.11 square mile incorporated area of the Village of River Hills lying within the Milwaukee River watershed. These 1,300 persons used approximately 0.1 mgd of water drawn from the shallow dolomite aquifer. The population of this portion of the Village of River Hills may be expected to increase to approximately 2,200 persons by 1990, and the water use may be expected to increae to 0.23 mgd. The shallow dolomite aquifer is adequate to meet this increase in demand due to the low anticipated population level and the relatively uniform distribution of this population by virtue of the country estate type of residential development existing in and projected for the Village. Although the shallow aquifer is subject to contamination, this danger is minimized within the Village of River Hills by virtue of the fact that the Village is served by a sanitary sewerage system and by virtue of the soil and depth to bedrock conditions existing within the Village.

The Village is, however, without a good source of water supply for fire protection and for this reason alone might give consideration to the construction of a public water supply system. Such a system would become a necessity should the long-range land use development objectives of the Village change and thereby permit either higher-density residential development or commercial or industrial development within the Village. Should the Village decide to provide a public water supply system, then that system should utilize, as its source of supply, Lake Michigan water.

Three alternative ways exist whereby the Village of River Hills could obtain access to Lake Michigan as a source of water supply. The first alternative is for the Village of River Hills to join with other municipalities within the area requiring a public water supply system in the cooperative provision of the necessary lake water intakes, treatment facilities, pumping station, and transmission mains. Potential members of such a cooperative arrangement would include, in addition to the Village of River Hills, the City of Mequon and the Villages of Bayside and Thiensville.

The second alternative is for the Village of River Hills to seek to obtain the necessary treated water from the North Shore water utility, which presently serves the adjacent Village of Fox Point, as well as the Village of Whitefish Bay and the City of Glendale.

A third alternative is for the Village of River Hills to seek to obtain the necessary treated water from the City of Milwaukee municipal water utility through the Village of Brown Deer, which is now served by the Milwaukee water utility.

A fourth alternative exists, similar to the first, but would involve the joint development of the dolomite aquifer as a source of supply, rather than Lake Michigan.

Other Communities: All of the other six communities within the Milwaukee County portion of the watershed presently served by municipal water supply systems utilize Lake Michigan as the source of supply and may be expected to continue to do so through the year 1990.

Ozaukee County

There were only three communities in the Ozaukee County portion of the Milwaukee River watershed that did not operate a municipal water supply system: the City of Mequon, the Village of Thiensville, and the unincorporated community of Waubeka, whose combined total area within the watershed is 33.6 square miles. In 1967, approximately 11,700 persons resided in this 33.6 square mile area and consumed an estimated 337 million gallons of water. These 337 million gallons of water were supplied solely by ground water from the dolomite and sandstone aquifers and delivered through private-domestic and private-cooperative water systems. By 1990 approximately 48,000 persons may be expected to reside in this same area, an increase over 1967 population levels of 310 percent, and utilize 1.7 billion gallons of water annually, an increase over 1967 water use of about 400 percent.

City of Mequon—Village of Thiensville:[7] In 1967 about 11,334 persons resided in the 32.6 square mile Mequon-Thiensville area of the Milwaukee River watershed. These 11,334 persons used approximately 0.90 mgd of water drawn from the dolomite and sandstone aquifers. The population of this portion of the Mequon-Thiensville area may be expected to increase to approximately 47,400 persons by 1990, and water use may be expected to increase to 4.74 mgd.

Three alternative water supply plan elements were considered for the Mequon-Thiensville area. The first provides for the continued use of existing sources of supply, but through common public "subdivision" water supply systems rather than through individual private wells. The dolomite and sandstone aquifers could continue to meet the water demand of these two communities through 1990, provided that any future use of these aquifers be made under a ground water management

[7] These two communities are discussed together herein, because of their location with respect to one another, the Village of Thiensville, with an area of 1.03 square miles and a 1967 population of 3,000 persons, being entirely surrounded by the City of Mequon, with an area of 46.88 square miles and a 1967 population of 11,700.

program, whereby the number, capacity, and location of any future wells are designed to provide the maximum efficiency from each well at the lowest possible cost. For this area, any future wells in the dolomite aquifer should be placed at least 5,000 feet apart, pumping at an equivalent full-term rate of 300 gallons per minute.

The second water supply alternative considered provides for the City of Mequon and Village of Thiensville to join with other municipalities within the area requiring a public water supply system in the cooperative provision of the lake intake, treatment facilities, and transmission mains necessary to provide the area with water from Lake Michigan. Potential members of such a cooperative arrangement would include, in addition to the City of Mequon and the Village of Thiensville, the Villages of Bayside and River Hills. This alternative would give Mequon and Thiensville a more reliable source of water, both in quantity and in quality.

The third water supply alternative considered is similar to the second, but would involve joint development of the dolomite aquifer as a source of supply.

The communities of Cedarburg and Grafton, although located in relatively close proximity to the City of Mequon, are presently served by municipal water supply systems utilizing the deep sandstone and dolomite aquifers as the source of supply. In 1967 these two communities together used a total of about 2.1 mgd of water, and it is anticipated that this demand will increase to about 4.2 mgd by 1990. The present ground water sources should be adequate to meet this anticipated demand, and service to the Cedarburg-Grafton area, therefore, was not provided for in the alternative water supply systems considered for the Mequon-Thiensville area. Moreover, the adopted regional land use plan recommends that a two-mile wide band across the northernmost part of the City of Mequon remain in essentially rural land use through 1990 and, therefore, should not require or be provided with a public municipal water supply system. Traversing this band of agricultural land with water transmission mains would raise the cost of supply to the Cedarburg-Grafton area from the proposed Mequon-Thiensville system. If, however, the sources of supply now being used by Cedarburg and Grafton should become inadequate with respect to either quality or quantity prior to 1990, for some presently unforeseen reason, there would be no areawide planning reason for not including Cedarburg and Grafton in a multi-municipal utility system, assuming that the cost of the necessary transmission mains did not prove prohibitive.

Waubeka (Unincorporated): In 1967 about 360 persons resided in the approximately one square mile area of urban development comprising the unincorporated Village of Waubeka. These 360 persons used approximately 0.017 mgd of water drawn from the shallow dolomite aquifer. The population of Waubeka may be expected to increase to approximately 600 persons by 1990 and water use may be expected to increase to 0.045 mgd. The dolomite aquifer in this area is capable of meeting the forecast water-needs both in terms of quality and quantity. The future water demand, however, should be met by a municipal water supply system so as to provide a reliable supply for all uses, including fire flow.

Sheboygan County

Only one community in the Sheboygan County portion of the watershed—the Village of Cascade—does not operate a municipal water supply system.

Village of Cascade: In 1967 about 500 persons resided in the 0.75 square mile incorporated area of the Village of Cascade. These 500 persons used approximately 0.025 mgd of water drawn from the shallow dolomite aquifer. The population of the Village of Cascade may be expected to be about the same, 500 persons, in 1990; however, the water use may be expected to increase to about 0.042 mgd. The existing source of supply, however, should be adequate to meet this forecast increase in demand, and no serious water quality problems should be encountered.

The dolomite aquifer in this area is capable of meeting the 1990 water needs of Cascade, both in quality and in quantity. This future water need, however, should be withdrawn, treated, and delivered by a municipal water system so as to provide a reliable water supply for all users. This municipal water supply system should also provide a fire protection system, which system would lower the community's fire insurance classification and decrease fire insurance premiums within the Village of Cascade.

Washington County

There were only two communities in the Washington County portion of the Milwaukee River watershed that did not, in 1967, operate a municipal water supply system: the Village of Jackson and the unincorporated community of Newburg. The total combined area of these two communities is 1.51 square miles. In 1967 approximately 914 persons resided in this 1.51 square mile area and used an estimated 34.7 million gallons of water. This 34.7 million gallons of water was supplied solely by ground water from the dolomite aquifer and delivered through private-domestic water systems. By 1990 approximately 2,600 persons may be expected to reside in this same area, an increase over 1967 population levels of 184 percent, and may be expected to utilize 93.8 million gallons of water annually, an increase over 1967 water use of 170 percent.

Village of Jackson: In 1967 about 500 persons resided in the 0.51 square mile incorporated area of the Village of Jackson. These 500 persons used approximately 0.07 mgd of water drawn from the dolomite aquifer. The population of the Village of Jackson may be expected to increase to 1,500 persons by 1990, and water use may be expected to increase to 0.169 mgd.

As of 1967 the Village of Jackson did not operate a municipal water supply system; however, the Village was operating a municipal fire protection system composed of water mains, hydrants, and water storage facilities. In July 1970 the Village of Jackson converted its fire protection water supply system to a full municipal water utility serving commercial, industrial, and domestic, as well as fire flow, needs. The dolomite aquifer in this area is capable of meeting the full 1990 water needs of Jackson, both in quality and in quantity.

Newburg (Unincorporated): In 1967 about 410 persons resided in the approximately one square mile of urban development comprising the unincorporated Village of Newburg. These 410 persons used approximately 0.021 mgd of water drawn from the shallow dolomite aquifer. The population of Newburg may be expected to increase to approximately 1,100 persons by 1990, and water use may be expected to increase to 0.088 mgd. The dolomite aquifer in this area is capable of meeting the forecast water needs both in terms of quality and quantity. The future water demand, however, should be met by a municipal water supply system so as to provide a reliable water supply for all uses, including fire flow.

Water Utility Alternatives for the Bayside-Mequon-River Hills-Thiensville Area

Preliminary engineering and economic analyses were made of alternative public water supply systems to serve the City of Mequon and the Villages of Thiensville, Bayside, and River Hills. Of the eight urban communities in the watershed not operating municipal water utilities in 1967, these four are contiguous and represent a large portion of the future water demand not now served by a public utility and, therefore, may benefit from a joint water supply effort. The previous discussion of alternative water supply elements suggested the formation of a joint water utility, preferably using Lake Michigan water, as one way in which each of these communities could meet present and future water supply needs. Three alternative water supply systems were considered: a joint system utilizing a ground water supply drawn from the dolomite aquifer; a joint system utilizing Lake Michigan as a direct source of supply; and a joint system utilizing Lake Michigan as an indirect source of supply through purchase of water from either the Milwaukee municipal water utility or the North Shore water utility.

The engineering and economic analyses were for comparative cost analyses purposes only and do not constitute a detailed engineering study. The analyses were intended to demonstrate the factors that must be considered in developing a public water supply system for these four communities, to evaluate the relative costs of the various components of such a system, and to explore the cost of using Lake Michigan as a water supply source rather than the ground water resource.

Common criteria were used in the design and analysis of the three alternative systems in order to facilitate comparisons. Each system was sized to simultaneously satisfy, in terms of discharge and pressure, the fire protection needs and peak daily water demands expected in 1990 for a service area consisting of the entire area of the four communities, that is, those portions of the communities both within and outside the Milwaukee River watershed. In addition to these water quantity requirements, the water utility systems are envisioned as supplying water of equally high quality. The technical and economic analyses considered only the large diameter transmission mains required for each of the systems. A complete distribution network would require, in addition to the large diameter main transmission conduits, a grid of smaller diameter distribution pipes composed primarily of new pipes, with some use of existing municipal or subdivision distribution pipes. This distribution network of smaller diameter pipes and appurtenances would be essentially the same for each of the alternative water utility systems and, therefore, would add approximately the same cost to each. This cost was not, therefore, estimated for the comparisons.

The basic components of the three alternative water utility schemes are summarized in Table 112 and are shown on Maps 62, 63, and 64. It is apparent from the costs, as set forth in the tables, that Lake Michigan is the most economic source of future water supply for a utility serving the City of Mequon and the Villages of Thiensville, Bayside, and River Hills.

Some factors involved in a comparison between the alternative water utility systems are not readily quantified in economic terms but do warrant consideration. Probable future availability of an adequate water supply beyond the year 1990 is one of these factors. In terms of quantity, Lake Michigan represents an unlimited water resource for the future, while the supply of ground water to meet ever-increasing water demands may ultimately be limited by the rate of vertical recharge of the dolomite aquifer. It is difficult to foresee the future water quality characteristics of a Lake Michigan supply. The two alternatives utilizing that supply, however, incorporate complete, centralized water treatment works and, therefore, could be operated so as to compensate for a deterioration in the quality of the water supply.

Table 112

COST ESTIMATES--ALTERNATIVE COOPERATIVE WATER SUPPLY SYSTEMS FOR THE BAYSIDE-MEQUON-RIVER HILLS-THIENSVILLE AREA

Alternative Plan Element				Present Worth			Annual Cost			
Number Designation	Description[a]	Component	Capital Cost[b]	Capital Cost	Operation, Maintenance and Electrical Energy	Total	Amortization[c]	Operation and Maintenance[d]	Electrical Energy[d]	Total
1	Independent Water Utility Obtaining Water Directly from Lake Michigan	Lake Intake Structure and Conduit...	$1,000,000	$1,000,000	$ --	$1,000,000	$ 87,200	$ --[e]	$ --[f]	$ 87,200
		Lakeshore Pumping Station....	154,000	154,000	187,000	341,000	13,400	--[g]	16,300	29,700
		Raw Water Transmission Line..	238,000	238,000	--	238,000	20,600	--[e]	--[f]	20,600
		Water Treatment Plant and Pumping Station............	1,716,000	1,716,000	1,570,000	3,286,000	149,000	103,000	34,000	286,000
		Treated Water Reservoir...............	880,000	880,000	--	880,000	76,600	--[g]	--[f]	76,600
		Main Distribution Loop...............	1,320,000	1,320,000	38,000	1,358,000	115,000	3,300	--[f]	118,300
		Total	$5,308,000	$5,308,000	$1,795,000	$7,103,000	$ 461,800	$106,300	$ 50,300	$618,400
2	Independent Water Utility Obtaining Water from the Shallow Dolomite Aquifer	25 Wells and Pumps..	$ 660,000	$ 660,000	$ 888,000	$1,548,000	$ 57,500	$ 25,000	$ 52,400	$134,900
		Main Collection and Distribution Network...............	2,189,000	2,189,000	--	2,189,000	191,000	--[i]	--	191,000
		Domestic Type Water Conditioners Serving 80 Percent of the Population.....	--[f]	--	4,880,000	4,880,000	--[f]	425,000	--[e]	425,000
		Total	$2,849,000	$2,849,000	$5,768,000	$8,617,000	$ 248,500	$450,000	$ 52,400	$750,900
3	Independent Water Utility Obtaining Water from the *City of Milwaukee*	Treated Water Reservoir...............	$ 880,000	$ 880,000	--	$ 880,000	$ 76,600	$ --[j]	$ --[f]	$ 76,600
		Pumping Station.....	308,000	308,000	620,000	928,000	26,800	20,000	34,000	80,800
		Main Distribution Loop[h]...............	1,480,000	1,480,000	42,000	1,522,000	129,000	3,700	--[f]	132,000
		Purchase of Treated Water...............	--[f]	--	5,980,000	5,980,000	--[f]	522,000	--[f]	522,000
		Total	$2,668,000	$2,668,000	$6,642,000	$9,310,000	$ 232,400	$545,700	$ 34,000	$812,100

[a]Each of the alternative cooperative water supply systems is designed to meet the water supply and fire protection needs of a 1990 forecast population of 62,500 persons within the Villages of Bayside and River Hills in Milwaukee County and the City of Mequon and the Village of Thiensville in Ozaukee County. This forecast population would require supplying simultaneously a peak daily demand of 180 gallons per capita per day (GPCD) or 11.2 million gallons per day (MGD) and a fire fighting flow of 170 GPCD or 10.6 MGD for a period of 10 hours. The 1970 per capita capital and annual costs for each alternative are, respectively- Alternative 1-$205 and $24, Alternative 2-$110 and $29, and Alternative 3-$103 and $31. The 1990 per capita capital and annual costs for each alternative are, respectively- Alternative 1-$85 and $10, Alternative 2-$46 and $12, and Alternative 3-$43 and $13.

[b]1970 prices; includes 10 percent for engineering and legal fees and land costs.

[c]20 year amortization period at a six percent annual interest rate.

[d]1980 values.

[e]*Negligible.*

[f]Not applicable.

[g]Included in water treatment plant operation and maintenance.

[h]The required distribution network of small diameter pipes is not included.

[i]Included in well and pump operation and maintenance.

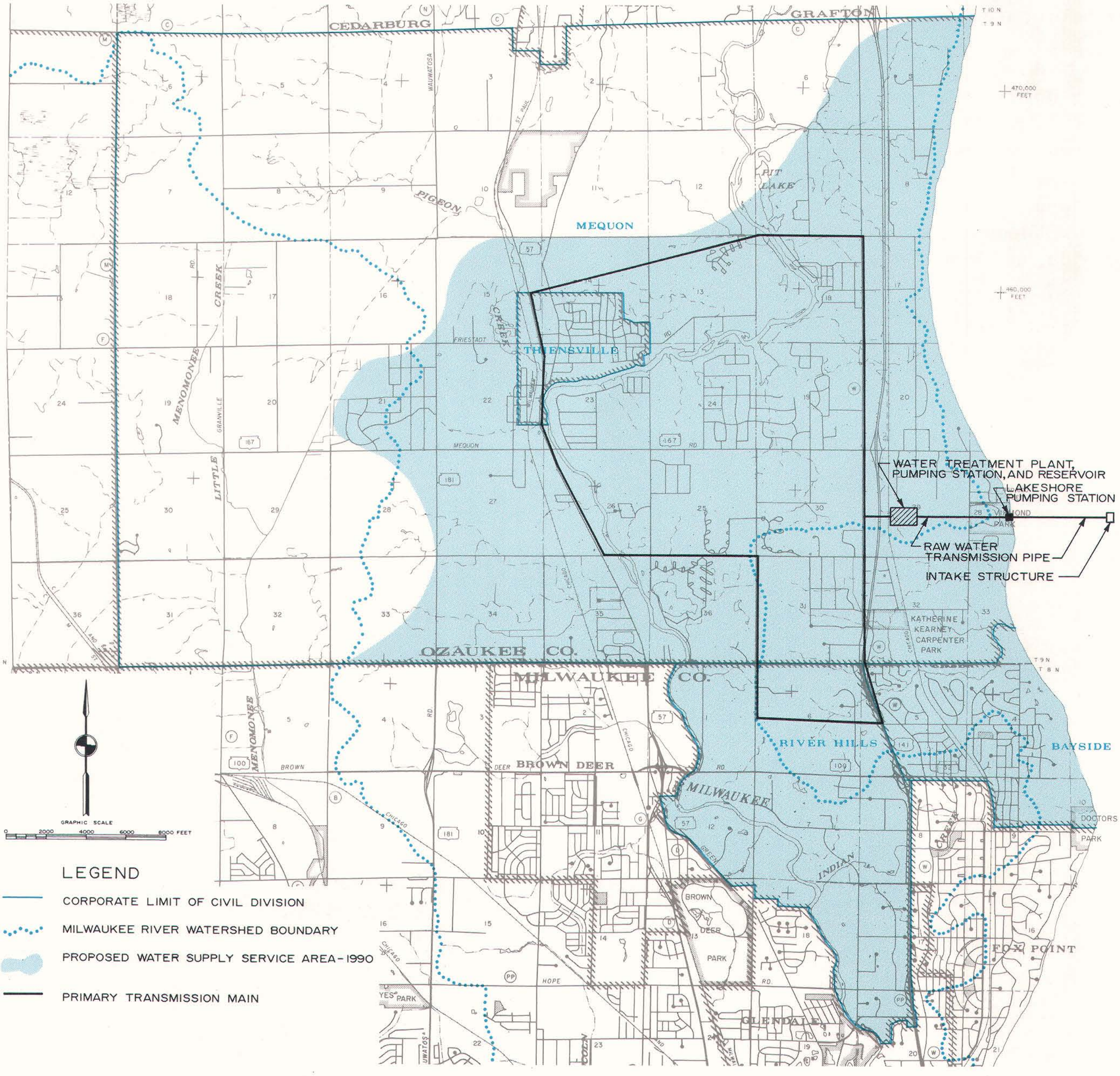
[j]Included in pumping station operation and maintenance.

Source- SEWRPC.

Map 62

ALTERNATIVE COOPERATIVE WATER SUPPLY SYSTEM NO. I FOR THE BAYSIDE - MEQUON - RIVER HILLS - THIENSVILLE AREA

INDEPENDENT WATER UTILITY OBTAINING WATER DIRECTLY FROM LAKE MICHIGAN



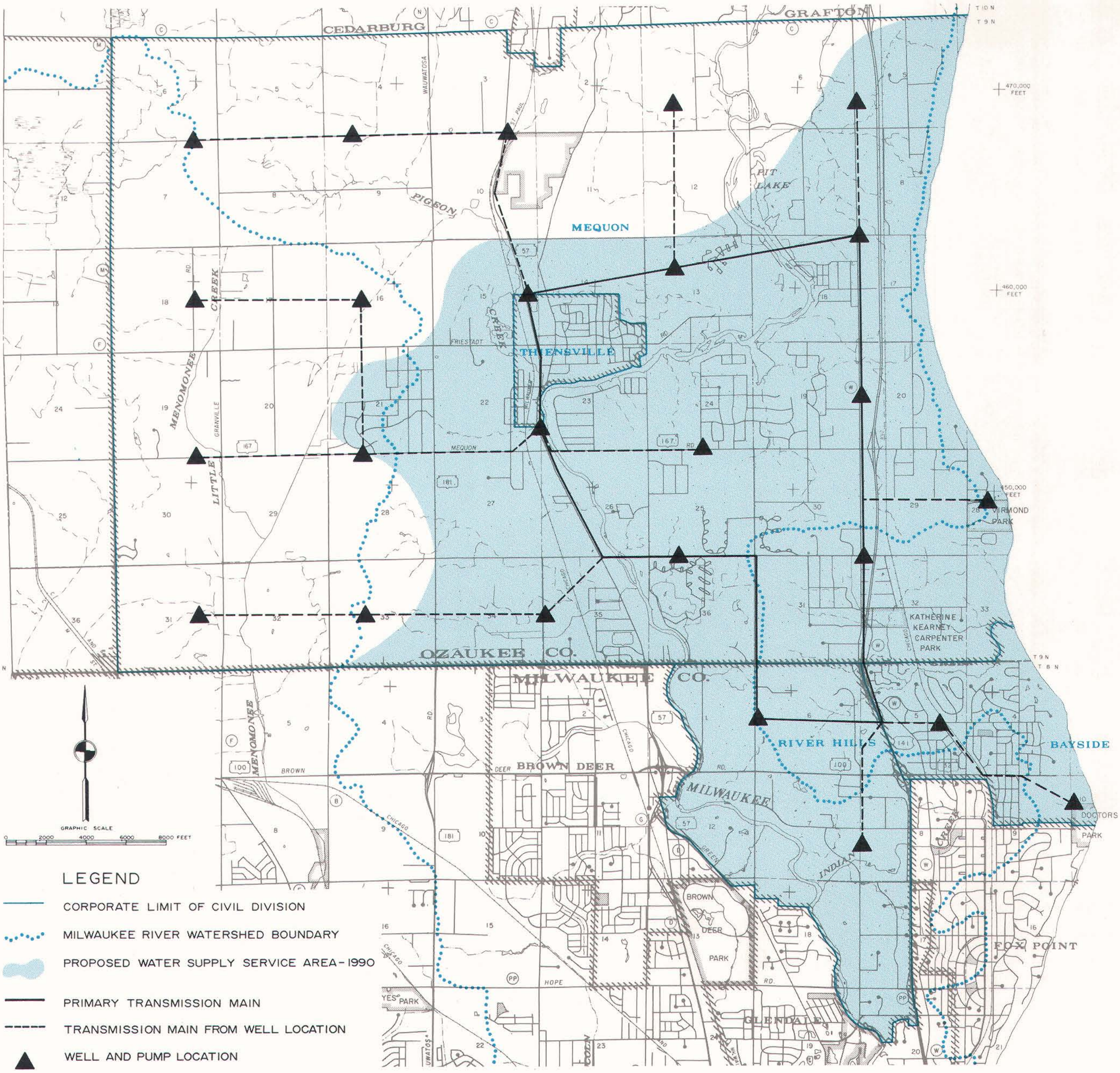
Three alternative means of providing a public water supply system for the Bayside-Mequon-River Hills-Thiensville area of the watershed were considered. The first alternative would use Lake Michigan as the source of supply. A cooperative intercommunity utility would construct, operate, and maintain a water intake from Lake Michigan, a water treatment plant, a system of storage reservoirs, and a main distribution loop, all located approximately as shown on this map. Each of the four individual communities would build and maintain their own local water distribution systems. This alternative water supply system would be designed to serve a 1990 connected population of about 62,500 persons. The creation of such a public water supply system would serve to avoid future problems created by extensive demands on the shallow ground water aquifers and would serve to provide a reliable source of water for fire fighting, as well as residential, commercial, and industrial supply, purposes.

Source: SEWRPC.

Map 63

ALTERNATIVE COOPERATIVE WATER SUPPLY SYSTEM NO. 2 FOR THE BAYSIDE - MEQUON - RIVER HILLS - THIENSVILLE AREA

INDEPENDENT WATER UTILITY OBTAINING WATER FROM THE SHALLOW DOLOMITE AQUIFER



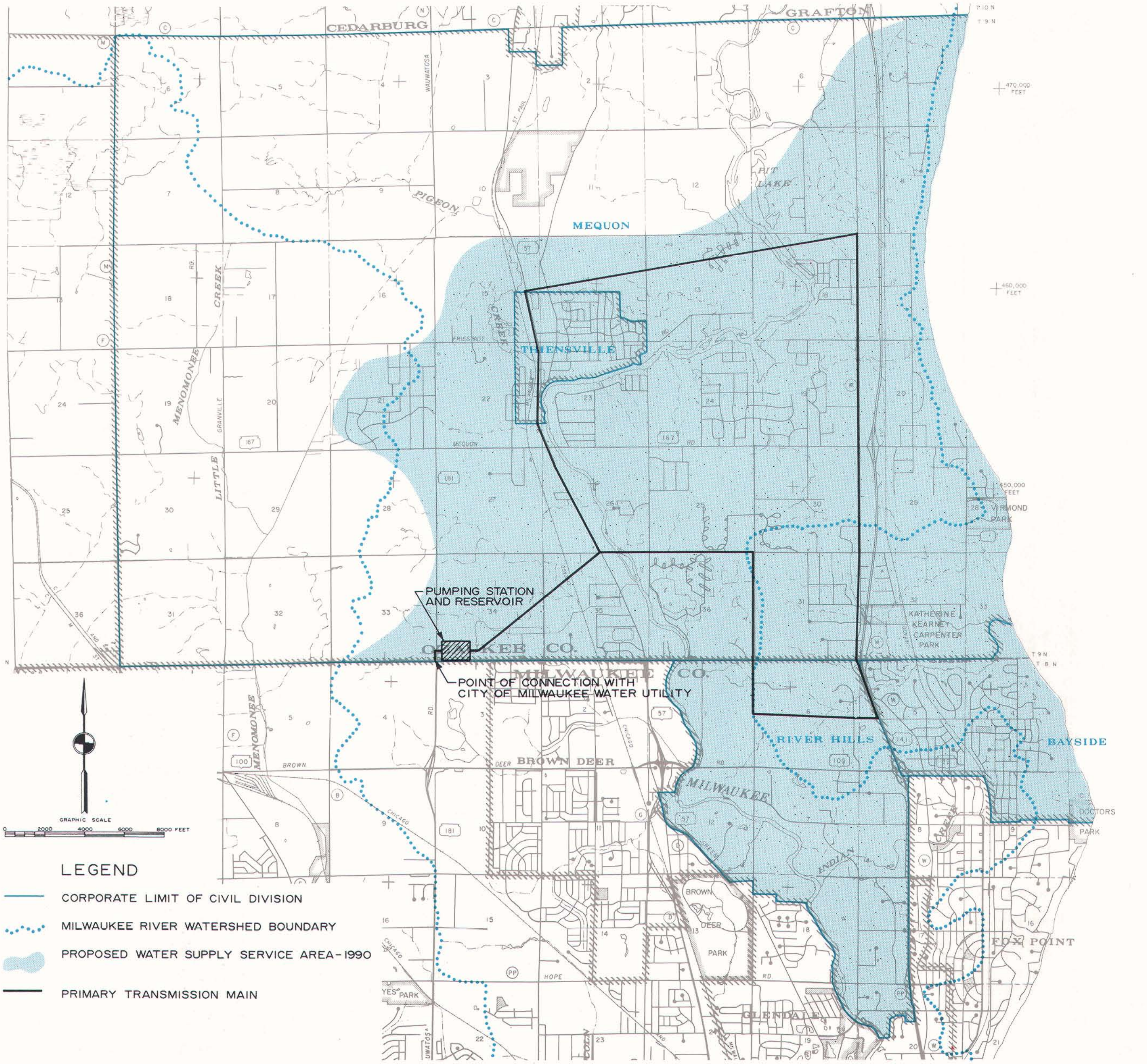
The second alternative water supply system plan considered to serve the Bayside-Mequon-River Hills-Thiensville area would utilize the shallow dolomite ground water aquifer as the source of supply. A total of 25 wells spaced approximately one mile apart on a grid pattern would be needed to meet the anticipated demand. As in the first alternative, the proposed cooperative, intergovernmental water supply utility would operate the water supply system, including the wells and main distribution loop, with the individual communities building, operating, and maintaining the local water distribution systems.

Source: SEWRPC.

Map 64

ALTERNATIVE COOPERATIVE WATER SUPPLY SYSTEM NO. 3 FOR THE BAYSIDE - MEQUON - RIVER HILLS - THIENSVILLE AREA

INDEPENDENT WATER UTILITY OBTAINING WATER DIRECTLY FROM THE CITY OF MILWAUKEE



The third alternative water supply system plan considered to serve the Bayside-Mequon-River Hills-Thiensville area would utilize treated Lake Michigan water purchased from the City of Milwaukee water utility as the source of supply. Connection to the City of Milwaukee system would be made near N. 76th Street and W. County Line Road. As in the first two alternatives, the area-wide cooperative water utility would build and maintain the storage, pumping, and primary distribution facilities, while the individual communities would build, operate, and maintain the local water distribution systems.

Source: SEWRPC.

Future trends in the quality of ground water are equally difficult to predict. The ground water system, because of the distributed nature of its source, does not include a central water treatment facility but relies solely on residence-type water conditioning units and, therefore, does not have the same potential for meeting possible future water quality deterioration. Complete treatment of the ground water, equivalent to that proposed for the Lake Michigan supply, would necessitate either individual treatment units at each of the 25 wells or a central water treatment facility with considerable additional transmission main. Both of these approaches to ground water treatment appear to be very costly.

OTHER MINOR SOURCES OF SUPPLY

Surface water resources presently supply few consumptive water needs within the watershed except livestock watering. Small quantities of water are pumped from streams and ponds for irrigation, and an expanded use of surface water for this purpose may occur in the future. The largest lakes within the watershed could be utilized as sources of potable water, although no lakes are so used now. Water could be pumped either directly from the lakes or indirectly through induced recharge of well fields located near the lake shorelines. The advantage of the use of well fields would be that the lake water would be partially filtered when it reached the well. In all cases, however, the lake water would require treatment before delivery to a public water supply system. Any major use of lake water in this manner may be expected to result in serious conflicts with recreational water uses and is, therefore, not recommended.

Stream water is presently used only for irrigation and cooling purposes within the watershed. A substantial increase in the amount of water withdrawn from streams for such uses is unlikely because the streams are shallow and the flow is highly variable. Moreover, since most streams within the watershed are also used for waste assimilation, treatment costs for uses other than irrigation and cooling could be expected to be high.

SUMMARY

The water supply resources of the Milwaukee River watershed are fortunately not only varied as to source but are also renewable. The shallow aquifers underlying the upper watershed can be developed to meet all foreseeable demands within those areas for domestic and livestock watering purposes. Increased use of this aquifer, however, for such uses as crop irrigation or extreme commercial uses, may result in some local water supply shortages or conflicts. This aquifer is more readily susceptible to pollution; and, therefore, the quality of the water in this aquifer, will have to be carefully protected through sound land use controls, as well as through careful surface and ground water quality management measures.

The deep sandstone aquifer underlying the upper watershed provides an additional source of large quantities of water for public supply. If and when this source of water is needed, a good ground water resource management program should be implemented. This program would include spacing of wells, controlling yields and drawdowns, and continuous monitoring of the aquifer, as well as protection from pollution, if the full potential of this source of supply is to be realized.

Although the shallow aquifers underlying the lower watershed can be developed to meet all foreseeable private domestic and livestock watering demands within the area, neither these aquifers nor the deep sandstone aquifer should be relied upon as a source of public supply. This area of the watershed is fortunate, however, in having an alternative surface source of supply readily available to it in the form of Lake Michigan.

Although the Waubeka reservoir site was investigated and analyzed as an alternative source of water supply within the watershed, it was determined that such an alternative source of supply was not needed nor its development warranted prior to the 1990 plan design year. In order to retain full flexibility in the future for the development of alternative sources of water supply within the watershed to meet the needs of development beyond the year 1990, however, the lands needed for this reservoir should be protected and preserved in essentially open use.

(This page intentionally left blank)

Chapter VII

RECOMMENDED COMPREHENSIVE PLAN FOR THE MILWAUKEE RIVER WATERSHED

INTRODUCTION

The design of a comprehensive plan for the Milwaukee River watershed required that a selection be made from among the several alternatives considered under each of the four major elements which together are to comprise the comprehensive watershed plan. These four major elements are: 1) a land use base element, including the natural resource protection, outdoor recreation, and parkway and scenic drive subelements of such a base; 2) a supporting flood control element; 3) a supporting water pollution abatement element; and 4) a supporting water supply element.

The selection of the best alternative from among the various alternatives considered under each of these four major elements must be based upon an evaluation of many tangible and intangible factors, with primary emphasis, however, upon the degree to which the various alternatives meet the established watershed development objectives and upon the accompanying costs. The final selection of the plan elements to be included in the comprehensive watershed plan must ultimately be made by the responsible public officials and not by the planning technicians, although the latter may properly make recommendations based upon an evaluation of engineering, economic, and legal considerations.

The plan selection process utilized, which involved the extensive use of advisory committees and both formal and informal public hearings, has been described in Chapter I of this volume. The alternative land use, natural resource protection, outdoor recreation, parkway and scenic drive, flood control, surface water pollution abatement, and water supply plan elements considered have all been described in previous chapters of this volume. This chapter presents a description of the recommended comprehensive watershed development plan as synthesized from the best alternatives under each of the four major plan elements, along with a presentation of the basis for the synthesis and an analysis of the attendant costs.

BASIS OF PLAN SYNTHESIS

The watershed development objectives which the final comprehensive Milwaukee River watershed plan is designed to meet are set forth in Chapter II of this volume. That chapter also sets forth the standards for relating these objectives to the physical development proposals which constitute the plan, thereby facilitating evaluation of the ability of each of the alternative plan proposals to meet the chosen objectives. In each of the four chapters in which the various alternative land use, natural resource protection, outdoor recreation, parkway and scenic drive, flood control, water pollution abatement, and water supply plan elements have been set forth, the alternative plan proposals have been evaluated and recommendations made for inclusion of the best alternatives in the comprehensive watershed plan. In this process of plan selection, the various alternative plan elements were evaluated, as appropriate, with respect to their engineering, economic, and legal feasibility, as well as with respect to their ability to meet the appropriate watershed development objectives and supporting standards. It is clear that no one land use or water control facility plan element can fully satisfy all of the watershed development objectives. The recommended comprehensive watershed plan must, therefore, consist of a combination of individual plan elements, with each plan element contributing toward the satisfaction of the development objectives. It should be noted also in this respect that many of the alternative plan elements were specifically designed to satisfy certain watershed development objectives and that, in this event, the selection from among the alternatives depends largely upon analysis of the attendant costs.

Of the two major land use development alternatives considered, the recommended alternative, described as the watershed plan land use base in Chapter III of this volume, is clearly superior to the unplanned alternative, described in Chapter VIII of this volume, with respect to the attainment of the watershed development objectives. As documented in Chapter VIII of this volume, the unplanned alternative would make certain watershed development objectives extremely difficult, if not impossible, to attain by creating an inefficient spatial distribution of urban development within the watershed which would be more susceptible to future flood damage and more difficult and costly to serve with sanitary sewerage facilities. The unplanned alternative would be particularly destructive of the natural resource base of the watershed through further intrusion of incompatible urban development into the primary environmental corridor and remaining prime agricultural areas. A continuation of uncontrolled land use development within the watershed could, therefore, be expected to reduce greatly the remaining high-value woodland, wetland, wildlife habitat, and prime agricultural areas within the watershed. The opportunity for the establishment of high-value home sites in the attractive setting of adjacent resource conservation areas would also be lost. On the basis of its failure to meet the watershed development objectives, therefore, the unplanned land use alternative must be rejected.

The recommended land use base element will not, however, in and of itself, fully attain all of the watershed development objectives. This land use base element must, therefore, be supplemented by other plan elements relating to natural resource protection, outdoor recreation, parkway and scenic drive development, flood control, water pollution abatement, and water supply. Careful inspection of Tables 8, 12, and 121, as set forth in other chapters of this volume, will indicate that the recommended natural resource protection, outdoor recreation, and water control facility plan elements all aid in the attainment of additional watershed development objectives which cannot be met by the recommended land use base element alone. The various recommended plan alternatives, as set forth in Chapters III, IV, V, and VI of this volume, are, in fact, complementary in nature and together provide the composition necessary to fully achieve all of the established watershed development objectives. The land use base and natural resource protection plan elements, for example, by providing a pattern of urban land use development which can be readily served by public sanitary sewerage and water supply facilities and by providing for the preservation of environmental corridor lands along the main stem of the Milwaukee River and selected major tributaries, contribute toward achieving not only the land use development objectives but also the water quality, water supply, and flood control objectives. Thus, the recommended comprehensive watershed plan represents a synthesis of carefully coordinated individual plan elements, which, taken together, will serve to fully satisfy and achieve all of the adopted watershed development objectives.

Because of the extreme difficulty, if not impossibility, of expressing all of the benefits and costs associated with the comprehensive watershed plan in monetary terms, the evaluation of the recommended comprehensive plan has been based primarily on its ability to satisfy the watershed development objectives and supporting standards, including the state-established water quality standards. The importance of economic analyses of certain of the individual plan elements, however, as set forth in previous chapters of this volume, cannot be overemphasized, since these economic analyses comprise important inputs to the plan selection process, particularly so, as already noted, where alternative plan elements were specifically designed to meet certain development objectives.

PLAN RECOMMENDATIONS

Based upon the analyses of the ability of the various plan elements to satisfy watershed development objectives and related benefit-cost analyses, as set forth in previous chapters of this volume, the following specific plan elements are recommended for inclusion in the comprehensive plan for the Milwaukee River watershed.

Recommended Land Use Base

The controlled existing trend land use plan adopted by the Commission for the Region as a whole is recommended for adoption as the land use base element for that portion of the Milwaukee River watershed lying within the Region. A complementary controlled existing trend land use plan for that portion of the Milwaukee River watershed lying outside the Region was prepared under the watershed study and is recommended for inclusion in the Milwaukee River watershed plan. Together these two controlled existing trend land use plan elements form the land use base for the recommended Milwaukee River watershed plan. This plan element envisions use of a combination of public acquisition and public regulation of private holdings of land to shape the development of a land use pattern which will meet future needs for residential, agricultural, conservancy, and park land use within the watershed efficiently and with a minimum deteriorating effect upon the underlying and supporting natural resource base. This plan element places continued emphasis upon the urban land market as the primary determinant of the location, intensity, and character of future development within the watershed. It does, however, propose to regulate, in the public interest, the effect of this market on development in order to provide for a more orderly and economical land use pattern and in order to avoid intensification of the already serious developmental and environmental problems existing within the watershed. The recommended land use plan element is shown in graphic summary form on Map 65.

Urban Development: Forecasts indicate that the population of the Milwaukee River watershed may be expected to reach a level of about 678,000 persons by 1990, an increase of approximately 134,000, or 25 percent, over the 1967 level, while employment may be expected to reach approximately 346,100 jobs by 1990, an increase of 56,200 jobs, or about 19 percent, over the 1967 level. The recommended land use plan for the watershed proposes to accommodate this anticipated growth in population and employment through the conversion of approximately 21 square miles of land from rural to urban use over the next two decades. As indicated in Table 3 of this volume, the recommended land use plan proposes to add about 7,900 acres to the existing stock of residential land within the watershed in order to meet the housing needs of the anticipated population increase. The recommended watershed land use plan proposes that about 82 percent of the new residential land be developed at medium densities, that about 16 percent be developed at high densities, and that the remaining 2 percent of the new residential land uses be developed at low densities.

The recommended land use plan proposes that all of the new medium- and high-density residential development be served by public sanitary sewerage and public water supply facilities so that, by 1990, 76 percent of the total urban area within the watershed and 94 percent of the total watershed population would be served by public sanitary sewerage facilities, as compared to 64 and 92 percent, respectively, in 1967. Similarly, 71 percent of the total urban area and 93 percent of the total watershed population would be served by public water supply facilities, as compared to 60 percent and 91 percent, respectively, in 1967. As set forth in Chapter III of this volume, the plan contains similar proposals for the conversion of land to commercial, industrial, governmental and institutional, transportation, communication, and utility land uses as required to meet the gross demand for land generated by the anticipated population and employment within the watershed.

Open Space—Environmental Corridors: The most important elements of the natural resource base of the watershed, including the best remaining woodlands, wetlands, and wildlife habitat; the surface waters, together with the associated floodlands and shorelands; and the best remaining potential park sites, have been found to occur within the watershed in combined linear patterns termed primary environmental corridors. These corridors, which encompass nearly 23 percent of the total area of the watershed, have been described in detail in Chapter IV of Volume 1 and Chapter III of Volume 2 of this report. The preservation and protection of these environmental corridors in accordance with regional and watershed development objectives are essential to the maintenance of a wholesome environment within the watershed and to the preservation of its unique cultural and natural heritage, as well as natural beauty.

It is recommended that the optimum alternative natural resource protection plan element, as presented in Chapter III of this volume, be included in the comprehensive plan for the Milwaukee River watershed. This plan element, through a combination of acquisition of land for public use and public regulation of the private development and use of land, will serve to protect approximately 100,300 acres of land and water contained within the primary environmental corridors of the watershed. Under this plan element, a total of about 65,900 acres, or about 66 percent of the primary environmental corridor land within the watershed and about 15 percent of the total area of the watershed, would eventually be placed in public ownership. Of this total acreage recommended for eventual public ownership, 24,300 acres, or about 37 percent, are already in such public ownership.

The recommended plan proposes public acquisition of all of the primary environmental corridors in those areas of the watershed expected to be in urban use by 1990, totaling about 9,800 acres, or nearly 10 percent of the total primary environmental corridor area in the watershed. The plan also recommends public acquisition of the entire primary environmental corridor along the main stem of the Milwaukee River in Ozaukee and Washington Counties, totaling about 3,400 acres, or about 3 percent of the total primary environmental corridor area in the watershed. In addition, the plan recommends public acquisition of selected remaining high-value wetland areas located in the primary environmental corridors, totaling about 16,000 acres, or about 16 percent of the total primary environmental corridor area in the watershed; public acquisition of selected remaining high-value woodland areas located in the primary environmental corridors, totaling about 3,400 acres, or about 3 percent of the total primary environmental corridor in the watershed; and public acquisition of selected additional undeveloped primary environmental corridor lands throughout the watershed, totaling about 8,900 acres, or about 9 percent of the total primary environmental corridor area in the watershed. The latter additional corridor lands were selected for inclusion in the recommended plan in order to provide additional protection for certain significant resource values, such as the remaining trout streams in the watershed and areas having future multiple-purpose reservoir potential.

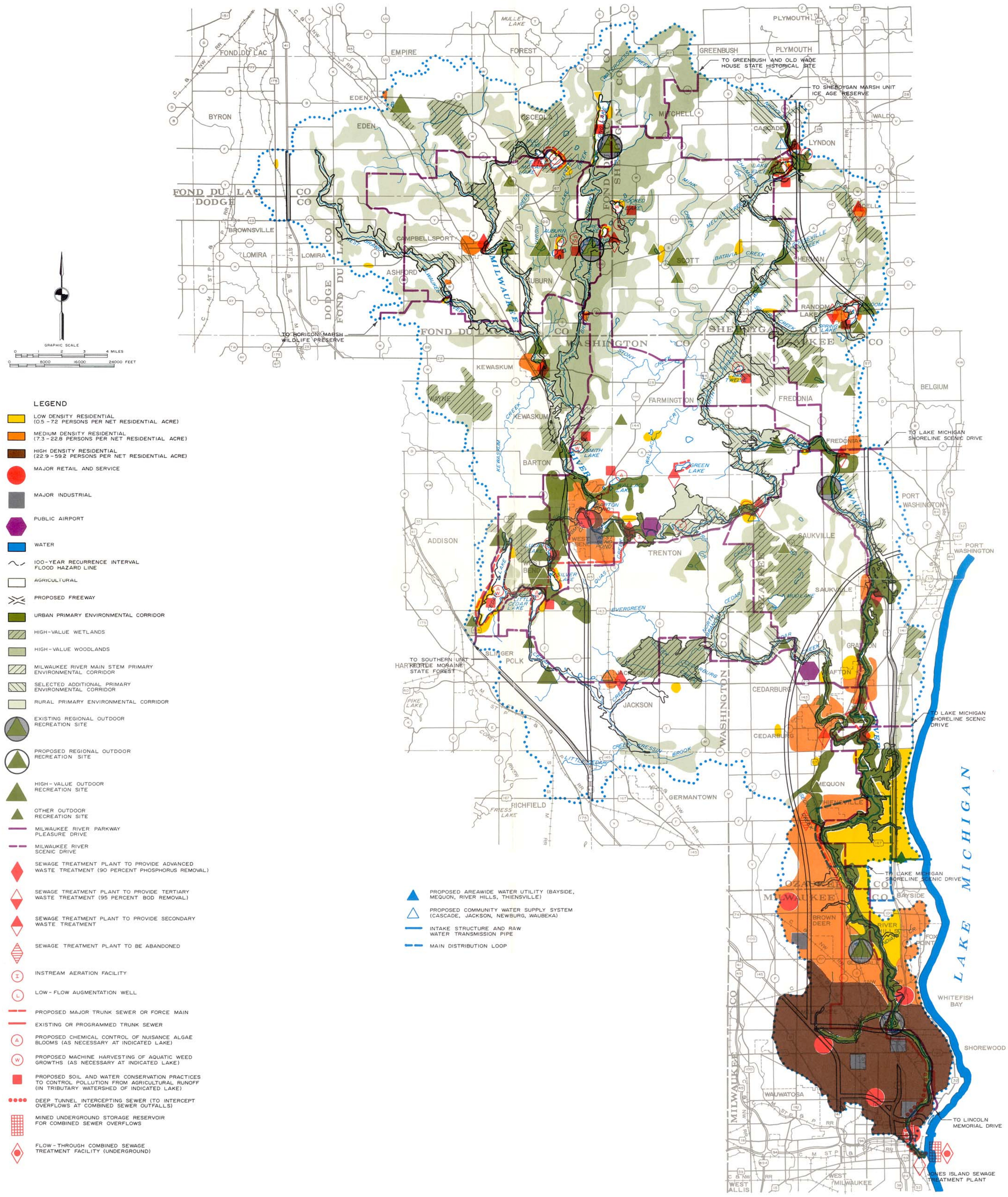
In all, the plan recommends public acquisition of about 41,600 acres of primary environmental corridor land which, when added to the 24,300 acres of primary environmental corridor land already in public ownership, would result, as already noted, in a total of about 65,900 acres of public ownership, or about 66 percent of the total primary environmental corridor area within the watershed, being permanently preserved and maintained through public ownership. About 19,000 acres of woodlands, or about 54 percent of the remaining woodlands and 4 percent of the total watershed area, and about 29,800 acres of wetlands, or about 51 percent of the remaining wetlands and 7 percent of the total watershed area, would be permanently protected through public ownership under this plan recommendation. All primary environmental corridor land not recommended for public acquisition, totaling about 34,000 acres, would be protected in the public interest against incompatible and destructive land use development through sound zoning measures, including agricultural, floodland, shoreland, recreational, and low-density residential zoning. Specific zoning recommendations for environmental corridors, including references to model regulations, are set forth in Chapter IX of this volume.

Open Space—Park and Outdoor Recreation Areas: It is recommended that the optimum alternative outdoor recreation-related open-space plan element be included in the comprehensive plan for the Milwaukee River watershed. This plan element would provide an additional 10,900 acres of public outdoor recreation land in the watershed and would bring the total of such land area within the watershed to about 14,600 acres in order to meet fully the forecast demand for outdoor recreation. It should be noted that, of the total of about 10,900 acres of additional recreation land recommended to be acquired, about 8,000 acres, or 73 percent, would be acquired under the recommended natural resource protection plan element.

The recommended park and outdoor recreation plan element provides for a total of six regional parks within the watershed having a total combined site area of about 2,600 acres. Of these six parks, four, with a total combined site area of about 1,600 acres, are existing regional parks—Lincoln and Brown Deer County parks in Milwaukee County and Mauthe Lake and Long Lake State Recreation Areas in Fond du Lac County. One park—Hawthorne Hills County Park in Ozaukee County—is an existing park proposed to be expanded from its existing site area of about 290 acres to a total site area of about 617 acres. One new regional park site is proposed to be established in the Lucas Lake-Paradise Valley area in Washington County, with a total proposed site area of about 1,500 acres, of which about 350 acres would be developed for intensive outdoor recreation purposes.

Failure to adopt and implement this plan element may be expected to result in overuse and overcrowding of existing outdoor recreation sites, in the development of serious conflicts between user demands, and in the deterioration and destruction of the recreation-related resource base. It should be noted that, while the recommendation is herein made to fully meet the forecast recreation demand through public acquisition and development, it is recognized that, to the extent that private recreational development occurs within the watershed to meet this demand, the public acquisition and development of park and related outdoor recreation sites can be reduced. It is known that, at the present time, about 13 percent of the developed recreation land in the watershed devoted to the five major outdoor recreational activities upon which the 1990 forecast demand for outdoor recreation land is based is in private ownership and operation. This level of private activity may

Map 65
RECOMMENDED COMPREHENSIVE PLAN
FOR THE MILWAUKEE RIVER WATERSHED
1990



Source: SEWRPC.

(This page intentionally left blank)

continue and perhaps increase in the future. In a very real sense, the recommended outdoor recreation plan element is thus a conservative one because implementation of the recommended plan, eventually through public acquisition programs, but initially through land reservation by sound land use control measures, will ensure that the best remaining outdoor recreation sites within the watershed are preserved for recreational development, whether ultimately that development is accomplished through public or private investment.

Open Space—Agricultural Land Use: Under the recommended watershed land use plan, urban expansion within the watershed would by 1990 require the conversion of about 14,000 acres of agricultural and related open-space land, or about 4 percent of the approximately 380,000 acres of land presently devoted to agricultural and agricultural-related open-space uses within the watershed. About 1,900 acres of this total would constitute prime agricultural land, or about 5 percent of the approximately 37,000 acres of prime agricultural land existing within the watershed. The recommended land use plan proposes to preserve the remaining 35,100 acres of prime agricultural land in permanent agricultural use. These prime agricultural areas have been delineated on the basis of soils, size and extent of the areas farmed, and the historic capability of the areas to consistently produce better than average crop yields.

Parkway and Scenic Drives: Pleasure driving constitutes the most popular outdoor recreational activity in the Milwaukee River watershed, with a forecast 1990 total participant demand on an average seasonal Sunday of about 124,000 persons, an increase of about 68 percent over the estimated current total of 74,000 participants. The recommended parkway and scenic drive plan includes the following combination of parkway pleasure drives and scenic pleasure drives in the watershed: a new parkway pleasure drive from Lincoln Memorial Drive near the McKinley Marina on Lake Michigan to and along the Milwaukee River valley to a junction with the existing Estabrook Park Drive at its intersection with Capitol Drive in the Village of Shorewood; maintenance of the existing Estabrook and Milwaukee River parkway pleasure drives northerly to the committed terminus of these drives at Good Hope Road; and a system of primary and secondary Milwaukee River scenic drives beginning at the northerly terminus of the Milwaukee River parkway pleasure drive at Good Hope Road in the City of Glendale and extending throughout the watershed along the major stream courses, with connections to the existing and long-established Kettle Moraine Scenic Drive. This recommended system of parkway and scenic drives would provide facilities necessary to meet the aforementioned anticipated 1990 recreational activity demand for pleasure driving and sightseeing.

Flood Control Plan Element

The basic flood control plan element recommended for inclusion in the comprehensive Milwaukee River watershed plan is nonstructural, consisting of the land use development proposals contained in the land use element of the watershed plan, particularly as these land use proposals affect the riverine areas of the watershed. Of particular importance in this respect are the land acquisition recommendations made for preservation of the environmental corridor areas within the watershed. No structural water control facilities are recommended for inclusion in the Milwaukee River watershed plan because, as indicated in Chapter IV of this volume, all available alternative structural flood control plan elements are either both economically unsound and aesthetically unacceptable or, in the case of the proposed Waubeka Reservoir, were deleted from the recommended plan by the Watershed Committee on the grounds that flood control benefits constitute a very small proportion, that is, only about 4 percent, of the total benefits to be derived from such a reservoir and would, in and of themselves, not economically justify construction of the reservoir; that there was neither the institutional structure available for, nor the public support required to create such an institutional structure for, the development of a reservoir having primarily recreational benefits; that construction of the reservoir, by reducing the frequency and extent of flooding, would alter the natural characteristics of the environmental corridors below the dam, and encourage the development of those corridors for intensive urban use by removing one of the principal constraints on such development and thereby make the preservation of these corridors more difficult; and that it was unwise to include, as a major plan element upon which the nature and effectiveness of other major plan elements depend, a facility the construction of which would be highly improbable in the face of both the growing discontent of conservation interests with reservoir proposals of any kind and the long-standing local public opposition to a reservoir project in the upper Milwaukee River watershed.

It should be noted, however, that the Waubeka Reservoir remains an economically sound and totally acceptable alternative when viewed on a watershed-wide, comprehensive basis. It is, therefore, recommended that the site for this reservoir be preserved in essentially open land uses in order to provide flexibility to meet changing water quality and flood control management needs in the Milwaukee River watershed and to preserve an option for future generations to develop an economically sound multiple-purpose reservoir in the watershed.

The following nonstructural plan elements are recommended for inclusion in the comprehensive watershed plan:

1. The institution of appropriate land use controls, including zoning, building, and subdivision control regulations, to prevent the construction of new buildings in floodways in areas already committed to urban development and within the 100-year recurrence interval flood hazard lines in all remaining areas of the watershed. Such zoning would serve to render all existing structures in the urban floodways as legal nonconforming structures, with the result that those structures could continue to be utilized and lived in but could not be rebuilt if destroyed by fire, flood, or other disaster, as provided under state legislation.

2. The gradual, voluntary removal over a long period of time by public purchase of all of the structures rendered nonconforming uses in the urban floodways.

3. The floodproofing of all existing structures located in the floodplains of the watershed which are not to be eventually removed.

4. The continuation of a long—established stream gaging program.

A complete description of each of these nonstructural plan elements, as well as the structural plan elements, together with their associated benefits and costs, as appropriate, has been set forth in Chapter IV of this volume and will not be repeated here. It is important to note, however, that the major flood-damage areas in the watershed are located in the Cities of Glendale and Mequon and the Villages of Thiensville and Saukville, such damages being attributed to relatively intense occupation by urban land uses of the floodway and floodplain of the Lower Milwaukee River. Flood abatement measures, consisting of various combinations of structure removal and floodproofing and dike and floodwall construction, were generally found to be extremely uneconomical, generally exhibiting benefit-cost ratios of less than 0.5. The Village of Thiensville was an exception in that floodproofing would yield a benefit-cost ratio of 1.67 within that reach of the river. The aggregate benefit-cost ratio for structure removal and floodproofing in the City of Mequon is 0.61, this value being the highest obtained for combined removal and floodproofing in any of the four high flood-damage communities. Structure removal and floodproofing would be economical in that small portion of Mequon consisting of the riverine area extending from the south corporate limits at STH 167 upstream to the southwest corner of Section 18, T9N, R22E, for which the estimated benefit-cost ratio is 1.22.

Floodplain Floodproofing: It is recommended that all existing homes and other major structures located in the floodplains of the watershed which are not subject to first-floor inundation by the 100-year recurrence interval flood and which lie outside the floodway (in general, those homes between the 10- and 100-year recurrence flood inundation lines), be floodproofed as a condition of continued occupance of the floodplains.

A total of 1,192 homes and other major structures are located in the floodlands of the watershed. Of these, 721 are located either outside of the floodways or the 10-year recurrence interval flood hazard lines, and, as such, would remain as permanent floodland uses. These 721 homes and major structures should, therefore, be floodproofed.

In addition, any new homes or other major structures which may be constructed on existing platted lots in floodplain areas are already heavily committed to urban development through the completed public works improvements, such as street and utility installation, should be constructed with the first-floor elevation at least two feet above the elevation of the 100-year recurrence interval flood. The cost of all floodproofing would be assumed by the individual homeowners and is not, therefore, included in the cost analysis of the recommended watershed plan.

Floodway Clearance: It is recommended that the local public agencies concerned, as a matter of public policy, establish a program for the eventual voluntary removal of all existing structures which have been unwisely located in the floodways of the watershed. A total of 471 homes and other major structures are located within the floodways or the 10-year recurrence interval flood hazard lines of the watershed, and would require eventual removal as nonconforming uses over a long period of time. The cleared sites should then be converted to park and related open-space uses. It is not recommended that condemnation powers be utilized to effect such removal. Rather, floodway zoning regulations should be enacted which would make all existing residential and commercial uses within the floodways or the 10-year recurrence interval flood hazard lines nonconforming uses, with the properties being subsequently purchased for public use only if offered for such use by the owners. It is, however, important that the local units of government concerned adopt an official policy of willingness to purchase homes located in the floodways of the watershed at market values so that owners of such homes would have an alternative to selling in the private real estate market.

Floodland Land Use Controls: It is recommended that local zoning and other regulatory ordinances seek to implement the foregoing floodproofing and eventual voluntary floodway clearance policies by providing for the floodproofing of all existing homes and other major structures located in the floodplains of the Milwaukee River stream system which are not to be eventually removed, and by providing for nonconforming status with respect to those existing homes located in the floodways of the watershed which are to be eventually removed. The local units of government should post the floodway area so as to inform those who are considering the purchase of residences in the floodway of the existence of floodway use regulations and that existing residences in the floodway are nonconforming uses.[1]

Most importantly, local zoning ordinances should prohibit any further intrusion of urban land use development into the as yet undeveloped and unplatted floodlands of the watershed. In this respect, it is important to note that implementation of the environmental corridor and natural resource protection land acquisition recommendations contained in the comprehensive plan will result in the public acquisition of all remaining undeveloped floodlands in urban areas of the watershed and along the main stem of the Milwaukee River in Ozaukee and Washington Counties. The specific nature of floodland land use controls will be discussed in more detail in Chapter IX of this volume.

Bridge Replacement: It is recommended that 33 bridges on the perennial stream system of the Milwaukee River watershed which have inadequate waterway openings be eventually replaced or modified so as to provide adequate waterway openings. Such replacement or modification, however, should be carried out only when required for traffic safety or other transportation purposes (see Table 36, Chapter IV, Volume 2, of this report). The location and design of all new bridges within the watershed should be based upon the application objectives and standards set forth in Chapter II of this volume. Of particular importance is the standard which requires that all new and replacement bridges and culverts over perennial waterways be designed so as to accommodate the 100-year recurrence interval flood event without raising the peak stage either upstream or downstream more than 0.5 foot above the peak stage for the 100-year recurrence interval flood, as established in the adopted comprehensive watershed plan.

Reservoir Land Protection: Although the proposed Waubeka multiple-purpose Reservoir is not recommended to be included in the comprehensive Milwaukee River watershed plan, it is recommended that the reservoir site itself be protected from encroachment by intensive urban land uses and thus be preserved in essentially open land uses in order to provide flexibility to meet changing water quality management and flood control needs in the Milwaukee River watershed beyond the design year of the plan. It is extremely important to note that the Waubeka reservoir site is the only site remaining in the Milwaukee River watershed which could accommodate a reservoir large enough to provide for extensive recreational benefits, for complete flood control, and for extensive amounts of low-flow augmentation with a minimum amount of drawdown of the reservoir itself. Loss of this site to intensive urban land uses would deprive future generations of virtually any options

[1] *The City of Mequon has already taken steps to post floodland warning signs. By resolution dated March 4, 1969, the Common Council of the City of Mequon directed the Plan Commission to erect floodland warning signs on public lands as appropriate.*

to develop an economically sound multiple-purpose reservoir within the watershed, should changing development factors and public attitudes warrant or necessitate such a reservoir in the future. It is also important to note that, if the basic land use development proposals, as described earlier in this chapter, are fully implemented, the entire reservoir site will be kept in essentially open-space uses. Furthermore, implementation of the natural resource protection plan element would result in the public acquisition of 4,300 acres, or about 30 percent of the total acreage needed to construct and operate the proposed Waubeka Reservoir.

Maintenance of Stream Gaging Stations: It is recommended that the four established continuous recording stream gaging stations within the watershed—Milwaukee (Estabrook Park), Fillmore, New Fane, and Waubeka—be maintained to provide a long-term, continuing record of streamflow at appropriate locations on the stream system in the watershed. It is further recommended that the existing staff gage at Kewaskum be upgraded to a continuous recording gaging station and the recently discontinued Cedarburg gage on Cedar Creek be re-established as a continuous recording gage.

Water Pollution Abatement Plan Element

The following water pollution abatement facilities and programs are recommended for inclusion in the comprehensive Milwaukee River watershed plan. A description of each of these facilities and programs in the form of alternative plan elements, together with their associated benefits and costs and their relationship to the watershed development objectives and standards, has been set forth in Chapter V of this volume and will not be repeated here.

Stream Water Quality Management Plan Elements: The following stream water quality control facilities and management programs—one for the lower Milwaukee River watershed and one for the upper Milwaukee River watershed—are recommended for inclusion in the comprehensive Milwaukee River watershed plan.

Lower Watershed: The recommended stream water quality management program for the lower Milwaukee River watershed should consist of the following elements:

1. Completion of the long-range trunk and relief sewer construction program currently being conducted by the Milwaukee-Metropolitan Sewerage Commissions. Completion of this relief sewer program should eliminate all of the separate sanitary sewer overflows to stream courses in the lower Milwaukee River watershed. Because this long-range relief sewer construction program constitutes a committed and programmed activity and because it affects not only the Milwaukee River watershed but the entire service area of the Milwaukee-Metropolitan Sewerage Commissions, which service area extends throughout Milwaukee County and includes portions of Ozaukee, Washington, Waukesha, and Racine Counties, no costs have been included in the recommended watershed plan for completion of this very important program.

2. The connection to the Milwaukee metropolitan sewerage system of eight of the 26 industrial waste outfalls which now discharge directly to Lincoln Creek or to the Milwaukee River within Milwaukee County (see Table 58, Chapter IX, Volume 1, of this report). Of the remaining 18 industrial waste outfalls, 13 discharge only cooling waters to the storm sewer system and would not require treatment; and five are inorganic waste sources which require improved pretreatment before discharge to the storm sewer system.

3. The construction of a combination deep tunnel mined storage/flow-through treatment system to collect, convey, and adequately treat all combined sewer overflows emanating not only in the 5,800-acre combined sewer service area of the Milwaukee River watershed but throughout the 17,200-acre combined sewer service area in Milwaukee County.

   The first step in implementation of this recommended plan element should be the undertaking of a preliminary engineering study to determine with greater precision and detail the configuration of the recommended deep tunnel mined storage/flow-through treatment system as required to serve and adequately handle the combined sewer overflows in Milwaukee County.

This detailed engineering feasibility study should utilize the same state-established water use objectives and effluent standards set forth in Chapter V of this volume, while refining the design parameters relating to the volume and strength of combined sewage to be treated.

Such a feasibility study should also explore the potential for applying the recommended combination of a deep tunnel mined storage/flow-through treatment system in an incremental manner to a portion of the total combined sewer service area, such as the Milwaukee River watershed, as opposed to the desirability of constructing the entire system all at one time. The feasibility study should further explore optimization with respect to the treatment capacity of the screening/dissolved-air flotation units and the storage capacity of the mined storage reservoirs. In addition, the study should explore the potential for combining the deep tunnel mined storage/flow-through treatment system with the installation of smaller flow-through treatment plants at some of the more isolated combined sewer outfalls.

The engineering feasibility study should also review the results of ongoing demonstration studies with respect to the flow-through treatment system to determine if further modifications can be made to reduce costs in the provision of the necessary facilities needed to solve the combined sewer overflow pollution problem throughout Milwaukee County. For the purposes of estimating the total cost of the comprehensive watershed plan, the cost of this plan element has been apportioned on the basis of the proportion of the total combined sewer service area in the Milwaukee River watershed to the total combined sewer service area in Milwaukee County.

The foregoing water pollution abatement measures recommended for the lower Milwaukee River watershed, by removing almost all of the organic matter and nutrients from sewage and waste waters discharged directly into the Milwaukee River and its tributaries, would achieve the established stream water quality objectives and standards, as set forth in this report, at the lowest possible cost. In addition, the foregoing water pollution abatement measures would serve to meet the effluent standards established by the federal Lake Michigan Enforcement Conference.

Upper Watershed: The recommended stream water quality management program for the upper watershed consists of the following elements:

1. The provision of secondary waste treatment and post-chlorination for disinfection at the municipal sewage treatment facilities serving the following communities: Adell, Fredonia, and Newburg. It is proposed that the Adell treatment facility continue to discharge its effluent to a seepage pond rather than to the stream system.

2. The provision of secondary waste treatment, post-chlorination for disinfection, and streamflow augmentation at a new sewage treatment facility proposed to serve the Village of Cascade and urban development in the nearby Lake Ellen area. Streamflow augmentation would be accomplished by utilizing a single small capacity well (0.5 cfs) located near the proposed sewage treatment plant site. If low-flow augmentation is not provided, then the sewage effluent should be discharged to a seepage pond.

3. The provision of secondary waste treatment, tertiary waste treatment, and post-chlorination for disinfection at the existing sewage treatment facility serving the Village of Random Lake. This facility would also be used to treat the wastes generated by the lake-oriented development located outside the Village along the north and east shores of Random Lake. Tertiary treatment would be accomplished through the use of a detention pond.

4. The provision of secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination for disinfection at the municipal sewage treatment facilities serving the following communities: Campbellsport, Cedarburg-Grafton, Jackson, Kewaskum, and Saukville. The Jackson sewage treatment facility would be proposed to be relocated

at a new site about 0.5 mile east of the present plant site in order to accommodate a major industrial waste source and to provide a more rational sewer service area. Advanced treatment of wastes generated in the Cedarburg-Grafton sewer service area would be accomplished at a new treatment facility located near the confluence of the Milwaukee River and Cedar Creek, with secondary waste treatment continuing to be provided at the existing Cedarburg and Grafton sewage treatment plants.

5. The provision of secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), post-chlorination for disinfection, and instream aeration at the West Bend sewage treatment facility. The West Bend treatment facility would be an areawide facility serving not only the West Bend sewer service area but also the sanitary sewer service areas around Big Cedar, Little Cedar, Silver, and Wallace Lakes. Instream aeration would be provided by mechanical aerators located on the Milwaukee River main stem below the West Bend sewage treatment plant at distances of 0.7 and 1.8 miles and by diffuser aerator units located in the Newburg Pond.

6. Connection of the Thiensville sanitary sewer service area to the Milwaukee metropolitan sewerage system through the City of Mequon sewerage system, together with abandonment of the existing Thiensville sewage treatment facility.

7. Compliance by industrial firms with Wisconsin Department of Natural Resources pollution abatement orders to improve inplant pretreatment of wastes (one firm); to connect to centralized municipal sanitary sewerage systems (three firms); and to provide improved private industrial waste treatment facilities (five firms), together with connection of the Libby, McNeill, & Libby canning plant to the Jackson sewage treatment plant and continued treatment levels at the Justro Feed Corporation and the Level Valley Dairy adequate to meet the established water quality objectives and standards.

8. The institution of appropriate agricultural land use management practices on about 65,000 acres of agricultural land in the Milwaukee River watershed located outside the subwatersheds of the major lakes in the watershed.

9. The continued operation of a water quality monitoring program at 12 sampling locations throughout the watershed. This sampling program is recommended to be intensified to include monthly sampling at selected locations and continuous sampling during one week of the summer season, also at selected locations.

The foregoing water pollution abatement measures recommended for the upper Milwaukee River watershed, by removing almost all of the organic matter and nutrients from sewage and waste water discharged directly into the Milwaukee River and its tributaries and by providing for additional nutrient removal from agriculturally related sources, would achieve the established stream water quality objectives and standards at the lowest possible cost. In addition, the foregoing water pollution abatement measures would serve to meet the effluent standards established by the federal Lake Michigan Enforcement Conference.

Lake Water Quality Management Plan Elements: The following four lake water quality management programs are recommended for inclusion in the comprehensive Milwaukee River watershed plan:

1. The provision of sanitary sewer service at Big Cedar, Ellen, Forest, Green, Kettle Moraine, Little Cedar, Random, Silver, and Wallace Lakes. Such service would be provided at three of the nine lakes—Forest, Green, and Kettle Moraine—through the establishment of new sanitary sewerage systems and treatment facilities providing secondary waste treatment and post-chlorination for disinfection. Sewer service for Big Cedar, Little Cedar, Silver, and Wallace Lakes would be provided through trunk sewer connections to the existing City of West Bend sanitary sewerage system, with secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination for disinfection provided at the West Bend sewage treatment plant.

Sewer service for Ellen Lake would be provided at the proposed Village of Cascade sewage treatment plant. Sewer service for Random Lake would be provided at the existing Village of Random Lake sewage treatment plant. The recommended treatment plant locations and trunk sewer configurations and sizing for each of the nine lakes included in this plan element were described in Chapter V of this volume and will not be repeated here.

2. The provision of chemical control of nuisance algal blooms, as necessary, at Big Cedar, Ellen, Forest, Little Cedar, Mauthe, Smith, Twelve, and Wallace Lakes. This recommendation can serve only to suppress the symptoms of the underlying water quality problem and, as such, should only be considered a temporary measure to be used until more permanent abatement is achieved through the other recommended plan proposals.

3. Machine harvesting of the aquatic weed growths, as necessary, at Auburn, Big Cedar, Crooked, Ellen, Forest, Kettle Moraine, Little Cedar, Long, Lucas, Mauthe, Random, Smith, and Twelve Lakes.

4. A long-term program for the institution of good soil and water conservation practices to control pollution from agricultural runoff through the construction of bench terraces and the institution of other appropriate agricultural land management measures on agricultural lands within the tributary watersheds of Auburn, Big Cedar, Crooked, Ellen, Little Cedar, Long, Lucas, Mauthe, Random, Smith, Twelve, and Wallace Lakes.

The provision of sanitary sewer service to serve existing development around the nine major lakes cited above would eliminate any public health hazards which may presently exist at these lakes as a result of inadequate or malfunctioning septic tank sewage disposal systems and will assist in significantly reducing the nutrient input to the lakes. The algae control and weed harvesting operations would alleviate nuisance conditions caused by excessive aquatic plant growths. The bench terraces and related agricultural soil and water conservation land management measures and practices would serve to reduce significantly the nutrient input and sediment loads to the lakes from agricultural areas. These recommended lake pollution abatement measures would serve to meet the established lake water use objectives set forth in this report for the 19 major lakes considered.

Water Supply Plan Elements

Lake Michigan and the three ground water aquifers which underlie the Milwaukee River watershed constitute the principal sources of water supply within the watershed and, if properly used and managed, comprise renewable water resources which can serve the watershed for all time to come. The shallow sand and gravel and dolomite aquifers can be developed to meet all foreseeable demand within the upper watershed for domestic and livestock watering purposes, providing that such aquifers are carefully protected from pollution from septic tank sewage disposal systems, dumps, and improperly located and operated sanitary land fills, and urban and agricultural runoff.

The deep sandstone aquifer provides the most dependable source of large quantities of ground water within the watershed with generally good quality except for high dissolved solids content occurring along the eastern boundary of the watershed. With proper well location and spacing, this aquifer may be expected to yield an adequate supply of water for municipal and industrial purposes through and beyond the design year of the watershed plan in those urban areas of the upper Milwaukee River watershed which have no practicable available surface water supply. Recommendations concerning well location and spacing necessary to achieve proper utilization of not only the deep sandstone aquifer but also the shallow sand and gravel and dolomite aquifers are set forth in Chapter VI of this volume and will not be repeated here.

In addition to the foregoing management recommendations with respect to the three ground water supply aquifers in the Milwaukee River watershed, it is recommended that the following water supply plan elements be included in the recommended comprehensive Milwaukee River watershed plan:

1. The creation of a municipal water supply system to serve jointly the Villages of Bayside and River Hills in Milwaukee County and the City of Mequon and the Village of Thiensville in Ozaukee County.

It is further recommended that this municipal water supply system utilize Lake Michigan as its source of water since analyses conducted under the watershed study revealed that Lake Michigan is the most economical source of a future water supply for this urbanizing area of the watershed. It should be noted that this system could be expanded to include the Village of Grafton and the City of Cedarburg if, at some future point in time, these communities choose to utilize a surface water supply.

2. It is recommended that public water supply systems be established in the unincorporated Village of Waubeka in Ozaukee County, the Village of Jackson and the unincorporated Village of Newburg in Washington County, and the Village of Cascade in Sheboygan County. It is further recommended that such municipal water supply systems utilize the shallow dolomite and deep sandstone aquifers as the major sources of water supply.[2]

COST ANALYSIS

In order to assist the responsible public officials concerned in evaluating the foregoing recommended comprehensive Milwaukee River watershed plan, a preliminary capital improvement program was prepared which, if followed, would result in total watershed plan implementation by the year 1990. This preliminary capital improvement program includes the staging of the necessary land acquisition and facility construction and the distribution of the attendant costs over a 20-year plan implementation period. This program is presented in summary form for the watershed as a whole in Table 113 and is presented in more detailed form by county in a series of tables in Chapter IX of this volume. These tables set forth the land acquisition and construction costs and the estimated maintenance and operation costs associated with implementation of each of the recommended plan elements by year and by level of government concerned. The ultimate adoption of capital improvement programs for implementation of the watershed plan will require determination by responsible public officials of not only those plan elements which are to be implemented, and the timing of such implementation, but also of the principal beneficiaries and the available means of financing.

The full capital investment cost of implementing the recommended comprehensive watershed plan for the Milwaukee River watershed is estimated at $112.8 million over the 20-year plan implementation period. Of this total cost, about $49.9 million, or about 44 percent, are required for implementation of the recommended natural resource base protection, outdoor recreation, and parkway and scenic drive plan elements and would be used primarily for land acquisition; about $47.3 million, or about 42 percent, are required for implementation of the recommended stream water quality management plan elements; about $10.3 million, or about 9 percent, are required for implementation of the recommended lake water quality management plan elements; about $5.3 million, or about 5 percent, are required for implementation of the recommended water supply plan elements; and $31,100, or less than 1 percent, are required for implementation of the recommended water resources monitoring and dam investigation programs.

The average annual cost of the total capital investment required for plan implementation would be approximately $5.6 million, or about $9.25 per capita, the per capita cost being based on the watershed population of 611,000 persons, equal to the anticipated average resident population of the watershed between the 1967 existing population level of 544,000 persons and the anticipated 1990 population level of 678,000 persons. The average annual capital costs of implementation of the natural resource protection, outdoor recreation, and parkway and scenic drive plan elements; the stream water quality management plan elements; the lake water quality management plan elements; the water supply plan elements; and the water resources monitoring and dam investigation programs are, respectively, about: $2.4 million; $2.4 million; $514,000; $265,000; and $1,555.

It is extremely important to note, in considering the total cost of plan implementation, that, of the total estimated watershed plan implementation cost of $112.8 million, an estimated $57.1 million, or about 50 percent, would be incurred in any case by the federal, state, and local units of gov-

[2] *It should be noted that the Village of Jackson, in October 1969, began operation of a total municipal water supply system as recommended in this plan element. The Village of Jackson had previously operated only a limited municipal water supply system for the purposes of fire protection.*

Table 113

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED MILWAUKEE RIVER WATERSHED PLAN BY MAJOR PLAN ELEMENT BY YEAR: 1971-1990

		NATURAL RESOURCE PROTECTION, OUTDOOR RECREATION, AND PARKWAY SCENIC DRIVE PLAN ELEMENT				WATER POLLUTION ABATEMENT PLAN ELEMENT						WATER SUPPLY PLAN ELEMENT		WATER RESOURCES MONITORING AND DAM INVESTIGATION PROGRAM		TOTAL WATERSHED PLAN	
						STREAM WATER QUALITY IMPROVEMENTS LOWER WATERSHED		STREAM WATER QUALITY IMPROVEMENTS UPPER WATERSHED		LAKE WATER QUALITY IMPROVEMENTS							
CALENDAR YEAR	PROJECT YEAR	LAND ACQUISITION[b]	PARK AND RECREATION FACILITY CONSTRUCTION[c]	PARKWAY AND SCENIC DRIVE CONSTRUCTION AND MARKING[d]	OPERATION AND MAINTENANCE[e]	FACILITY CONSTRUCTION[f]	OPERATION AND MAINTENANCE[f]	FACILITY CONSTRUCTION[g]	OPERATION AND MAINTENANCE[g]	FACILITY CONSTRUCTION[h]	OPERATION AND MAINTENANCE[h]	FACILITY CONSTRUCTION[i]	OPERATION AND MAINTENANCE[i]	FACILITY CONSTRUCTION[j]	OPERATION AND MAINTENANCE[k]	LAND ACQUISITION AND FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE
1971	1	$ 2,729,730	$ --	$ --	$ --	$ --	$ --	$ 32,900	$ --	$ 165,500	$ 11,050	$ --	$ --	$12,000	$ 16,800	$ 2,940,130	$ 27,850
1972	2	2,680,230	525,752	1,005	--	400,000	--	784,465	--	295,800	11,050	530,800	--	19,100	16,800	5,237,152	27,850
1973	3	2,680,230	520,757	1,005	28,209	7,380,000	--	3,736,340	25,000	328,040	11,050	2,123,200	--	--	16,800	16,769,572	81,059
1974	4	2,680,230	520,757	1,005	56,418	7,380,000	100,000	1,113,000	503,300	157,420	11,050	2,123,200	--	--	16,800	13,975,612	687,568
1975	5	2,680,230	520,757	1,005	84,627	7,380,000	200,000	221,445	844,100	1,490,605	11,050	530,800	156,600	--	16,800	12,824,842	1,313,177
1976	6	2,680,230	520,757	1,005	112,836	7,380,000	300,000	--	870,600	3,339,730	58,350	--	156,600	--	16,800	13,921,722	1,515,186
1977	7	2,680,230	520,757	1,003	141,045	7,380,000	400,000	--	870,600	2,082,645	144,350	--	156,600	--	16,800	12,664,635	1,729,395
1978	8	2,680,230	520,757	--	169,254	4,100,000	495,000	--	870,600	808,130	177,350	--	156,600	--	16,800	8,109,117	1,885,604
1979	9	2,680,230	520,757	--	197,463	--	495,000	--	870,600	622,240	180,350	--	156,600	--	16,800	3,823,227	1,916,813
1980	10	2,660,230	520,757	115,260	225,672	--	495,000	--	870,600	622,240	197,350	--	156,600	--	16,800	3,918,487	1,962,022
1981	11	1,036,630	839,084	115,260	256,185	--	495,000	--	870,600	363,900	197,350	--	156,600	--	16,800	2,354,874	1,992,535
1982	12	1,036,630	735,457	115,200	318,628	--	495,000	--	870,600	--	197,350	--	156,600	--	16,800	1,887,287	2,054,978
1983	13	1,036,630	735,457	115,200	380,071	--	495,000	--	870,600	--	197,350	--	156,600	--	16,800	1,887,287	2,116,421
1984	14	1,036,630	735,457	115,200	443,514	--	495,000	--	870,600	--	197,350	--	156,600	--	16,800	1,887,287	2,179,864
1985	15	1,036,630	735,457	--	505,957	--	495,000	--	870,600	--	197,350	--	156,600	--	16,800	1,772,087	2,242,307
1986	16	1,036,630	735,457	--	566,096	--	495,000	--	870,600	--	186,300	--	156,600	--	16,800	1,772,087	2,291,396
1987	17	1,036,630	735,457	--	626,235	--	495,000	--	870,600	--	186,300	--	156,600	--	16,800	1,772,087	2,351,535
1988	18	1,036,630	735,457	1,005	686,374	--	495,000	--	870,600	--	186,300	--	156,600	--	16,800	1,773,092	2,411,674
1989	19	1,036,630	735,457	1,005	746,513	--	495,000	--	870,600	--	186,300	--	156,600	--	16,800	1,773,092	2,471,813
1990	20	1,036,630	735,457	1,005	805,852	--	495,000	--	870,600	--	186,300	--	156,600	--	16,800	1,773,152	2,531,152
TOTAL		$37,198,100	$12,150,005	$585,223	$6,350,949	$41,400,000	$7,435,000	$5,888,150	$14,431,400	$10,276,250	$2,731,250	$5,308,000	$2,505,600	$31,100	$336,000	$112,836,828	$33,790,199
ANNUAL AVERAGE		$ 1,859,905	$ 607,500	$ 29,262	$ 317,548	$ 2,070,000	$ 371,750	$ 294,408	$ 721,570	$ 513,811	$ 136,562	$ 265,400	$ 125,280	$ 1,555	$ 16,800	$ 5,641,841	$ 1,689,510

[a] MORE DETAILED COST ESTIMATES OF THE MAJOR WATERSHED PLAN ELEMENTS ARE SET FORTH IN TABLES 122 THROUGH 132 IN CHAPTER IX OF THIS VOLUME.

[b] SEE FOOTNOTES A THROUGH E TO TABLE 122 AND FOOTNOTE A TO TABLE 123.

[c] SEE FOOTNOTE B TO TABLE 123.

[d] SEE FOOTNOTES A AND C TO TABLE 124.

[e] SEE FOOTNOTE C TO TABLE 123 AND FOOTNOTE B TO TABLE 124.

[f] SEE FOOTNOTES A, B, AND C TO TABLE 126.

[g] SEE TABLES 69 AND 127 THROUGH 130.

[h] SEE TABLES 106 AND 127 THROUGH 130.

[i] SEE TABLES 112 AND 131.

[j] SEE TABLES 125 AND 132.

[k] SEE FOOTNOTE A TO TABLE 132.

SOURCE- HARZA ENGINEERING COMPANY, WISCONSIN DEPARTMENT OF NATURAL RESOURCES, AND SEWRPC.

ernment concerned simply to provide the facilities necessary to accommodate the forecast population growth and accompanying urbanization as would be manifested in land development within the watershed, as well as to meet current state standards with respect to surface water pollution abatement. For example, of the estimated $49.9 million required for implementation of the natural resource protection, outdoor recreation, and parkway and scenic drive plan elements, it is estimated that $4.9 million, or 10 percent, would be incurred in any case by the state, county, and local units of government for the provision of park and outdoor recreation facilities required to serve the growing watershed population. Similarly, of the $47.3 million required for implementation of the stream water quality management plan elements in the lower and upper Milwaukee River watersheds, an estimated $46.7 million, or about 99 percent, would be incurred in any case by governmental units in order to provide the increment in sewage collection and treatment facilities required to serve the growing watershed population and to comply with state pollution abatement orders. Yet, the expenditures of these funds in the absence of the comprehensive watershed plan would not serve to fully meet the watershed development objectives and standards but could, on an overall basis, be expected to lead instead to a further deterioration of the overall quality of the environment within the watershed and the intensification of environmental and developmental problems.

It should be noted that Table 113 recommends that well over two-thirds of the total land acquisition recommended for the preservation of the primary environmental corridors and the best remaining park and open-space sites within the watershed be carried out during the first half of the 20-year plan implementation period. This accelerated land acquisition is recommended in order to acquire the necessary open-space lands while these lands are still in predominantly rural use and before they are preempted by urban development. The average annual capital cost of implementing the natural resource protection, outdoor recreation, and parkway and scenic drive plan elements is, as noted above, estimated to be $2.4 million, or about $4.00 per capita, which amount would largely be expended for land acquisition. Of the total estimated cost of $49.9 million for implementation of the land use related plan elements, about $34.5 million, or about 69 percent, would be expended to implement the natural resource protection plan subelement; about $14.8 million, or about 30 percent, would be expended to implement the outdoor recreation plan subelement; and about $0.6 million, or about 1 percent, would be expended to implement the parkway and scenic drive plan subelements.

The total capital construction cost for the recommended stream water quality management plan element in the lower watershed is $41.4 million. All of this cost would be allocated to the design and construction of the recommended deep tunnel mined storage screening/dissolved-air flotation flow-through treatment system as applied to resolve the surface water pollution problems created by the combined sewer overflows within the Milwaukee County portion of the Milwaukee River watershed. The total capital cost of implementing the recommended stream water quality management plan element for the upper watershed is $5.9 million. The average annual capital cost of implementing the recommended stream water quality management plan element for the lower watershed and the recommended stream water quality management plan element for the upper watershed is $2.1 million and $294,000; respectively.

Implementation of the recommended lake water quality management plan elements, which would assist in maintaining or improving the level of water quality in 19 of the 21 major lakes of the Milwaukee River watershed and which would include the extension or construction of sanitary sewer systems around nine of the 19 lakes, would have an average annual capital cost of about $514,000, or $115 per capita, the per capita cost being based upon the existing watershed population expected to be served by the lake water quality management plan element. The per capita cost will vary with each lake community, depending upon the size of the year-round resident population of the lake community and the complexity of the alternative plan element from as little as $17 per capita per year for the Long Lake community to as much as $1,537 per capita per year for the Kettle Moraine Lake community.

Implementation of the recommended water supply system plan element would require an average annual capital cost of about $265,000, or $6 per capita, the per capita cost being based upon the anticipated average population between 1967 and 1990 proposed to be served by the water supply facilities included within the plan element.

Implementation of the recommended water resources monitoring and dam investigation programs would require an average annual capital cost of about $1,555, or $0.0025 per capita, the per capita cost being based upon the anticipated average watershed population between 1967 and 1990.

Although the primary beneficiaries of the implementation of the recommended comprehensive watershed plan will be the residents of the Milwaukee River watershed, certain regional, state, interstate, and national benefits would accrue from full plan implementation. This fact should make many of the major plan recommendations eligible for financial assistance from the state and federal levels of the government. The possible sources of state and federal financial assistance are described in Chapter IX of this volume. It is estimated that full utilization of these financial resources for watershed plan implementation could serve to reduce the local plan implementation costs by approximately 50 percent.

In order to assess the possible impact of implementation of the watershed plan on the public financial resources of the local units of government within the watershed, an analysis was made of the long-term public expenditures by the counties, cities, villages, and towns within the watershed for public park and outdoor recreation-related purposes, for public sanitary sewerage facilities, and for major open channel drainage improvements. The period of study selected was the 11-year period extending from 1958 through 1968; and, with the exceptions of the City of Milwaukee and Milwaukee County, the data reviewed and collected pertained to those local units of government having 50 percent or more of their geographic area within the boundaries of the watershed itself. Because about 74 percent of the 1967 population of the watershed was located within the City of Milwaukee and because about 85 percent of the 1967 population of the watershed was located within Milwaukee County, expenditures for sewers, parks, and channel improvements by the City and County of Milwaukee were included in the historic financial resource analyses and in the forecast of financial resources. Such expenditures were apportioned to the watershed based upon an average between the following ratios: 1) the proportion of the total land area of the City and County of Milwaukee lying within the watershed to the total land area of the City and County of Milwaukee as a whole; and 2) the proportion of the total population of the City and County of Milwaukee within the watershed to the total population of the City and County of Milwaukee as a whole. This resulted in 45 percent of the expenditures for the City of Milwaukee and 33 percent of the expenditures of Milwaukee County for the above-named purposes being included in the financial resource analyses.

As indicated in Table 114, a total of approximately $85.5 million was expended by the local units of government within the watershed for the construction, maintenance, and operation of public sanitary sewerage facilities over the 11-year period analyzed. This amounts to an average annual expenditure of about $7.8 million, which, as indicated in the table, is equivalent to 7.0 percent of the average annual public revenues received by the local units of government over the 11-year period. Similarly, approximately $57.8 million was expended by the local units of government in the watershed for the acquisition, development, maintenance, and operation of park and related open spaces over the time period study. This amounts to an average annual expenditure of $5.3 million, or an average of 4.7 percent of the average annual revenues received by the local units of government over the 11-year period. In addition, approximately $8.8 million was expended by the local units of government within the watershed for the land acquisition, construction, and maintenance required for open channel drainage improvements over this period. This amounts to an average annual expenditure of $0.8 million, or an average of 0.7 percent of the average annual revenue received by the local units of government over the 11-year period.

In order to further augment the analysis, three alternative forecasts were prepared to indicate the possible range of future expenditures by local units of government within the watershed for public sanitary sewerage, channel improvements, and park and related purposes under differing assumptions. If it is assumed that the average annual rate of increase in expenditures which obtained over the 1958 through 1968 period were to remain constant to the year 1990, approximately $533.8 million would become available for sanitary sewerage purposes; $255.5 million would become available for park purposes; and $49.7 million would become available for drainage improvements. If it is assumed that total annual receipts by the local units of government within the watershed were to increase to the year 1990 at the same average annual rate which obtained over the 1958 through 1968 period; if it is further assumed that monies expended for sanitary sewerage, channel improvements, and park purposes will constitute a constant proportion of the total receipts over the forecast period; and if it is still further assumed that this constant proportion would be equivalent to the average annual proportion of total receipts which obtained over the 1958 through 1968 period, approximately $355.5 million would become available for sanitary sewerage purposes; $239.4 million would become available for park purposes; and $36.0 million would become available for drainage improvements. If it is assumed that the per capita expenditures which obtained in 1967 for sanitary sewerage, channel improvement, and park purposes were to remain constant to the year 1990, approximately $333.3 million would become available for sanitary sewerage purposes; $155.0 million would become available for park purposes; and $25.8 million would become available for drainage improvements (see Table 115 and Figure 33).

Table 115

ALTERNATIVE FORECASTS OF EXPENDITURES FOR PUBLIC SANITARY SEWERAGE, PARK AND OUTDOOR RECREATION, AND MAJOR OPEN CHANNEL DRAINAGE PURPOSES BY THE LOCAL UNITS OF GOVERNMENT IN THE MILWAUKEE RIVER WATERSHED: 1969-1990

EXPENDITURE CATEGORY	ALTERNATIVE A	ALTERNATIVE B	ALTERNATIVE C
SANITARY SEWERAGE..............	$ 533.8[a]	$ 355.5[b]	$ 333.3[c]
PARK AND OUTDOOR RECREATION...	255.5[a]	239.4[d]	155.0[e]
MAJOR OPEN CHANNEL DRAINAGE...	49.7[a]	36.0[f]	25.8[g]
TOTAL	$ 839.0	$ 630.9	$ 514.1

[a]BASED UPON A LEAST SQUARES LINEAR PROJECTION OF THE 1958-1968 EXPENDITURES LISTED IN TABLE 114.

[b]BASED UPON A CONSTANT (7.0%) PROPORTION OF TOTAL FORECAST ANNUAL RECEIPTS.

[c]BASED UPON A PER CAPITA EXPENDITURE OF $24.57 PER YEAR.

[d]BASED UPON A CONSTANT (4.7%) PROPORTION OF TOTAL FORECAST ANNUAL RECEIPTS.

[e]BASED UPON A PER CAPITA EXPENDITURE OF $11.43 PER YEAR.

[f]BASED UPON A CONSTANT (0.7%) PROPORTION OF TOTAL FORECAST ANNUAL RECEIPTS.

[g]BASED UPON A PER CAPITA EXPENDITURE OF $1.90 PER YEAR.

SOURCE- SEWRPC.

Table 114

EXPENDITURES FOR PUBLIC SANITARY SEWERAGE, PARK AND OUTDOOR RECREATION, AND MAJOR OPEN CHANNEL DRAINAGE PURPOSES AND TOTAL RECEIPTS REPORTED BY LOCAL UNITS OF GOVERNMENT IN THE MILWAUKEE RIVER WATERSHED: 1958-1968

YEAR	SANITARY SEWERAGE EXPENDITURES[b]	PERCENT OF TOTAL RECEIPTS	PARK AND OUTDOOR RECREATION EXPENDITURES[c]	PERCENT OF TOTAL RECEIPTS	DRAINAGE EXPENDITURES[d]	PERCENT OF TOTAL RECEIPTS	TOTAL RECEIPTS[e]
1958	$ 3.8	4.7	$ 3.7	4.5	$ 0.1	0.1	$ 80.9
1959	4.2	5.0	3.8	4.5	0.2	0.2	84.3
1960	4.6	5.3	4.2	4.8	0.4	0.5	87.7
1961	5.5	5.8	4.5	4.7	0.7	0.7	96.0
1962	6.3	6.2	5.0	5.0	1.0	1.0	101.3
1963	8.4	7.5	5.1	4.6	1.7	1.5	112.0
1964	8.8	7.7	7.8	6.8	1.0	.8	113.8
1965	11.9	9.5	4.6	3.7	0.6	.5	124.4
1966	10.4	8.4	5.7	4.6	1.1	.9	123.5
1967	10.0	7.2	6.2	4.5	1.0	.7	139.2
1968	11.6	7.2	7.2	4.5	1.0	.6	160.7
TOTAL	$85.5	---	$57.8	---	$ 8.8	---	$1223.8
11 YEAR AVERAGE	$ 7.8	7.0	$ 5.3	4.7	$ 0.8	0.7	$ 111.3

[a]INCLUDES THOSE LOCAL UNITS OF GOVERNMENT WITH 50 PERCENT OR MORE OF THEIR LAND AREA LOCATED WITHIN THE MILWAUKEE RIVER WATERSHED AND A PRO RATA PROPORTION OF RECEIPTS AND DISBURSEMENTS FOR THE CITY OF MILWAUKEE, MILWAUKEE COUNTY, AND SHEBOYGAN COUNTY (SEE ACCOMPANYING TEXT).

[b]INCLUDES EXPENDITURES REPORTED FOR SUCH PURPOSES AS CONSTRUCTION AND OPERATION AND MAINTENANCE OF SANITARY SEWERAGE FACILITIES.

[c]INCLUDES EXPENDITURES REPORTED FOR SUCH PURPOSES AS LAND ACQUISITION AND CONSTRUCTION AND OPERATION AND MAINTENANCE OF PARK AND RELATED OPEN-SPACE FACILITIES.

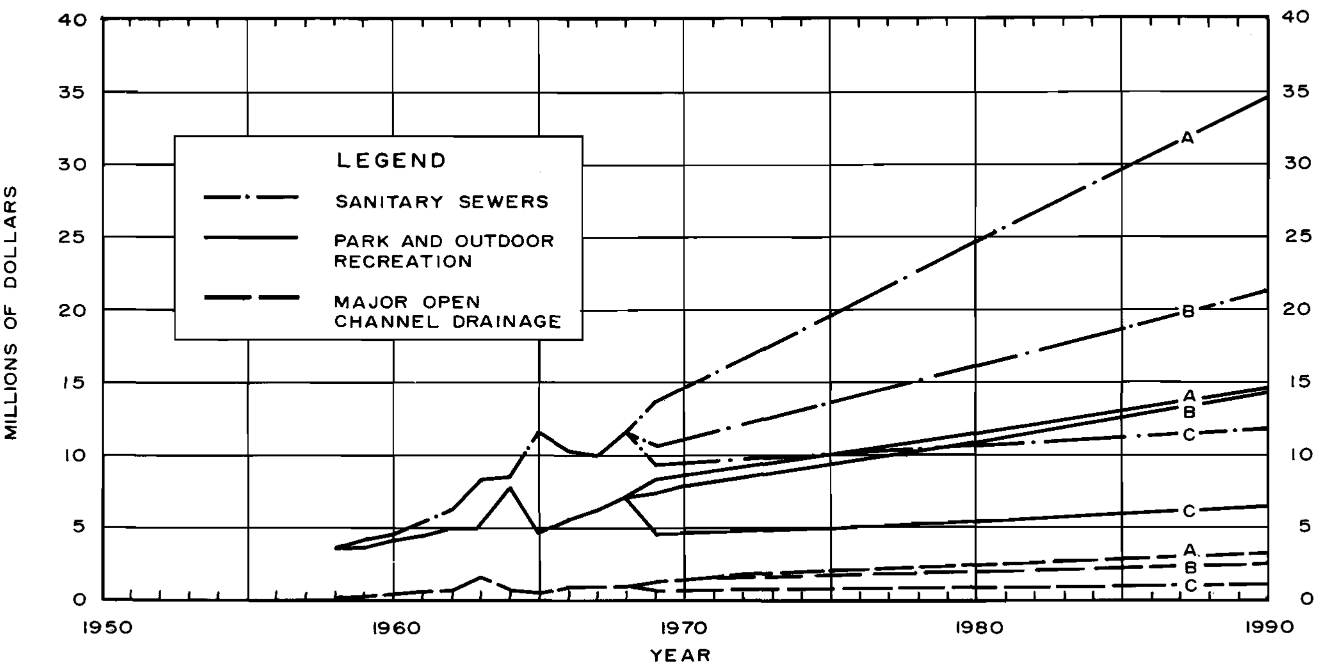
[d]INCLUDES EXPENDITURES REPORTED FOR SUCH PURPOSES AS LAND ACQUISITION, CONSTRUCTION, AND MAINTENANCE OF OPEN CHANNEL IMPROVEMENTS.

[e]INCLUDES ALL RECEIPTS REPORTED FOR USE BY THE MUNICIPAL OR COUNTY UNIT OF GOVERNMENT.

SOURCE- WISCONSIN DEPARTMENT OF ADMINISTRATION, BUREAU OF MUNICIPAL AUDIT, LOCAL UNITS OF GOVERNMENT, AND SEWRPC.

Figure 33

PUBLIC EXPENDITURE TRENDS AND ALTERNATIVE FORECASTS FOR PUBLIC SANITARY SEWERAGE, PARK AND OUTDOOR RECREATION, AND MAJOR OPEN CHANNEL DRAINAGE PURPOSES IN THE MILWAUKEE RIVER WATERSHED: 1958-1990



Source: Wisconsin Department of Administration, Bureau of Municipal Audit; Local Units of Government; and SEWRPC.

A review of past expenditure patterns, along with the range of possible future expenditure levels, thus indicates that between \$333.3 million and \$533.8 million may be expected to be expended by the local units of government within the watershed for sanitary sewerage purposes by 1990; between \$155.0 million and \$255.5 million may be expected to be expended for park and open-space purposes; and between \$25.8 million and \$49.7 million may be expected to be expended for drainage improvements. These forecast ranges do not represent any major departures from past expenditure levels or patterns and, therefore, may be considered conservative in nature.

The estimated total cost of implementing the water pollution abatement plan element of the recommended Milwaukee River watershed plan, including capital and operation and maintenance costs, is \$82.2 million (see Table 113). This amount can be compared on a gross basis with a possible expenditure of \$407.5 million, the average of the three alternative forecasts of the expenditures for sanitary sewerage purposes presented above. While such a comparison would indicate that the plan implementation costs for water pollution abatement are reasonable, it is important to note that the two figures are not strictly comparable. The pollution abatement plan element does not include, for example, the cost of constructing lateral, common, branch, or trunk sewers except in the case of the sanitary sewerage systems recommended for the nine major lake communities. Thus, expenditures can be expected for public sanitary sewerage purposes in addition to those provided for in the recommended plan element. Also, the operation and maintenance costs in the plan do not reflect total operation and maintenance costs but only the incremental operation and maintenance costs attendant to the reccommended facilities. At least partially offsetting these facts are the following important considerations: 1) the water quality management plan element contains costs for water pollution control measures in addition to sanitary sewerage systems, such as the construction of bench terraces and the conduct of aquatic weed harvesting and algae control programs; 2) implementation of the recommended plan would result in lower expenditures being made by homeowners for the installation and maintenance of private water supply and sewage disposal systems; 3) large portions of the cost of installing lateral and branch sewers can be recouped through application of appropriate financing techniques, such as special assessments, and through regulations requiring land developers to install sanitary sewerage facilities as an integral part of the land development process; 4) it is reasonable to conclude that nonlocal expenditures for sanitary sewerage facilities in the form of state and federal aid will play an increasingly important role in future years; and 5) with respect to expenditures in Milwaukee County, it is reasonable to conclude that the major trunk and relief sewer construction program now underway by the Milwaukee-Metropolitan Sewerage Commissions will be completed well before the end of the design year of the watershed plan (1990) and will thus permit funding of the lower watershed pollution abatement plan element, dealing with the combined sewer overflows, without any substantial increase in local expenditures.

From the foregoing discussion, it is fair to conclude that sufficient monies to implement substantially the recommended water pollution abatement plan element of the comprehensive Milwaukee River watershed plan should become available without significant shifts in local expenditure patterns. Implementation of the plan would not only meet the federal and state-established water use objectives and supporting standards but would eliminate certain existing public health hazards and avoid the creation of new public health hazards due to malfunctioning septic tank sewage disposal systems located on soils poorly suited for the absorption of sewage effluent and would contribute toward achieving a land use pattern that can be efficiently and economically provided with municipal sanitary sewer service.

The estimated total cost of implementing the natural resource protection, outdoor recreation, and parkway and scenic drive plan element of the recommended watershed plan, including capital and operation and maintenance costs, is $56.3 million. This amount can be crudely compared on a gross basis with a possible expenditure of $216.6 million, the average of the three alternative forecasts for expenditures for park purposes. The foregoing comparison indicates that substantially more money would be available to implement the plan than would be needed. However, it is important to note that the great majority of the money forecasted to be spent would be spent in Milwaukee County, where the plan recommends only minor public expenditures for park and outdoor recreation-related purposes. On the other hand, substantial expenditures would be required in Fond du Lac, Ozaukee, Sheboygan, and Washington Counties, where historic expenditures would likely not be sufficient to indicate an excess of future expenditures over the plan cost. In addition, it should be recognized that the plan implementation costs do not include the total operation and maintenance costs but only the incremental operation and maintenance costs attendant to the recommended new outdoor recreation facilities. On the other hand, partially offsetting this is the fact that, of the $56.3 million required for park and open-space plan implementation, about $16 million is recommended to be provided by state agencies. In addition, it is reasonable to assume that greater amounts of state and federal aid for open-space land acquisition and development will be made available in future years, thus further offsetting the need for additional local expenditures.

Since the recommended watershed plan contains no structural flood control plan elements, there is no basis for comparing the forecast of expenditures for drainage improvements against a plan element. Minor drainage and channel improvements will, however, continue to be made as supporting actions in the implementation of the comprehensive watershed plan. In addition, it is possible that some of the funds normally allocated to channel improvements may be able to be shifted in support of land acquisition so that sound land use development may occur in accord with the comprehensive plan and avoid the necessity in the future of constructing additional channel and drainage improvements.

Although the recommended comprehensive plan for the Milwaukee River watershed contains a water supply element, it was not considered meaningful to compare past and forecast expenditures for public water supply purposes within the watershed to the plan element recommended for adoption. The recommended water supply plan element consists of the establishment of municipal water supply systems in eight urban areas of the Milwaukee River watershed which presently do not have such systems. Hence, any expenditures for plan implementation would, in these eight communities, be new expenditures not incurred in past years. It should be noted, however, that water supply expenditures were made by private individuals in past years in the eight communities and that such private expenditures would no longer be necessary if the recommended watershed plan is implemented.

In summary, the foregoing cost analysis demonstrates that the cost of implementing the watershed plan is such as to be reasonably attainable through continuing the current public expenditure patterns for sanitary sewerage and park and open-space purposes. It is clear that, if the adopted water uses and standards are to be met and if the remaining prime elements of the sustaining natural resource base are to be permanently protected and preserved, the level of expenditures needed to implement the recommended watershed plan is necessary and fully warranted.

SUMMARY

The various plan elements recommended as integral parts of the comprehensive plan for the Milwaukee River watershed have all been described separately and in considerable detail in the preceding chapters of this volume. In the comprehensive watershed plan described in this chapter, each plan element was selected so as to complement and strengthen all of the others.

Under the comprehensive watershed plan recommended herein, future urban development within the watershed would be guided through locally exercised land use controls into a more efficient and attractive pattern. Continued encroachment of urban development onto the natural floodplains would be arrested and future intensification of flood problems avoided. Residential development would be concentrated within sanitary sewer and public water service areas tributary to existing and proposed systems and would be located on soils suited for such use, thus avoiding future public health problems. The remaining prime agricultural areas of the watershed would be protected from destruction through urban encroachment. The environmental corridors of riverine woodlands, wetlands, and surface water, together with the associated floodlands, would be preserved first by immediate zoning to prohibit inadvisable development and then gradually by public acquisition for park, parkway, and open-space purposes. Eventually, the Milwaukee River stream valley system would be transformed into an attractive greenbelt, parkway, recreation, and other open land areas serving to attract in urban areas high-value residential development.

The flood-damage hazard would not increase, as new flood-vulnerable development would be prohibited under the watershed plan. In addition, the flood-damage hazard would be reduced through the imposition of floodproofing conditions and nonconforming zoning status, the latter condition being applied only to those residences and other flood-vulnerable development actually located in the floodway of the river system. Other flood-vulnerable development in the floodplain areas would be subject only to the floodproofing requirements and would be allowed to remain as permitted land uses. No structural flood control plan elements have been recommended, as such structural elements were found to be either economically unfeasible; aesthetically unacceptable; or, in the case of the proposed Waubeka Reservoir, not recommended by the Watershed Committee because of public policy considerations.

The large private investment in homes and in public recreation and conservation lands, which is dependent to a considerable extent upon suitable water quality, would be protected by the recommended water pollution abatement programs. Existing waste loadings on the stream and lake systems would be reduced by the provision of advanced waste treatment for nutrient removal at critical locations throughout the watershed to produce stream and lake water quality levels capable of meeting the established water use objectives and standards. These objectives state that all surface waters within the watershed should meet the standards for whole-body-contact recreational uses and for the preservation of fish and other aquatic life, with the exceptions of the streams noted below, and, additionally, that the Milwaukee River over its entire length and Cedar Creek at Cedarburg should also meet the standards for industrial and cooling water uses. The exceptions to these objectives are Lincoln Creek and the Milwaukee River downstream from the North Avenue Dam, which are not required to meet the standards for fish and other aquatic life or for whole-body-contact-recreation, and Indian Creek, which must meet only minimum standards.

The water supply resources of the watershed would be protected through proper well location and spacing in the development of the ground water aquifers. In addition, eight urban communities not now having centralized public water supply systems would be served by such systems by 1990 if the plan is implemented.

(This page intentionally left blank)

Chapter VIII

THE UNPLANNED ALTERNATIVE

INTRODUCTION

The recommended land use and water control facility elements of a comprehensive plan for the physical development of the Milwaukee River watershed in southeastern Wisconsin were described in the preceding chapter of this volume. These plan components were selected after careful test and evaluation of the alternatives available and after presentation of these alternatives to the Milwaukee River Watershed Committee, the SEWRPC Technical Advisory Committee on Natural Resources and Environmental Design, the constituent local units of government, and to certain state and federal agencies for further technical and nontechnical review and evaluation. The plan test, evaluation, and review process indicated that implementation of the recommended comprehensive watershed plan would best meet the recommended watershed development objectives formulated as a part of the watershed planning process.

Another alternative is, however, available to the watershed—that of continued existing trend development in the absence of any attempt to guide such development on an areawide basis in the public interest. In order to assess the possible impact of such unplanned development upon the future environment within the watershed and upon the need for water control facilities, this unplanned alternative was explored in some depth. This alternative is not to be construed as a plan but rather as a forecast of one of the many possible end results of unplanned development within the watershed. It is intended to serve not as a recommendation but as a basis of comparison for the evaluation of the potential benefits of the recommended comprehensive watershed development plan; and, in this respect, it serves a particularly important function as a basis for the calculation of flood control benefits attendant to the recommended land use pattern. The flood control benefits associated with the latter were determined by subtracting the residual flood-damage risk associated with the planned alternative from the flood-damage risk projected for the unplanned alternative.

This chapter presents a brief description of the unplanned alternative, a discussion of the implications of this alternative for the water quality control facility systems within the watershed, and a comparison of the unplanned alternative with the recommended plan in terms of attainment of the watershed development objectives.

LAND USE FORECAST METHODOLOGY

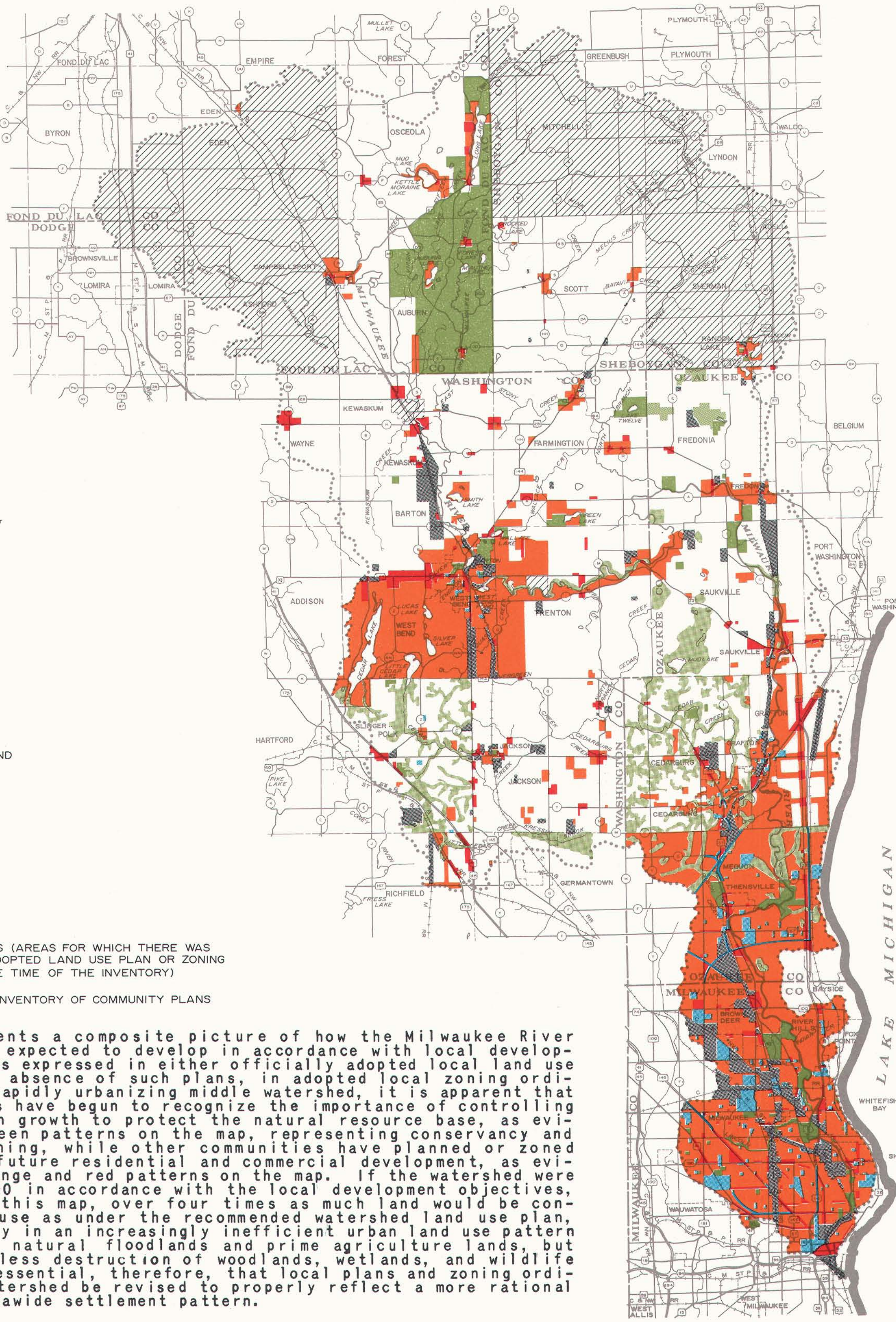
The land use pattern chosen to represent the unplanned alternative within the watershed was taken from a similar alternative prepared for the Region as a whole under the regional land use-transportation planning effort and was further expanded to include that portion of the Milwaukee River watershed outside of the Region. The methodology applied in the development of this land use pattern, including the use of supplemental landuse simulation model techniques, is described in SEWRPC Planning Report No. 7, Volume 3, Recommended Regional Land Use and Transportation Plans—1990.

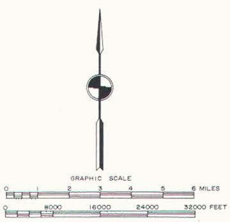
In the assignment of land use activities to subareas of the Region under this methodology, the only major constraint placed on the continuation of historic development trends within the Region and the watershed was that of the probable effect of adopted local plans and plan implementation devices. Land use development was assumed, in the absence of an agreed-upon areawide land use plan, to be guided only by private decisions and the constraints on these decisions imposed by adopted local land use plans and, in the absence of such plans, local zoning ordinances. It should be noted, however, that those lands locally planned or zoned for conservancy and related open space uses were not considered to be irrevocably committed to such uses and, in the absence of public ownership, were considered developable for more intensive urban land uses. Thus, the concept of the unplanned alternative, as used herein, relates to the absence of planning and plan implementation on an areawide, and not on a local, basis. The land use proposals of the local communities comprising the watershed are shown graphically on Map 66 and are quantitatively compared to the proposals advanced in the recommended watershed plan in Tables 116 and 117.

The spatial distribution of the various land uses resulting from the unplanned alternative, as projected for the Region as a whole, was modified

Map 66

LOCALLY PROPOSED FUTURE LAND USE PATTERN IN THE MILWAUKEE RIVER WATERSHED[1]





LEGEND

- RESIDENTIAL
- COMMERCIAL
- INDUSTRIAL
- GOVERNMENTAL AND INSTITUTIONAL
- TRANSPORTATION
- RECREATIONAL
- CONSERVANCY
- AGRICULTURAL
- UNPLANNED AREAS (AREAS FOR WHICH THERE WAS NO OFFICIALLY ADOPTED LAND USE PLAN OR ZONING ORDINANCE AT THE TIME OF THE INVENTORY)

[1] GENERALIZED FROM 1970 INVENTORY OF COMMUNITY PLANS AND ZONING ORDINANCES

This map represents a composite picture of how the Milwaukee River watershed may be expected to develop in accordance with local development objectives as expressed in either officially adopted local land use plans, or in the absence of such plans, in adopted local zoning ordinances. In the rapidly urbanizing middle watershed, it is apparent that a few communities have begun to recognize the importance of controlling and shaping urban growth to protect the natural resource base, as evidenced by the green patterns on the map, representing conservancy and recreational zoning, while other communities have planned or zoned excessively for future residential and commercial development, as evidenced by the orange and red patterns on the map. If the watershed were to develop by 1990 in accordance with the local development objectives, as expressed on this map, over four times as much land would be converted to urban use as under the recommended watershed land use plan, resulting not only in an increasingly inefficient urban land use pattern that would usurp natural floodlands and prime agriculture lands, but also in the needless destruction of woodlands, wetlands, and wildlife habitat. It is essential, therefore, that local plans and zoning ordinances in the watershed be revised to properly reflect a more rational and efficient areawide settlement pattern.

Source: SEWRPC.

Table 116

URBAN AND RURAL LAND USE IN THE MILWAUKEE RIVER WATERSHED: EXISTING 1967, 1990 RECOMMENDED LAND USE PLAN, AND AS PROPOSED IN COMMUNITY PLANS AND ZONING ORDINANCES

LAND USE CATEGORY	EXISTING (1967)		1990 RECOMMENDED PLAN		LOCALLY PROPOSED[a]	
	ACRES	PERCENT	ACRES	PERCENT	ACRES	PERCENT
URBAN LAND USE						
RESIDENTIAL	27,020	6.1	34,889	7.8	75,642	17.0
LOW-DENSITY	12,258	2.8	12,555	2.8	35,152	7.9
MEDIUM-DENSITY	6,014	1.4	12,351	2.8	24,472	5.5
HIGH-DENSITY	8,748	1.9	9,983	2.2	16,018	3.6
COMMERCIAL	1,368	0.3	1,991	0.4	8,008	1.8
INDUSTRIAL	1,763	0.4	2,399	0.5	13,349	3.0
MINING	1,113	0.3	1,113	0.3	--	--
TRANSPORTATION	25,511	5.7	27,889	6.4	--	--
GOVERNMENTAL	3,452	0.8	4,194	0.9	4,044	0.9
RECREATIONAL	5,081	1.1	5,977	1.3	21,803	4.9
TOTAL URBAN LAND USE	65,308	14.7	78,452	17.6	122,806	27.6
RURAL LAND USE						
AGRICULTURAL	271,370	61.0	261,901	59.0	204,233	45.9
WATER, WOODLANDS, WETLANDS	108,273	24.3	104,598	23.4	117,912[b]	26.5
TOTAL RURAL LAND USE	379,643	85.3	366,499	82.4	322,145	72.4
TOTAL	444,951	100.0	444,951	100.0	444,951	100.0

[a] COMMUNITY PLANS AND ZONING ORDINANCES INVENTORY DATED 1970.

[b] INCLUDES LAND UNPLANNED AND UNZONED, AS WELL AS LAND ZONED IN AN UNRESTRICTED MANNER.

SOURCE- SEWRPC.

Table 117

CHANGES IN LAND USE IN THE MILWAUKEE RIVER WATERSHED: 1990 RECOMMENDED LAND USE PLAN AND AS PROPOSED IN COMMUNITY PLANS AND ZONING ORDINANCES

LAND USE CATEGORY	1990 RECOMMENDED PLAN CHANGE		LOCALLY PROPOSED CHANGE[a]	
	ACRES	PERCENT	ACRES	PERCENT
RESIDENTIAL	7,869	29.1	48,622	179.9
LOW-DENSITY	297	2.4	22,894	186.8
MEDIUM-DENSITY	6,337	105.4	18,458	306.9
HIGH-DENSITY	1,235	14.1	7,270	83.1
COMMERCIAL	623	45.5	6,640	485.4
INDUSTRIAL	636	36.1	11,586	657.2
TRANSPORTATION	2,378	9.3	--	--
GOVERNMENTAL	742	21.5	592	17.1
RECREATION[b]	896	17.6	16,722	329.1
AGRICULTURE	-9,469	- 3.5	-67,137	- 24.7
OTHER OPEN LAND[c]	-3,675	- 3.4	9,639	8.9

[a] COMMUNITY PLANS AND ZONING ORDINANCE INVENTORY DATED 1970.

[b] INCLUDES ONLY THE INTENSIVELY USED PORTIONS OF RECREATION AREAS, SUCH AS BALL DIAMONDS AND TENNIS COURTS.

[c] INCLUDES WATER, WETLANDS, WOODLANDS, AND UNUSED LANDS.

SOURCE- SEWRPC.

somewhat for the watershed by giving special attention to the probable location of future urban development in the riverine areas of the watershed. Development in the riverine areas was projected on the basis of observed existing trends and in consideration of the effect of existing and committed utility and transportation system service areas. Stage-discharge and damage frequency curves relating to uncontrolled floodland development were then prepared for the resulting projected future floodland development pattern, as described in Chapter VIII, Volume 1, of this report.

UNPLANNED ALTERNATIVE—LAND USE

The spatial distribution of the various land uses which could be expected to result from the unplanned alternative is shown graphically on Map 67 and quantitatively compared to the proposals advanced in the recommended watershed plan in Table 118.

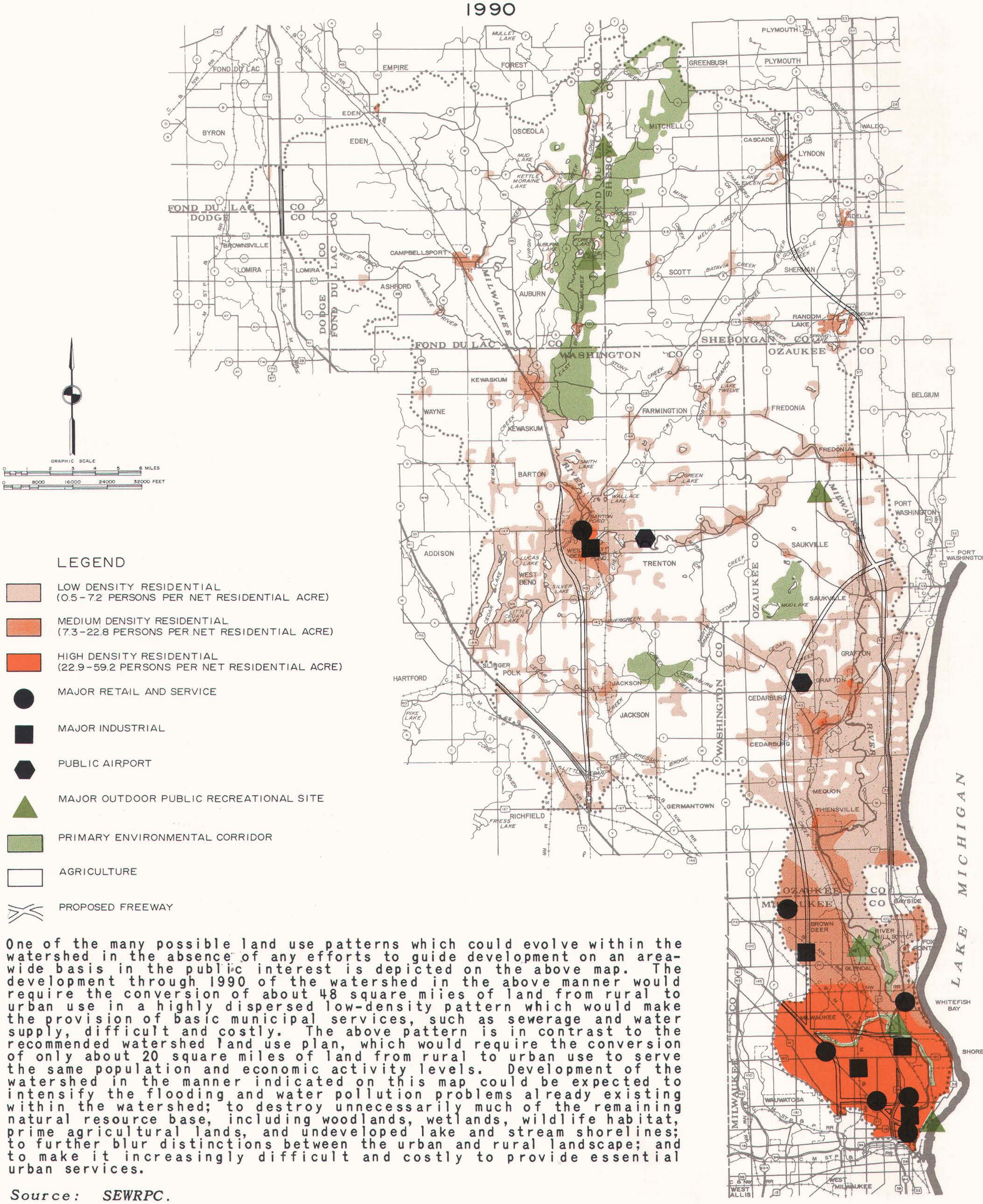
Residential Development

The land use pattern which would result from the unplanned alternative reflects the probable effects of a continuation of recent historic development trends in the Region as a whole and of the assumed influence of the adopted local community plans and zoning ordinances. This land use pattern would result in an expected watershed population increase of about 129,000[1] persons by 1990, primarily through continued outward expansion of existing urban areas, leapfrog residential development in outlying areas of the watershed, and continued heavy reliance upon very low residential development densities and on-site sewage disposal systems. As indicated in Table 118, more than 20,000 acres of new residential development would be added to the existing stock of residential land within the watershed under the unplanned alternative, 2.5 times as much as under the recommended land use plan. Nearly 90 percent of this additional residential acreage would be developed at low densities, with net lot sizes ranging from one-half to five acres per dwelling unit and gross population densities ranging from 350 to 3,499 persons per square mile. This is in sharp contrast to the recommended land use plan, wherein nearly 90 percent of the additional residential acreage would be developed at medium densities, with net lot sizes ranging from 6,300 to 19,800 square feet per dwelling unit and gross

[1] *It is important to note that this incremental population of 129,000 persons is about 5,000 persons less than the forecast incremental population (134,000) utilized in the design of the adopted regional land use plan, which plan, as noted in Chapter III of this volume, has been recommended as the land use base for the comprehensive Milwaukee River watershed plan. This decrease in incremental watershed population under the unplanned alternative is due to the underlying assumptions of the unplanned alternative for the Region as a whole, that the land use development trends (predominant within the Region from 1950 through 1963) would continue through 1990. The net result would be a slightly greater population increase in the western portion of the Region, particularly in the Fox River watershed, with a concomitant decrease in the expected population in the northern portion of the Region, including the Milwaukee River watershed.*

Map 67

THE UNPLANNED LAND USE ALTERNATIVE IN THE MILWAUKEE RIVER WATERSHED 1990



One of the many possible land use patterns which could evolve within the watershed in the absence of any efforts to guide development on an area-wide basis in the public interest is depicted on the above map. The development through 1990 of the watershed in the above manner would require the conversion of about 48 square miles of land from rural to urban use in a highly dispersed low-density pattern which would make the provision of basic municipal services, such as sewerage and water supply, difficult and costly. The above pattern is in contrast to the recommended watershed land use plan, which would require the conversion of only about 20 square miles of land from rural to urban use to serve the same population and economic activity levels. Development of the watershed in the manner indicated on this map could be expected to intensify the flooding and water pollution problems already existing within the watershed; to destroy unnecessarily much of the remaining natural resource base, including woodlands, wetlands, wildlife habitat, prime agricultural lands, and undeveloped lake and stream shorelines; to further blur distinctions between the urban and rural landscape; and to make it increasingly difficult and costly to provide essential urban services.

Source: SEWRPC.

population densities ranging from 3,500 to 9,999 persons per square mile. In the unplanned alternative, medium-density lands would increase by only 2,100 acres.

The recommended land use plan seeks to provide an overall urban population density of about 7,100 persons per square mile within the watershed by 1990. Under the unplanned alternative, urban population densities within the watershed could be expected to continue to decrease from the 1967 level of approximately 7,500 persons per square mile to a 1990 density of about 4,700 persons per square mile (see Table 119). Failure to substantially achieve the overall density provided for in the recommended land use plan will continue to present the local units of government within the watershed with all of the problems attendant to highly dispersed low-density residential development, including incomplete neighborhoods requiring extensive urban services which can only be provided inefficiently and at a high cost. Failure to achieve the desired density will also result in the continued breakup of economic farm units, leaving a residual of scattered underdeveloped and undeveloped areas of land which lack potential for either good rural or urban development. Finally, failure to achieve the desired density will greatly

Table 118

URBAN AND RURAL LAND USE IN THE MILWAUKEE RIVER WATERSHED: EXISTING 1967, 1990 RECOMMENDED LAND USE PLAN, AND 1990 UNPLANNED ALTERNATIVE

LAND USE CATEGORY	EXISTING 1967		CHANGE 1967-1990				TOTAL 1990			
			PLANNED		UNPLANNED		PLANNED		UNPLANNED	
	ACRES	PERCENT OF MAJOR CATEGORY	ACRES	PERCENT CHANGE	ACRES	PERCENT CHANGE	ACRES	PERCENT OF MAJOR CATEGORY	ACRES	PERCENT OF MAJOR CATEGORY
URBAN LAND USE										
RESIDENTIAL	27,020	41.3	7,869	29.1	20,050	74.1	34,889	44.5	47,073	49.1
LOW-DENSITY[a]	12,258	18.7	297	2.4	17,823	145.4	12,555	16.0	30,081	31.4
MEDIUM-DENSITY[a]	6,014	9.2	6,337	105.4	2,087	34.6	12,351	15.8	8,101	8.4
HIGH-DENSITY[a]	8,748	13.4	1,235	14.1	143	1.6	9,983	12.7	8,891	9.3
COMMERCIAL	1,368	2.1	623	45.5	770	56.0	1,991	2.5	2,138	2.2
INDUSTRIAL	1,763	2.7	636	36.1	612	34.7	2,359	3.1	2,375	2.5
MINING	1,113	1.7	--	--	--	--	1,113	1.4	1,113	1.2
TRANSPORTATION[b]	25,511	39.1	2,378	9.3	7,613	29.8	27,889	35.6	33,124	34.5
GOVERNMENTAL[c]	3,452	5.3	742	21.5	852	24.6	4,194	5.3	4,304	4.5
RECREATIONAL[d]	5,081	7.8	896	17.6	705	13.8	5,977	7.6	5,786	6.0
TOTAL URBAN LAND USE	65,308	100.0	13,144	20.1	30,605	46.8	78,452	100.0	95,913	100.0
RURAL LAND USE										
AGRICULTURAL	271,370	71.5	-9,469	-3.5	-28,426	-10.5	261,901	71.4	242,944	69.6
WOODLAND	35,032	9.2	-3,675	-10.5	-2,179	-6.2	39,548	10.8	41,044	11.8
UNUSED LAND	8,191	2.2								
WATER AND WETLAND	65,050	17.1	--	--	--	--	65,050	17.8	65,050	18.6
TOTAL RURAL LAND USE	379,643	100.0	-13,144	-3.5	-30,605	8.1	366,499	100.0	349,038	100.0
TOTAL LAND USE	444,951	--	--	--	--	--	444,951	--	444,951	--

[a]ESTIMATED FROM 1967 LAND USE INVENTORY INFORMATION.

[b]INCLUDES OFF-STREET PARKING AND UTILITY USES.

[c]INCLUDES INSTITUTIONAL USES.

[d]INCLUDES MAJOR AND NEIGHBORHOOD PARKS.

SOURCE- SEWRPC.

Table 119

DEVELOPED AREA AND POPULATION DENSITY IN THE MILWAUKEE RIVER WATERSHED: EXISTING 1967, 1990 RECOMMENDED LAND USE PLAN, AND 1990 UNPLANNED ALTERNATIVE

FACTOR	EXISTING (1967)	INCREMENT 1967-1990				TOTAL 1990	
		PLANNED		UNPLANNED			
		NUMBER	PERCENT	NUMBER	PERCENT	PLANNED	UNPLANNED
SQUARE MILES OF DEVELOPED AREA[a]	68	24	35.3	67	98.5	92	135
URBAN POPULATION	512,900	140,100	27.3	121,911	23.8	653,000	634,811
POPULATION PER SQUARE MILE OF DEVELOPED AREA	7,542	5,838	--	1,820	--	7,098	4,702

[a]DETERMINED BY MEASURING THE EXTENT OF UNINTERRUPTED URBAN DEVELOPMENT (SEE SEWRPC PLANNING REPORT NO. 7, VOLUME 1, CHAPTER V, FOOTNOTE 1).

SOURCE- SEWRPC.

intensify environmental problems in the watershed and will result in continued deterioration and destruction of such elements of the resource base as the woodlands and wetlands.

Sewer and Water Services

The unplanned alternative would require the conversion of nearly 48 square miles of land within the watershed from rural to urban use by 1990. It would increase the urban land use of the watershed by more than 46 percent, as contrasted to the conversion of 21 square miles of land, an increase of only 20 percent, under the recommended plan (see Table 118). The need to restrict intensive urban development within the watershed, having both soils suitable for such development and gravity drainage sanitary sewer service readily available, would not be recognized under the unplanned alternative as it would by implementation of the recommended land use plan. Under the unplanned alternative, about 72 percent of the total developed area of the watershed could be readily provided in 1990 with public sanitary sewer facilities (see Table 120) tributary to existing and locally proposed systems; and about 60 percent of the total developed area of the water-

Table 120

DEVELOPED URBAN AREA AND POPULATION SERVED BY PUBLIC SANITARY SEWER AND PUBLIC WATER SUPPLY FACILITIES IN THE MILWAUKEE RIVER WATERSHED: EXISTING 1967, 1990 RECOMMENDED WATERSHED PLAN, AND 1990 UNPLANNED ALTERNATIVE

EXTENT OF SERVICE	EXISTING (1967)		INCREMENT 1967-1990				TOTAL 1990			
			PLANNED		UNPLANNED		PLANNED		UNPLANNED	
	PUBLIC SEWER	PUBLIC WATER SUPPLY	PUBLIC SEWER	PUBLIC WATER SUPPLY	PUBLIC SEWER	PUBLIC WATER SUPPLY	PUBLIC SEWER	PUBLIC WATER SUPPLY	PUBLIC SEWER	PUBLIC WATER SUPPLY
DEVELOPED URBAN AREA										
TOTAL SQUARE MILES.....	68	68	24	24	67	67	92	92	135	135
SQUARE MILES SERVED FROM FACILITIES LOCATED IN WATERSHED...........	11.1	12.0	27.8	19.4	3.9	12.2	38.9	31.4	15.0	24.2
SQUARE MILES SERVED FROM FACILITIES LOCATED OUTSIDE WATERSHED[a].....	53.9	52.0	24.1	26.0	27.8	5.0	78.0	78.0	81.7	57.0
TOTAL SQUARE MILES SERVED.................	65.0	64.0	51.9[b]	45.4[b]	31.7	17.2	116.9[c]	109.4[c]	96.7	81.2
PERCENT OF TOTAL DEVELOPED URBAN AREA SERVED.................	95.5	94.0	--	--	--	--	100.0	100.0	71.6	60.2
POPULATION										
TOTAL IN DEVELOPED URBAN AREA.............	512,900	512,900	140,100	140,100	121,911	121,911	653,000	653,000	634,811	634,811
POPULATION SERVED BY FACILITIES LOCATED IN WATERSHED..............	38,200	34,000	38,600	25,100	33,200	30,900	76,800	59,100	71,400	64,900
POPULATION SERVED BY FACILITIES LOCATED OUTSIDE WATERSHED[a].........	463,700	461,200	116,300	125,900	73,900	22,700	580,000	587,100	537,600	483,900
TOTAL POPULATION SERVED.................	501,900	495,200	154,900[b]	151,000[b]	107,100	53,600	656,800[c]	646,200[c]	609,000	548,[illegible]00
PERCENT OF TOTAL WATERSHED POPULATION SERVED.	92.4	91.2	--	--	--	--	97.0	95.3	90.5	81.5

[a]CONSISTS OF ALL AREAS AND POPULATION SERVED BY THE MILWAUKEE-METROPOLITAN SEWERAGE COMMISSIONS, THE NORTH SHORE WATER UTILITY, AND THE CITY OF MILWAUKEE WATER UTILITY.

[b]THE INCREMENT IN TOTAL SQUARE MILES AND POPULATION SERVED BY PUBLIC SEWER AND PUBLIC WATER SUPPLY FACILITIES WITHIN THE WATERSHED IS LARGER THAN THE INCREMENT IN THE TOTAL DEVELOPED AREA AND THE TOTAL POPULATION IN THE DEVELOPED AREA BECAUSE PUBLIC SEWER AND WATER SUPPLY SERVICES, UNDER THE PLANNED ALTERNATIVE, WOULD BE EXTENDED TO INCLUDE NOT ONLY THE INCREMENT OF DEVELOPED AREA BUT ALSO SOME EXISTING URBAN AREAS NOT NOW SERVED BY THESE TWO PUBLIC UTILITIES.

[c]THE TOTAL SQUARE MILES AND POPULATION SERVED BY PUBLIC SEWER AND PUBLIC WATER SUPPLY FACILITIES IN 1990 UNDER THE PLANNED ALTERNATIVE EXCEEDS THE TOTAL AREA AND POPULATION OF THE DEVELOPED URBAN AREA BECAUSE THE PUBLIC SEWER AND WATER SUPPLY SERVICE AREAS INCLUDE AREAS WHICH CONTAIN LAND USES NOT CLASSIFIED AS DEVELOPED FOR URBAN PURPOSES, SUCH AS THE DEVELOPMENT AROUND THE MAJOR LAKES IN THE WATERSHED.

SOURCE- SEWRPC.

shed could be readily provided with public water supply facilities. Thus, the unplanned alternative would result in an increasing emphasis upon not only low-density residential development but upon the concomitant widespread utilization of private wells and domestic septic tank systems rather than upon municipal water supply and sewerage facilities.

The impact of such development upon surface water quality is extremely difficult to forecast because, unlike sewage treatment plant effluent, septic tank effluent is usually discharged to streams and lakes only indirectly after percolation through the soil and dilution by both surface and ground water. Other environmental problems attendant to the widespread utilization of on-site septic tank facilities and private wells, however, would probably far outweigh any consideration of the effects of the use of such facilities on surface water quality. Continued widespread use of septic tank sewage disposal systems could be expected to subject the shallow ground water aquifers to pollution in more numerous locations, involving larger and larger areas with serious attendant public health problems. Odor and drainage problems could be expected to continue to develop where residential development is located on soils poorly suited for septic tank filter fields, as could attendant public health hazards. As noted in Chapter IV, Volume 1, of this report, such soils are widespread, covering over 56 percent of the total area of the watershed.

Under the unplanned alternative, about 49 square miles, or 74 percent of all new development within the watershed, would probably have to rely on shallow wells as a source of water supply; and over 35 square miles, or 53 percent of the new development, would have to rely on on-site sewage disposal systems. Consequently, by 1990 about 96 percent of the total watershed population could be expected to be served by public sanitary sewer facilities and about 86 percent of the total watershed population could be expected to be served by public water supply facilities. In 1967 about 65 square miles, or 95 percent of the developed urban area of the watershed, and 92 percent of the total population were served by public sanitary sewer facilities, while about 64 square miles, or 94 percent of the developed urban area and 91 percent of the 1967 population of the watershed, were served by public water supply facilities. In contrast to the unplanned alternative, the recommended land use plan would make possible the provision of public sewer and water supply facilities to all new residential development within the watershed and would, by 1990, facilitate the provision of public sewer and water service to virtually all of the total developed urban area of the watershed and about 97 percent of the total population.

Local Park Land Use

The recommended watershed land use plan calls for the acquisition and eventual development of 335 acres of local park land in the form of neighborhood parks to serve the additional residential development anticipated to occur within the watershed by the year 1990. In addition, the recommended watershed land use plan calls for the ultimate development of an additional 1,003 acres of local park land in the form of community parks within the acquired urban environmental corridors in order to meet fully the recommended standard of 10 acres of local park land per 1,000 resident population. Thus, the recommended watershed land use plan provides for a total of 1,338 acres of additional local park land. Under the unplanned alternative, the amount of land needed for neighborhood and community parks totals 1,290 acres, or about 48 acres less than the local park land proposed in the recommended watershed land use plan. It should also be noted that the unplanned alternative would not be nearly as effective in protecting the natural resource base of the watershed because of the large amount of residential development which would be likely to occur within the environmental corridors. While some of the neighborhood and community parks which would be established under the unplanned alternative might be located within the environmental corridors, it is likely that the uncontrolled residential development would usurp most of the high-value natural resource areas, with the local and community parks then relegated to the remaining low-value resource areas. Thus, while the recommended watershed land use plan proposes to develop only slightly more acres for local park use than would be developed under the unplanned alternative, the recommended plan, because of the proposed acquisition and preservation of the primary environmental corridors, would be far more effective in protecting the natural resource base of the watershed.

Agricultural Land Use

Under the unplanned alternative, the expansion of urban activities in the presently rural areas of the watershed could result in the conversion of 30,605 acres of rural land uses to urban uses between 1967 and 1990. This would be an equivalent annual rate of conversion of about 1,330 acres, or 2.08 square miles. As indicated in Table 118, much of the urban expansion of 30,605 acres would take place on land that is now in agricultural use and would result in a decrease of about 10 percent of the existing stock of agricultural land within the watershed. The recommended land use plan would require the conversion of only about 13,140 acres, or 3.5 percent of the existing stock of such land, by 1990. Moreover, the unplanned alternative would result in a conversion of 10,116 acres, or about 20 percent of the remaining prime agricultural lands, while the recommended plan would require the conversion of only 1,866 acres, or about 4 percent of these lands.

THE UNPLANNED ALTERNATIVE—FLOOD DAMAGES AND WATER QUALITY MANAGEMENT

Implications for Flood Control

The floodplains of the Milwaukee River watershed, as delineated by the 100-year recurrence interval flood hazard lines, encompass a total of about 49 square miles of land, or 7 percent of the total watershed area. By 1967, about two square miles, or about 4 percent of this total floodplain area, had been converted to urban use; and the average annual flood-damage risk totaled $119,000, with major floods, such as the 1960 flood, causing total damages of over $335,000.

Under the unplanned alternative, an additional 11 square miles of floodplain lands could be expected to be converted from rural to urban use within the watershed by 1990, resulting in an increase in the annual risk of flood damage from $119,000 to $160,000 and an increase in the risk of flood damage from a major flood, such as the 1924 flood, from about $1.8 million to about $2.2 million.

At the present time, about 96 percent of the Milwaukee River watershed floodlands remain in open space use. These unoccupied riverine lands comprise a critical element in the hydraulic system of the watershed inasmuch as they have the potential to temporarily store floodwaters thereby reducing flood discharges and stages. These unoccupied floodlands also provide flood conveyance capacity, the loss of which will also produce increased flood stages and, therefore, higher flood damages. The direct relationship between the loss of floodplain conveyance capacity and significantly increased flood stages has been demonstrated for various locations within the watershed by means of the application of the flood flow simulation model developed in the Milwaukee River watershed study. Indiscriminate floodland filling and development resulting in the loss of natural conveyance may be expected to significantly increase flood stages, areas of inundation, and, most important, flood damage in certain portions of the Milwaukee River watershed. Under the unplanned alternative, an additional 11 square miles, or about 22 percent of the floodland area, could be expected to be converted from rural to urban use; and, as a direct consequence, significant amounts of floodland conveyance, and storage, could be expected to be lost to urban development. Additional channel improvements and other structural flood control measures would then be necessary to both accommodate the new urban floodland development and to provide protection to that existing development which would be subjected to higher levels of inundation. Effects of these increased flood stages would be particularly significant along most of the lower reaches of the Milwaukee River through the Village of Saukville, the City of Mequon, the Village of Thiensville, and the City of Glendale; along the Middle Milwaukee River through the City of West Bend; and along Cedar Creek through the City of Cedarburg.

The increase in flood damage and in peak flood discharges accompanying the unplanned land use alternative could be expected to increase the need and demand for structural flood control measures. These might include channel improvements of an indeterminate extent, together with the construction of extensive systems of dikes and floodwalls.

Of the alternative structural flood control plan elements described in Chapter IV of this volume, dike and floodwall construction within the City of Mequon and the Villages of Thiensville and Saukville; a floodwater retarding structure near Waubeka; and a diversion channel near Saukville, would all be physically compatible with the unplanned alternative.

Implications for Water Quality Management

Although certain alternative water pollution abatement measures, such as the provision of secondary treatment with disinfection of the effluent and nutrient removal, would be applicable to any sewage treatment plant configuration serving the unplanned landuse alternative, the problems associated with the economical extension of centralized sanitary sewer service under the unplanned alternative would make these pollution abatement measures less effective. More importantly, the proliferation of small sewage treatment plants serving highly dispersed, relatively small enclaves of urban development within the watershed make the attainment of tertiary and advanced sewage treatment extremely difficult, if not impossible. The probable effects of the lack of such tertiary and advanced treatment on future stream water quality within the watershed have been described in Chapter V of this volume. The unplanned land use alternative would also make the attainment of any centralized sanitary sewerage systems for those reaches of the Milwaukee River, where recommended, more difficult. Consequently, the Milwaukee River above the Milwaukee County line could be expected to become unsuited for any use but waste assimilation and transmission, due to frequent discharges causing violation of standards. Enforcement actions would follow, which in the absence of a comprehensive areawide plan, could be expected to result in ad hoc abatement measures and greatly increased costs. Lake eutrophication could be expected to continue at a rapid rate, with the lakes becoming increasingly undesirable for recreational activities and increasingly undesirable for aesthetic values. The foregoing may be expected to be accompanied by decreasing property valuations in the lake-oriented communities of the watershed.

BENEFITS OF THE UNPLANNED ALTERNATIVE

One advantage that can be advanced for the unplanned alternative is that decision-making as to land use would continue to be decentralized in individual landowners and developers. This is an extremely intangible benefit, however; and any monetary benefit is and would continue to be derived by relatively few persons. In a free enterprise economy, each landowner and developer should be subject to a minimum of constraints in selecting the utilization of his land that, to him, appears to offer the greatest profit; and each consumer should be free to choose the opportunity that, to him, appears to offer the greatest value. Theoretically, in a free enterprise economy, the individual is in the best position to evaluate his own particular set of circumstances and then to choose the opportunity that appears most profitable to him. For example, a land developer and homebuilder would be free to choose whether or not to locate on the floodplain, in theory that he would have weighed the attendant benefits and costs and have concluded that the risk of flood damage was outweighed by other benefits of the floodplain location, fully realizing that future owners should not expect nor obtain any governmental aid through publicly funded flood protection or drainage programs.

For this theory to apply in practice, however, it would be necessary for all individual decision-makers to have full knowledge of the existence and magnitude of the flood risk in making their decision and be willing to act responsibly upon that knowledge. This is seldom the case in the Milwaukee River watershed, and it is highly unlikely that an individual deciding whether or not to buy an existing building in the floodplain would do so if all of the flood risk facts were made available to him to help him in determining his home or business location. The costs attendant to water pollution are not recognized at all in such decisions.

COSTS OF THE UNPLANNED ALTERNATIVE

Both heavy direct and spillover costs would be incurred under the unplanned alternative, with the latter costs being defined as those costs which the community as a whole must bear as a result of private development decisions. Direct costs would result from recurring flood damages which would be incurred by residents of the floodplain and by the watershed communities, the magnitude of these costs having been discussed in the previous section of this chapter. Major areas in which spillover costs would be incurred include the loss to the community of prime park and related open-space lands; loss in recreational value of the streams and lakes of the watershed due to water pollution; and the increased cost of providing community services to a highly dispersed land use pattern, including, in addition to sanitary sewer and water supply services, school services and police and fire protection. Although these spillover costs have real monetary values, they are virtually impossible to calculate and must, therefore, be considered as intangibles.

A benefit-cost analysis was not made for the unplanned alternative because the only recognized benefit would be the maximization of individual decision-making, to which a monetary value cannot be assigned. Presumably, this alternative

Table 121

COMPARISON OF THE RELATIVE ABILITY OF THE RECOMMENDED MILWAUKEE RIVER WATERSHED PLAN AND THE UNPLANNED ALTERNATIVE TO MEET ADOPTED WATERSHED DEVELOPMENT STANDARDS

LAND USE OBJECTIVE	RECOMMENDED WATERSHED LAND USE PLAN	UNPLANNED ALTERNATIVE
OBJECTIVE NO. 1		
STANDARD		
1. RESIDENTIAL LAND ALLOCATION		
A. LOW-DENSITY--250 ACRES/1,000 PERSONS	MET[a]	240 ACRES/1,000
B. MEDIUM-DENSITY--70 ACRES/1,000 PERSONS	MET[a]	70 ACRES/1,000
C. HIGH-DENSITY--25 ACRES/1,000 PERSONS	MET[a]	25 ACRES/1,000
2. GOVERNMENTAL AND INSTITUTIONAL LAND ALLOCATION		
A. LOCAL--6 ACRES/1,000 ADDED POPULATION	MET[a]	NOT MET
B. REGIONAL--3 ACRES/1,000 ADDED POPULATION	MET[a]	NOT MET
3. PARK AND RECREATION LAND ALLOCATION		
A. LOCAL--1.0 ACRE/100 ADDED POPULATION	0.59 ACRE/100[a]	0.30 ACRE/100
B. REGIONAL--0.4 ACRE/100 ADDED POPULATION	0.63 ACRE/100[a]	0.24 ACRE/100
C. SWIMMING--0.45 ACRE BEACH/100 PARTICIPANTS	MET[a]	PARTIALLY MET
D. PICNICKING--12.5 ACRES/100 PARTICIPANTS	MET[a]	PARTIALLY MET
E. GOLFING--32.8 ACRES/100 PARTICIPANTS	MET[a]	NOT MET
F. CAMPING--133.3 ACRES/100 PARTICIPANTS	MET[a]	NOT MET
G. SKIING--3.7 ACRES/100 PARTICIPANTS	MET[a]	MET
4. COMMERCIAL LAND ALLOCATION		
A. 5 ACRES/100 ADDED EMPLOYEES	3.68 ACRES/100	4.55 ACRES/100
5. INDUSTRIAL LAND ALLOCATION		
A. 7 ACRES/100 ADDED EMPLOYEES	5.60 ACRES/100	3.66 ACRES/100
OBJECTIVE NO. 2		
STANDARD		
1. SOILS		
A. URBAN USES	MET[a]	LARGELY UNMET
B. RURAL USES	MET[a]	LARGELY UNMET
C. SANITARY SEWER SERVICE AREAS	MET[a]	LARGELY UNMET
2. INLAND LAKES AND STREAMS		
A. LARGE INLAND LAKES OVER 50 ACRES		
1. 25% OF SHORE IN NATURAL STATE	MET FOR 14 OF 21 LAKES	MET FOR 8 OF 21 LAKES
2. 10% OF SHORE IN PUBLIC USE	MET FOR 8 OF 21 LAKES[b]	MET FOR 5 OF 21 LAKES
3. 50% OF SHORE IN NONURBAN USES	MET FOR 13 OF 21 LAKES[b]	MET FOR 6 OF 21 LAKES
B. SMALL INLAND LAKES UNDER 50 ACRES		
1. 25% OF SHORE IN NATURAL STATE	COULD BE MET[c]	NOT MET
C. PERENNIAL STREAMS		
1. 25% OF SHORE IN NATURAL STATE	MET FOR 26 OF 30 STREAMS	MET FOR 19 OF 30 STREAMS
2. 50% OF SHORE IN NONURBAN USES	MET FOR 26 OF 30 STREAMS	MET FOR 13 OF 30 STREAMS
3. RESTRICT URBAN USES IN FLOODPLAINS	MET[a]	NOT MET
4. RESTRICT DEVELOPMENT IN CHANNELS AND FLOODWAYS	MET[a]	NOT MET
3. WETLANDS		
A. PROTECT WETLANDS OVER 50 ACRES AND THOSE WITH HIGH RESOURCE VALUE	MET[a]	NOT MET
4. WOODLAND		
A. 10% OF WATERSHED	PARTIALLY MET	NOT MET
B. 40 ACRES EACH OF 4 FOREST TYPES	COULD BE MET[c]	COULD BE MET
C. 5 ACRES/1,000 REGIONAL POPULATION[d]	30 ACRES/1,000	UNKNOWN
5. WILDLIFE[e]		
A. MAINTAIN A WHOLESOME HABITAT	MET	NOT MET
OBJECTIVE NO. 3		
STANDARD		
1. MAJOR TRANSPORTATION ROUTES PENETRATING RESIDENTIAL PLANNING UNITS	COULD BE MET	DIFFICULT TO MEET
2. MAJOR TRANSPORTATION ROUTES PENETRATING RESOURCE AREAS	PARTIALLY MET	UNKNOWN
3. TRANSPORTATION SERVICE TO APPROPRIATE AREAS	COULD BE MET[c]	DIFFICULT TO MEET
4. TRANSPORTATION TERMINAL AREAS	COULD BE MET[c]	COULD BE MET
5. SEWER SERVICE TO RESIDENTIAL AREAS	100% SERVED	72% SERVED
6. WATER SUPPLY TO RESIDENTIAL AREAS	100% SERVED	60% SERVED
7. MAXIMIZE USE OF EXISTING TRANSPORTATION AND UTILITY FACILITIES	MET[a]	NOT MET
OBJECTIVE NO. 4		
STANDARD		
1. LOCAL PARK SPATIAL LOCATION	COULD BE MET	DIFFICULT TO MEET
2. REGIONAL PARK SPATIAL LOCATION	MET[a]	NOT MET
OBJECTIVE NO. 5		
STANDARD		
1. PRESERVE PRIME AGRICULTURAL AREAS	96% PRESERVED	80% PRESERVED
2. PRESERVE OTHER APPROPRIATE AGRICULTURAL AREAS	95% PRESERVED	89% PRESERVED

WATER CONTROL OBJECTIVE	RECOMMENDED WATERSHED WATER CONTROL FACILITIES PLAN	UNPLANNED ALTERNATIVE
OBJECTIVE NO. 1		
STANDARD		
1. NEW AND REPLACEMENT BRIDGES AND CULVERTS		
A. MINOR STREETS--PASS THE 10-YEAR FLOOD	MET[a]	COULD BE MET
B. ARTERIAL STREETS AND HIGHWAYS--PASS THE 50-YEAR FLOOD	MET[a]	DIFFICULT TO MEET
C. FREEWAYS AND EXPRESSWAYS--PASS THE 100-YEAR FLOOD	MET[a]	MET
D. RAILROADS--PASS THE 100-YEAR FLOOD	MET	MET
2. NEW AND REPLACEMENT BRIDGES AND CULVERTS SHALL PASS THE 100-YEAR FLOOD WITHOUT REACHING THE PEAK STAGE MORE THAN 0.5 FOOT	MET	COULD BE MET
3. STRUCTURE DESIGN SHALL MAXIMIZE PASSAGE OF ICE FLOES AND DEBRIS	MET	MET
4. CERTAIN NEW AND REPLACEMENT BRIDGES AND CULVERTS SHALL PASS THE 100-YEAR FLOOD WITH 2.0 FEET OF FREEBOARD	MET	COULD BE MET
5. EXISTING BRIDGES AND CULVERTS TO MEET STANDARDS 1, 3, AND 4 ABOVE	MET	COULD BE MET
6. CHANNEL IMPROVEMENTS SHOULD BE RESTRICTED TO THE ABSOLUTE MINIMUM NECESSARY	MET[a]	NOT MET
7. ALL OTHER WATER CONTROL FACILITIES, SUCH AS DAMS OR DIVERSION CHANNELS, SHALL ACCOMMODATE THE 100-YEAR FLOOD	MET[a]	COULD BE MET
8. EFFECTIVE DATE OF REDUCED FLOOD PROTECTION ELEVATIONS AT TIME OF CONSTRUCTION AND OPERATION OF FLOOD CONTROL WORKS	MET	MET
9. PUBLIC LAND ACQUISITIONS TO ELIMINATE WATER CONTROL FACILITIES SHALL ENCOMPASS THE ENTIRE 100-YEAR FLOODPLAIN	MET	NOT MET
OBJECTIVE NO. 2		
STANDARD		
1. STREAM REACH WATER QUALITY LEVELS SHALL MEET STATE WATER QUALITY STANDARDS FOR ALL REACHES	MET[a]	DIFFICULT TO MEET
2. ALL STREAM REACHES SHALL MEET STATE MINIMUM STANDARDS	MET	UNKNOWN
3. RESIDENTIAL LOTS LESS THAN 5 ACRES ON POOR SOILS SHALL BE SERVED BY PUBLIC SANITARY SEWERS.	PARTIALLY MET	NOT MET
OBJECTIVE NO. 3		
STANDARD		
1. ALL LAKE WATER USES SHALL BE COMPATIBLE WITH RECREATION, FISHING, AND AESTHETIC USES	MET[a]	DIFFICULT TO MEET
2. LAKE WATER USES NOT ALLOWED	MET[a]	UNKNOWN
3. LAKE WATER QUALITY STANDARDS SHALL MEET STATE WATER QUALITY STANDARDS	MET[a]	DIFFICULT TO MEET
4. ALGAE AND WEEDS SHALL NOT CREATE A NUISANCE	MET[a]	NOT MET
OBJECTIVE NO. 4		
STANDARD		
1. RELATE GROUND WATER WITHDRAWAL RATES TO POTENTIAL YIELDS AND TOTAL DEMAND ON AQUIFER	MET	UNKNOWN
2. AVOID CONTAMINATION OF AQUIFER DURING WELL CONSTRUCTION AND OPERATION	MET	MET
3. PREVENT INFILTRATION OF CONTAMINANTS FROM WASTE DISPOSAL FACILITIES INTO SOURCES OF USABLE GROUND WATER	MET	DIFFICULT TO MEET

[a] THIS STANDARD HAS BEEN MET UNDER THE RECOMMENDED LAND USE PLAN BECAUSE IT SERVED AS AN INPUT TO THE PLAN DESIGN PROCESS.

[b] IF THE RECOMMENDATIONS CONTAINED IN THE SERIES OF LAKE USE REPORTS PREPARED UNDER THE MILWAUKEE RIVER WATERSHED STUDY ARE CARRIED OUT, 17 OF THE 21 MAJOR LAKES WOULD MEET THE STANDARD OF 10 PERCENT OF SHORE IN PUBLIC USE AND 15 OF THE 21 MAJOR LAKES WOULD MEET THE STANDARD OF 50 PERCENT OF SHORE IN NONURBAN USE.

[c] THIS STANDARD COULD BE MET ONLY BY LOCAL COMMUNITY ACTION.

[d] ONLY THAT WOODLAND COVER CONTAINED WITHIN THE PRIMARY ENVIRONMENTAL CORRIDORS WAS ASSUMED TO BE PRESERVED.

[e] THIS STANDARD HAS BEEN MET UNDER THE RECOMMENDED WATERSHED LAND USE PLAN BECAUSE ALL OF THE ENVIRONMENTAL CORRIDORS ARE PROPOSED TO BE PROTECTED AND PRESERVED.

SOURCE- SEWRPC.

would be acceptable only if the benefit-cost ratios of all other alternative plans, including allowances for intangible considerations, were found to be less than one. A comparative evaluation of the recommended comprehensive watershed plan with the unplanned alternative was made on the basis of the relative ability to meet established watershed development objectives and standards. This evaluation is presented in summary form in Table 121.

SUMMARY

This chapter has presented a description, comparison, and evaluation of the recommended comprehensive Milwaukee River watershed plan with the unplanned alternative. The recommended comprehensive watershed plan was designed specifically to meet established watershed development objectives, whereas the unplanned alternative was prepared to reflect one possible consequence of a continuation of existing development trends within the watershed in the absence of any attempt to guide such development on an areawide basis in the public interest. The recommended watershed plan best meets the adopted watershed development objectives and standards; and its implementation could be expected to provide a safer, more healthful, and more pleasant, as well as a more orderly and efficient, environment within the watershed. Implementation of the recommended watershed plan would abate many of the existing areawide development problems, would avoid the development of new problems, and would do much to protect and enhance the underlying and sustaining natural resource base.

The unplanned alternative would require the least amount of areawide effort toward regulation of development in the public interest and would require few restraints on the operation of the urban land market in determining the future character, intensity, and spatial distribution of land use development within the watershed. The unplanned alternative, however, could be expected to lead to a continued intensification of existing environmental problems within the watershed, including flooding and water pollution; could be expected to result in the almost total destruction of the natural resource base; and could be expected to result in a land use pattern which would be as disorderly and inefficient as it would be ugly. The need to protect the floodways and floodplains of the perennial stream system, the best remaining woodlands and wetlands, the best remaining wildlife habitat, and the best remaining agricultural areas would be ignored, as would the value of developing an integrated system of park and open-space areas centered on the primary environmental corridors of the Region. Failure to recognize these needs and values has, indeed, been the case within the watershed in the past, as attested to by growing environmental problems. Continuation of these past practices can only lead to the further deterioration and destruction of the natural resource base of the watershed, increasing costs for governmental facilities and sources, and a decline in the overall quality of life within the watershed.

(This page intentionally left blank)

Chapter IX

PLAN IMPLEMENTATION

INTRODUCTION

The recommended comprehensive plan for the Milwaukee River watershed, as described in Chapter VII of this report, provides a design for the attainment of the specific watershed development objectives formulated under the Milwaukee River watershed study in cooperation with the local, state, and federal units and agencies of government concerned. The final watershed plan emphasizes six main elements: 1) the regulation, in the public interest, not only of the use of private lands lying in areas subject to periodic flooding but also of the use of land and water throughout the entire watershed; 2) the public acquisition of certain riverine areas and other lands for the protection and preservation of the underlying and sustaining natural resource base of the watershed; 3) the provision of adequate park and related open-space sites and parkways and scenic drives to meet the growing demand within the watershed for outdoor recreation and related activities; 4) the institution of floodland land use controls to provide for the floodproofing of all existing major structures located in the floodplains of the watershed which are not subject to first-floor inundation by the 100-year recurrance interval flood and which lie between the 10- and 100-year recurrence interval flood inundation lines, together with the eventual voluntary removal of all existing structures located in the 10-year recurrence interval floodplains or in designated floodways of the watershed through the provision of nonconforming use provisions, supported by acquisition programs established by appropriate public agencies; 5) the construction of certain water pollution abatement facilities; and 6) the application of certain sound water supply development and management practices to protect the ground water supply. In a practical sense, the recommended watershed plan is not complete, however, until the steps required to implement the plan—that is, to convert the plan into action policies and programs—are specified.

This chapter is, therefore, presented as a guide for use in the implementation of the Milwaukee River watershed plan. Basically, it outlines the actions which must be taken by the various levels and agencies of government concerned if the recommended comprehensive watershed plan is to be fully carried out by the design year 1990. Those units and agencies of government which have plan adoption and plan implementation powers applicable to the Milwaukee River watershed plan are identified; necessary or desirable formal plan adoption actions specified; and specific implementation actions recommended with respect to the land use, natural resource protection, outdoor recreation, parkway and scenic drive, flood-damage prevention and abatement, water pollution abatement, and water supply plan elements to each of the units and agencies of government concerned. In addition, financial and technical assistance programs available to such units and agencies of government in the implementation of the watershed plan are discussed.

The plan implementation recommendations contained in this chapter are, to the maximum extent possible, based upon, and related to, existing governmental programs and are predicated upon existing enabling legislation. Because of the ever-present possibility of unforeseen changes in economic conditions, state and federal legislation, case law decisions, governmental organization, and tax and fiscal policies, it is not possible to declare once and for all time exactly how a process as complex as watershed plan implementation should be administered and financed. In the continuing regional planning program for southeastern Wisconsin, it will, therefore, be necessary to periodically update not only the watershed plan elements and the data and forecasts on which these plan elements are based, but also the recommendations contained herein for plan implementation.

BASIC CONCEPTS AND PRINCIPLES

It is important to recognize that plan implementation measures must not only grow out of formally adopted plans, but must also be based upon a full understanding of the findings and recommendations contained in those plans. Thus, action policies and programs must not only be preceded by formal plan adoption, and, following such adoption, must not only be consistent with the adopted plans, but should also emphasize implementation of the most important and essential elements of the comprehensive watershed plan and those areas of action which will have the greatest impact on guiding and shaping development in accordance with those elements. Of particular importance in this regard are those plan implementation efforts which are most directly related to achieving the basic watershed development objectives, especially those objectives relating to the protection of the underlying and sustaining natural resource base; with flood control and flood damage abatement; with water quality control and pollution abatement; and with the provision of an adequate supply of high quality water.

Natural Resource Protection

With respect to natural resource protection, watershed plan implementation will be largely achieved if: 1) future residential development within the watershed approximates the density and spatial distribution patterns recommended in the land use base element of the watershed plan; 2) all of the remaining undeveloped primary environmental corridor lands lying within the existing and probable future urban areas of the watershed and along the main stem of the Milwaukee River from Milwaukee to Kewaskum are publicly acquired for conservancy, outdoor recreation, and related open-space purposes; 3) certain additional high-value wetlands, high-value woodlands, and selected environmental corridors are publicy acquired for conservancy purposes; and 4) the proposed regional park sites are first reserved and then acquired for eventual public recreational use.

Flood Control

With respect to flood control and flood-damage abatement, watershed plan implementation will be largely achieved if: 1) the remaining undeveloped floodways and floodplains are kept in substantially open use throughout the watershed, either through floodland zoning and ultimate public acquisition of floodlands, as recommended in all existing and probable future urban areas and along the main stem of the Milwaukee River, or through effective floodland zoning in rural areas; 2) existing residences and other major structures located in the 10-year recurrence interval floodplains or designated floodways of the major flood-damage reaches within the watershed are gradually removed on a voluntary basis through the institution of land use controls resulting in a nonconforming use status for such uses; and 3) appropriate land use control measures are instituted to require adequate floodproofing of existing structures located in the floodplains of the already developed urban reaches of the watershed.

The importance to the entire Milwaukee River watershed plan of maintaining the primary environmental corridors and associated floodways and floodplains of the Milwaukee River system permanently in open uses and of not allowing further encroachment of urban land use development into such floodways and floodplains, such as has been allowed to occur in recent years in those reaches of the main stem of the Milwaukee River from Glendale through Saukville, cannot be overemphasized. Elimination of the existing natural valley storage and encroachment in the form of dumping, filling, and structure placement in the floodways and floodplains will inevitably destroy the present naturally regulated flood-flow characteristics of the Milwaukee River system and will result in increased flooding and flood damages within the watershed. Continued encroachment of urban development into the floodplains and floodways will also result in more vociferous public demands for the construction of flood control facilities, such as the Waubeka Reservoir and the Saukville diversion channel considered under the watershed study. It should be recognized by all concerned that, if urban encroachment is allowed to continue in the floodplains and floodways, thus increasing flood damages, and if the Waubeka reservoir site is not preserved in essentially open uses, future generations in the watershed will be left with no alternatives to flood-damage abatement except either floodland structure clearance or single-purpose diversion channel construction.

Water Pollution Abatement

With respect to stream water pollution abatement and water quality control, watershed plan implementation will be largely achieved if: 1) overflows from both the separate and combined sewers in the Milwaukee River watershed are controlled; 2) the specified levels of secondary, tertiary, and advanced waste treatment are provided at the major-municipal sewage treatment plants in the upper watershed; and 3) the pollutants contained in agricultural runoff are reduced through the institution of good soil and water conservation practices.

With respect to the lake water quality management plans, plan implementation will be largely achieved if: 1) new sanitary sewerage systems are established at Forest, Green, and Kettle Moraine Lakes; 2) sewer service for Big Cedar, Little Cedar, Silver, and Wallace Lakes is provided at the West Bend sewage treatment facility; 3) sewer service for Ellen Lake is provided at the proposed Village of Cascade sewage treatment facility; 4) sewer service for Random Lake is provided at the existing Random Lake sewage treatment facility; and if the pollutants contained in agricultural runoff are reduced through the institution of good soil and water conservation practices.

Water Supply

With respect to water supply, watershed plan implementation will be largely achieved if: 1) the plan recommendations concerning well locations and spacing for proper development of the shallow and deep aquifers underlying the watershed are followed; 2) a municipal water utility is established to serve the communities of Bayside and River Hills in Milwaukee County and Mequon and Thiensville in Ozaukee County, utilizing Lake Michigan as a source of water supply; and 3) municipal water supply systems are established in the urban communities of Waubeka, Jackson,[1] Newburg, and Cascade.

Concluding Comments—Basic Concepts and Principles

Primary emphasis in plan implementation, then, should be placed upon the following five aspects of watershed development: 1) the preservation in open uses, through a combination of public acquisition and public regulation, of the primary environmental corridors and associated floodways and floodplains of the entire Milwaukee River system; 2) the preservation, through public acquisition, of certain designated high-value park lands and high-value woodland or wetland areas; 3) the provision of the specified levels of secondary, tertiary, and advanced waste treatment at designated sewage treatment facilities throughout the watershed, together with abatement of the pollutional effects of the separate and combined sewer overflows in the lower watershed; 4) the institution of appropriate land use control measures to provide for floodproofing of structures located in floodplains and for eventual voluntary removal of structures located in floodways; and 5) the establishment of necessary public water supply systems.

There are three principal ways in which the necessary watershed plan implementation may be achieved; and these parallel the three functions of the Regional Planning Commission: inventory, or the collection, analysis, and dissemination of basic planning data on a uniform, areawide basis; plan design, or the preparation of a framework of long-range plans for the physical development of the Region; and plan implementation, or the provision of a center for the coordination of planning and plan implementation activities. All require at least a receptive attitude and preferably active planning and plan implementation programs at the local, county, and state levels of government.

A great deal can be achieved with respect to guiding watershed development into a more desirable pattern through the simple task of collecting, analyzing, and disseminating basic planning and engineering data on a continuing, uniform, areawide basis. Experience within the Southeastern Wisconsin Region to date has shown that, if this important inventory function is properly carried out, the resulting information will be used and acted upon both by local and state agencies of government and by private investors. Since such data were used as a primary input to the preparation of the Milwaukee River watershed plan, the utilization of these data in arriving at public and private decisions on a day-to-day basis will tend to contribute substantially toward implementation of the recommended watershed plan.

With respect to the function of plan preparation or design, it is essential that some of the watershed plan elements be carried into greater depth and detail for sound implementation. Specifically, the plan recommendations dealing with pollution abatement facilities must be carried through preliminary engineering to the final design stages. Further study must be given to the actual geographic limits of the public land acquisitions and land use controls necessary to protect adequately the primary environmental corridors and the high-value wetlands and woodlands. The preparation of such detailed plans will require the continuing development of very close working relationships between the Commission, the county boards concerned, the local units of government concerned, and certain special-purpose units or agencies of government and state agencies and, in particular, the Wisconsin Department of Natural Resources.

[1] *The Village of Jackson has already implemented this recommendation when, in October 1969, it began operation of a complete municipal water supply system.*

It will be highly desirable, although not absolutely essential, to achieve a high degree of watershed plan implementation through fulfillment of the Commission's function as a center for the coordination of local, areawide, state, and federal planning and plan implementation activities within the watershed. The community assistance program, through which the Commission upon request actively assists the local municipalities in the preparation of local plans and plan implementation devices, is an important factor in this respect and, if properly utilized, will make possible the full integration of watershed and local plans, adjusting the details of the latter to the broader framework of the former.

Under the provisions of recently enacted federal legislation and subsequent federal administrative determinations,[2] applications by state and local units of government for federal grants in partial support of the planning, acquisition of land for, and the construction of such public works facilities as sewerage and water supply systems, parks, waste treatment facilities, and soil and water conservation projects must be submitted to an officially designated areawide planning agency for review, comment, and recommendation before consideration by the administering federal agency. The comments and recommendations of the areawide planning agency must include information concerning the extent to which the proposed project is consistent with the comprehensive planning program for the Region, including, in southeastern Wisconsin, the Milwaukee River watershed planning program, and the extent to which such a project contributes to the fulfillment of such planning programs. The review comments and recommendations by the areawide planning agency are entirely advisory to the local, state, and federal agencies of government concerned and are intended to provide a basis for achieving the necessary coordination of public development programs in urbanizing regions of the United States on a voluntary, cooperative basis. If used properly, such review can be of material assistance in achieving implementation of the recommended Milwaukee River watershed plan.

In this respect, it should be noted that the Regional Planning Commission has formally adopted a policy statement on review of applications for federal grants-in-aid. This policy requires that adopted plan elements, such as a comprehensive watershed plan, form the basis for review and comment by the Commission. All projects that are the subject of applications are certified as being in conformance with and serving to implement, not in conflict with, or in conflict with, adopted regional plan elements.

Finally, it is extremely important that local public officials and concerned citizens recognize that the failure to implement any part of the recommended comprehensive watershed plan will proportionately lower the value of the watershed, not only in terms of providing a livelihood for its people, but also in terms of providing a pleasant, safe, and healthful place in which to live. In addition, it is essential that the state and federal implementing agencies recognize that the watersheds of southeastern Wisconsin, and in particular the Milwaukee River watershed, concern that part of the State of Wisconsin wherein reside the largest concentration of people, where the degree of natural resource base destruction has been the greatest, and where existing demands on the resource base are highest.

PLAN IMPLEMENTATION ORGANIZATIONS

Although the Regional Planning Commission can promote and encourage watershed plan implementation in various ways, as discussed above, the completely advisory role of the Commission makes actual implementation of the recommended Milwaukee River watershed plan entirely dependent upon action by certain local, areawide, state, and federal agencies of government. Examination of the various agencies that are available under existing enabling legislation to implement the recommended watershed plan reveals an array of departments, commissions, committees, boards, and districts at all levels of government. These agencies range from general-purpose local units of government, such as cities, villages, and towns, to special-purpose districts, suoh as metropolitan sewerage districts and flood control boards; to state regulatory bodies, such as the Wisconsin Department of Natural Resources; and to federal agencies that provide financial and technical assistance for plan implementation, such as the U. S. Soil Conservation Service.

---

[2] *Section 204 of the Demonstration Cities and Development Act of 1966; Title IV of the Intergovernmental Cooperation Act of 1968; and U. S. Office of Management and Budget Circular No. A-95 (Revised), dated February 9, 1971.*

Because of the many and varied agencies in existence, it becomes exceedingly important to identify those agencies having the legal authority and financial capability to most effectively implement the recommended watershed plan elements. Accordingly, those agencies whose action will have significant effect either directly or indirectly upon the successful implementation of the recommended comprehensive watershed plan and whose full cooperation in plan implementation will be essential are listed and discussed below.[3] The agencies are, for convenience, discussed by level of government; however, the interdependence between the various levels, as well as between agencies, of government and the need for close intergovernmental cooperation cannot be overemphasized. Most of the agencies needed for implementation of the recommended watershed plan are already in existence within the watershed. The creation of new agencies for watershed plan implementation should, therefore, be considered only if such agencies are absolutely essential; and, if essential, the creation of the new agencies should be in such form as to complement and supplement most effectively the plan implementation activities of the agencies already in existence.

Watershed Committee

Since planning at its best is a continuing function, a public body should remain on the scene to coordinate and advise on the execution of the watershed plan and to undertake plan updating and renovation as necessitated by changing events. Although the Regional Planning Commission is charged with and will perform this continuing areawide planning function, it cannot do so properly without the active participation and support of local governmental officials through an appropriate advisory committee structure. It is, therefore, recommended that the Milwaukee River Watershed Committee be reconstituted as a continuing intergovernmental advisory committee to provide a focus for the coordination of all levels of government in the execution of the Milwaukee River watershed plan. The Milwaukee River Watershed Committee would thus continue to be a creature of the Southeastern Wisconsin Regional Planning Commission, pursuant to Section 66.945(7) of the Wisconsin Statutes, and would report directly to the Commission. It is recommended that all agency representatives and individuals currently serving on the Milwaukee River Watershed Committee remain as members of the continuing committee and that the question of committee membership be left open so that additional members could be added to the Committee as appropriate.

Local Level Agencies

Statutory provisions exist for the creation at the county and municipal level of the following agencies having planning and plan implementation powers important to comprehensive watershed plan implementation, including police powers and acquisition, condemnation (eminent domain), and construction (tax appropriation) powers.

County Park and Planning Agencies: County units of government have a great deal of flexibility available in the creation of agencies to perform the park and outdoor recreation and zoning and planning functions within the county. Counties may create park commissions or park and planning commissions pursuant to Section 27.02 of the Wisconsin Statutes. In addition, counties may elect to utilize instead committees of the county board to perform the park and outdoor recreation and zoning and planning functions. The powers are essentially the same no matter how an individual county chooses to organize these functions. If, however, a county elects to establish a county park or county park and planning commission, these commissions have the obligation to prepare a county park system plan and a county street and highway system plan. There is no similar mandate for plan preparation when a county elects to handle these functions with committees of the county board.

The five counties comprising the Milwaukee River watershed have chosen to perform the park and outdoor recreation and planning and zoning functions in several different ways. In Milwaukee County there is a County Park Commission with full authority and responsibility for park and parkway acquisition, development, operation, and maintenance. Because Milwaukee County contains no unincorporated area, there is no county zoning authority. The Milwaukee County Park Commission, however, does perform a limited subdivision review function with respect to subdivision plats

---

[3] *A more detailed discussion of the duties and functions of local, areawide, and state agencies as they relate to plan implementation may be found in SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin--1966; SEWRPC Technical Report No. 6, Planning Law in Southeastern Wisconsin--1966; and SEWRPC Planning Guide No. 4, Organization of Planning Agencies--1964.*

lying in, or adjacent to, proposed park and parkway developments. Milwaukee County has also created a County Planning Commission to essentially perform a capital budgeting and programming function. This planning commission reviews all requests for capital improvements by Milwaukee County agencies.

In Ozaukee County responsibility for park and parkway acquisition, development, operation, and maintenance has been assigned to the Ozaukee County Park Commission. Recently, Ozaukee County, which has had up to the present a long history of nonparticipation in land use planning and development, preferring instead to leave that function at the town level of government, enacted a county shoreland and floodland zoning ordinance. This action was required by state legislation enacted in 1965 (Sections 59.971 and 87.30 of the Wisconsin Statutes) and the enactment of the county ordinance may well indicate the beginning of a new county attitude toward land use planning. Responsibility for the administration of this ordinance was assigned to a Zoning Committee of the County Board, and administration is carried out by the Ozaukee County Clerk.

Washington County created in 1967 a County Park and Planning Commission with full zoning, subdivision plat review, and park functions. In Fond du Lac County responsibility for park and parkway development and for planning and zoning rests with the Parks and Development Committee of the County Board. In Sheboygan County two county board committees share responsibility for the park and parkway and zoning and planning functions. The Parks, Property, and Aviation Committee has the primary responsibility for park land acquisition. The Resources Committee has full responsibility for the zoning and planning functions and for park development.

In addition to having the obligation to prepare a county park system plan and a county street and highway system plan, county park and planning commissions may be used to prepare and administer county shoreland, floodland, and comprehensive land use zoning ordinances and to administer county subdivision plat review. Such commissions are empowered to acquire, develop, and operate county parks and other open-space land. The existence of a county park and planning commission in each county in the watershed is, therefore, highly desirable for proper implementation of the recommended watershed plan, especially with respect to the natural resource protection, park and outdoor recreation, and general land use recommendations.

It is, therefore, recommended that the Ozaukee County Board of Supervisors consider the recreation and reconstitution of its existing park Commission, pursuant to Section 27.02 of the Wisconsin Statutes, assigning to it all duties relating to planning, zoning, subdivision plat review, sanitary codes, and modified official mapping, as well as the county park acquisition and development function. Such an Ozaukee County Park and Planning Commission would have, along with the existing Park Commission in Milwaukee County and the existing Park and Planning Commission in Washington County, primary responsibility for implementation of the land use, park and outdoor recreation, and natural resource protection plan elements of the Milwaukee River watershed plan within the Southeastern Wisconsin Region. A model ordinance creating a county park and planning commission may be found in SEWRPC Planning Guide No. 4, Organization of Local Planning Agencies, Appendix E. Sections 27.03(2), 27.06, and 59.97 of the Wisconsin Statutes provide for the staffing and financing of such commissions.

It is further recommended that the Fond du Lac and Sheboygan County Boards of Supervisors also consider the creation of park and planning commissions to consolidate the responsibility for implementation of the land use, park and outdoor recreation, and natural resource protection plan elements of the comprehensive Milwaukee River watershed plan. It should be noted that the creation of such commissions is not only essential to watershed plan implementation but represents a course of action thought to be highly desirable for implementation of other types of areawide, county, and local plans as well.

County Highway Committees: County highway committees of the county board are required in every county of Wisconsin pursuant to Section 83.015 of the Wisconsin Statutes. Each county highway committee is given the responsibility to lay out, construct, and maintain all county highways as authorized by the county board of supervisors. The county highway committees work in close cooperation with the Wisconsin Department of Transportation, Division of Highways. County highway committees in each of the five counties of the watershed can play an important role in implementation of the Milwaukee River watershed plan with respect to the construction and reconstruction of bridges and other highway facilities within the watershed and the designation and marking of a system of scenic drives throughout the Milwaukee River watershed.

Municipal Planning Agencies: Municipal planning agencies include city, village, and town park boards or plan commissions created pursuant to Sections 27.08, 27.13, 62.23(1), 61.35, and 60.18(12) of the Wisconsin Statutes. Such agencies may be used to supplement the actions of the county park and planning commissions or other county park and planning agencies in implementation of the various elements of the proposed Milwaukee River watershed plan. An extended discussion of the extent and limitations of the power of these agencies may be found in SEWRPC Planning Guide No. 4, Organization of Local Planning Agencies, 1964. It is recommended that those cities, villages, and towns in the Milwaukee River watershed without plan commissions duly created in accordance with Section 62.23 of the Wisconsin Statutes create such commissions. These included, as of January 1, 1971, the Villages of Campbellsport and Eden and the Towns of Ashford, Auburn, Byron, Eden, and Osceola in Fond du Lac County; the Village of Fredonia and the Town of Port Washington in Ozaukee County; the Villages of Adell and Random Lake and the Towns of Greenbush, Lyndon, Mitchell, Scott, and Sherman in Sheboygan County; and the Towns of Barton, Farmington, Kewaskum, Trenton, and West Bend in Washington County. A model ordinance and resolution creating such commissions and giving towns power to create such commissions is provided in the above-cited SEWRPC local planning guide, Appendices D and F.

Municipal Utility and Sanitary Districts: A municipal utility and sanitary district may be created by cities, villages, and towns pursuant to Sections 66.072, 60.30, 61.36, 62.18, and 198.22 of the Wisconsin Statutes and is authorized to plan, design, construct, operate, and maintain various public sanitary sewer and water supply systems. Such districts have an important plan implementation function to perform with respect to the water pollution abatement elements of the Milwaukee River watershed plan.

As of January 1, 1971, there were established the following six town sanitary districts in the watershed: Big Cedar Lake Sanitary District in the Towns of Polk and West Bend, Washington County; Little Cedar Lake Sanitary District in the Towns of Polk and West Bend, Washington County; Newburg Sanitary District in the Town of Trenton, Washington County; Sanitary District No. 1 (Lake Ellen area) in the Town of Lyndon, Sheboygan County; Silver Lake Sanitary District in the Town of West Bend, Washington County; and Wallace Lake Sanitary District in the Town of Trenton, Washington County.

Soil and Water Conservation Districts: The importance of proper soil and water conservation and management practices to the full implementation of the land use, natural resource protection, and water quality control elements of the Milwaukee River watershed plan cannot be overemphasized. Lack of such practices will have a critical adverse effect upon land use, water quality, drainage and flood control, and recreational pursuits within the watershed. Soil and water conservation districts, as authorized under Section 92.05 of the Wisconsin Statutes, have the authority to develop plans for the conservation of soil and water resources, prevention of soil erosion, and prevention of floods and the authority to request the county board of supervisors to adopt special land use regulations that would implement such plans in unincorporated areas. Such adoption, however, must follow a referendum in which two-thirds of the land occupiers approved the regulations.[4] Soil and water conservation districts have the authority to acquire through eminent domain any property or rights therein for watershed protection; soil and water conservation; flood prevention works; and fish and wildlife conservation and recreational works, all of which may be constructed under federal Public Law 83-566, as amended, as part of the watershed plan implementation program.

Soil and water conservation districts are by law in Wisconsin made geographically coterminus with counties, and all of the five counties in the Milwaukee River watershed concerned with implementation of the Milwaukee River watershed plan have created such districts. All of these districts have entered into basic and supplemental memoranda of understanding with the U. S. Department of Agriculture, Soil Conservation Service, for technical assistance. Thus, there exists within

[4] *Senate Bill 288 (1971), introduced into the Wisconsin Legislature on March 16, 1971, would remove the requirement that two-thirds of the land occupiers approve proposed regulations.*

the watershed the duly constituted bodies required to represent the counties of the watershed in those agricultural, conservation, and land management programs which are administered by state and federal agencies.

Harbor Commissions: The authority to develop and operate harbors and make harbor improvements is granted to every municipality in Wisconsin having navigable waters within or adjoining its boundaries by Section 30.30 through 30.38 of the Wisconsin Statutes. Such authority may be exercised directly by the governing body of the municipality or by a board of harbor commissioners created for that purpose. Under the authority, the boards of harbor commissioners are authorized to create or improve inner or outer harbor turning basins, slips, canals, and other waterways; to construct, maintain, or repair dock walls and shore protection walls; and to plan, construct, operate, and maintain docks, wharves, warehouses, piers, and related port facilities. Boards of harbor commissioners may also serve as a regulatory enforcement agency for the municipality with respect to dock wall construction and shoreline encroachment. The City of Milwaukee Common Council has created a Board of Harbor Commissioners to exercise such authority. The geographic jurisdiction of the Milwaukee Board of Harbor Commissioners implicitly extends along the Milwaukee River from the harbor entrance upstream to the Humboldt Avenue Brudge located just downstream from the North Avenue Dam.

Areawide Agencies

Except as noted below, statutory provisions exist for the creation of the following multi-county or other areawide agencies having both general and specific planning and plan implementation powers important to the implementation of the Milwaukee River watershed plan.

Metropolitan Sewerage Commissions: Until recently the Wisconsin Statutes provided for the creation of two types of metropolitan sewerage commissions generally empowered to plan sanitary sewerage and storm water drainage systems and to construct such systems over large areas which may include many local units of government. One type of commission is provided for in counties having a population of 500,000 or more and containing a city of the first class and is by definition at the present time applicable only to Milwaukee County. The other type of commission could, until recently, be formed by cities, villages, and towns in all other parts of Wisconsin. While these two types of commissions differ with respect to organization and method of financing, their basic powers are very similar (see Chapter XV, Volume 1, of this report). The Metropolitan Sewerage Commission of the County of Milwaukee, which operates and exists pursuant to the provisions of Section 59.96 of the Wisconsin Statutes, has the power to project, plan, and construct main sewers; pumping and temporary disposal works for the collection and transmission of house, industrial, and other sanitary sewage to and into the intercepting sewer system of the district; and may improve any watercourse within the district by deepening, widening, or otherwise changing the same where it may be necessary in order to carry off surface waters or drainage waters. The Metropolitan Sewerage Commission, however, may only exercise its powers outside the City of Milwaukee. The Sewerage Commission of the City of Milwaukee, on the other hand, may build treatment plants and build main and intercepting sewers and may improve watercourses in its area of operation, which is within the City of Milwaukee.

The second type of metropolitan sewerage district was, until recently, authorized under Sections 66.20 through 66.209 of the Wisconsin Statutes. Such metropolitan sewerage districts also have broad powers to plan, construct, and maintain intercepting and sanitary sewers, storm sewers, and sewage treatment plants similar to those granted to the Metropolitan Sewerage Commission of the County of Milwaukee. The future role of such metropolitan sewerage districts in watershed plan implementation, however, became clouded when, in 1969, the Wisconsin Supreme Court ruled that the Wisconsin Legislature, in providing for the creation of such metropolitan sewerage districts by county courts, had unconstitutionally delegated legislative authority to the judiciary.[5] Subsequent to this action by the Wisconsin Supreme Court, the Wisconsin Legislature provided curative legislative validating the existence of the three metropolitan sewerage districts previously established under those sections of the Wisconsin Statutes within the State of Wisconsin.[6] The Leg-

[5]*In re: petition for Fond du Lac Metropolitan Sewerage District, 42 Wis. 2nd 323 (1969).*

[6]*Chapter 132, Laws of Wisconsin, 1969. These three districts are the Madison Metropolitan Sewerage District, the Green Bay Metropolitan Sewerage District and the Western Racine County Sewerage District.*

islature, however, had not as yet provided any mechanism to make it possible to create new metropolitan sewerage districts or expand the districts now in existence.[7]

County Drainage Boards and Districts: Chapter 88 of the Wisconsin Statutes authorized landowners to petition the county court to create a drainage district under the control of the county drainage board. Such districts are intended to provide for the execution of specific areawide drainage improvements. A drainage district may lie in more than one municipality and in more than one county. The cost of any drainage improvements is assessed against the lands that are specifically benefited. As discussed in Chapter III of Volume 1 of this report, there are a total of eight legally established drainage districts in the Milwaukee River watershed. However, only one of these districts—the Jackson-Germantown Drainage District—remains active within the watershed.

Flood Control Boards: As discussed in more detail in Chapter XV of Volume 1 of this report, Chapter 87 of the Wisconsin Statutes makes provision for property owners living in a single drainage area to petition for the formation of a flood control board for the sole purpose of effecting flood control measures. Application for the creation of such a board must be made through the Wisconsin Department of Natural Resources, which Department has the responsibility for determining the need and engineering feasibility of the proposed flood control projects. The Milwaukee River watershed is unique in the Southeastern Wisconsin Region in that a Milwaukee River Flood Control Board has been created in the watershed under Chapter 87 of the Wisconsin Statutes. However, while the Board is officially in existence, only two of the three appointments to the Milwaukee River Flood Control Board have been made, with no member as yet certified to the Board by the Milwaukee County Board of Supervisors. The Milwaukee River Flood Control Board, never being fully constituted, has never met; and no proposed flood control projects have been undertaken.

Because the recommended flood control plan elements in the Milwaukee River watershed plan are nonstructural in nature and consist of land use regulations, floodproofing measures, and eventual voluntary removal of structures located in the floodways of the watershed, there is no role for the Milwaukee River Flood Control Board to play in watershed implementation. All of the nonstructural flood control elements can be accomplished by existing agencies and in particular by the county park and planning agencies and the municipal planning agencies. Should the Waubeka multiple-purpose reservoir be reconsidered and adopted in the future as a plan element, an areawide river basin authority or the Milwaukee River Flood Control Board could be assigned the responsibility for the design, construction, operation, and maintenance of such a reservoir.

Comprehensive River Basin District: One possibility for areawide flood control, water quality, and land use plan implementation is the creation of a special comprehensive river basin district embracing the entire watershed and capable of raising revenues through taxation and bonding; acquiring land; constructing and operating any necessary facilities; and otherwise dealing with the wide range of problems, alternatives, and projects inherent in comprehensive watershed planning. Such a district might be specifically charged in the enabling legislation by which it is created with carrying out the plans formulated under the Milwaukee River watershed study. Although enabling legislation to permit the creation of such districts has been proposed to the Wisconsin Legislature in the past and is currently pending,[8] such legislation has not, to date, been adopted, and thus is not presently available as a means of dealing with the watershed plan implementation problem. Should such legislation be adopted and should the Waubeka Reservoir ever be reconsidered and adopted in the future as a plan element, such an areawide river basin authority could be assigned the responsibility for the design, construction, operation, and maintenance of such a reservoir.

In addition, should the county and local units of government which are charged in this chapter with the responsibility for implementation of the natural resource protection, park and outdoor recreation, and water pollution abatement plan elements evidence a lack of interest in pursuing vigorously

---

[7] *Assembly Bill 836 (1971), introduced into the Wisconsin Legislature on May 5, 1971, would enable the creation of metropolitan sewerage districts by county boards of supervisors.*

[8] *Assembly Bill 312 (1971), introduced into the Wisconsin Legislature on February 16, 1971, represents the latest attempt to create enabling legislation authorizing river basin authorities.*

the necessary plan implementation actions, it is recommended that the Milwaukee River Watershed Committee consider recommending revising, and the Regional Planning Commission consider revising, the plan implementation recommendations to include pursuit of the creation of a comprehensive river basin district that could be given the authority to fully implement, in particular, the natural resource protection, park and outdoor recreation, and water pollution abatement plan elements, as well as the flood control plan elements. Such a comprehensive district or river basin authority could become the key agency to carry out the floodway clearance proposals as contained in the recommended flood control plan element.

Cooperative Contract Commissions: Section 66.30 of the Wisconsin Statutes provides that municipalities[9] may contract with each other to form cooperative service commissions for the joint provision of any services or joint exercise of any powers that such municipality may be authorized to exercise separately; and such commissions have been given bonding powers for the purposes of acquiring, developing, and equipping land, building, and facilities for areawide projects. Significant economies can often be effected through providing governmental services and facilities on a cooperative, areawide basis. Moreover, the nature of certain developmental and environmental problems often requires that solutions be approached on an areawide basis. Such an approach may be efficiently and economically provided through the use of a cooperative contract commission.

An excellent example of the use of the cooperative contract commission technique is the North Shore water utility, cooperatively established by contract between the City of Glendale and the Villages of Fox Point and Whitefish Bay in Milwaukee County for the purpose of providing municipal water supply service to the three communities, all or part of which lie within the Milwaukee River watershed.

Intergovernmental cooperation under such cooperative contract commissions may range from the sharing of expensive public works equipment through the construction, operation, and maintenance of major public works facilities on an areawide basis. A cooperative contract commission may be created for the purpose of watershed plan implementation and may be utilized in lieu of any of the aforementioned areawide organizations for such implementation. A model agreement creating a cooperative contract commission is provided in SEWRPC Technical Report No. 6, Planning Law in Southeastern Wisconsin, Appendix A.

Regional Planning Commission: Although not a plan implementation agency itself, one other areawide agency warrants comment, that is, the Regional Planning Commission. As already noted, the Commission has no statutory plan implementation powers. In its role as a coordinating agency for planning and development activities within the Southeastern Wisconsin Region, however, the Commission may, through community planning assistance services and through the review of federal and state grants-in-aid (using adopted plan elements as a basis for this review), play an extremely important role in plan implementation. In addition, the Commission provides a basis for the creation and continued functioning of the Milwaukee River Watershed Committee, which Committee should remain as an important continuing public planning organization in the watershed.

State Level Agencies

There exist at the state level the following agencies that either have general or specific planning authority and certain plan implementation powers important to the adoption and implementation of the comprehensive Milwaukee River watershed plan.

Wisconsin Department of Natural Resources: This Department has broad pertinent authority and responsibility in the areas of park development, natural resources protection, water quality control, and water regulation. As such, it combines the park development and land-based natural resource protection functions of the former State Conservation Commission and the water regulatory functions formerly assigned to the State Public Service Commission. The Department has the obligation to prepare a comprehensive statewide plan for outdoor recreation; to develop long-range, statewide conservation and water resource plans; the authority to designate such sites, as necessary, to protect, develop, and regulate the use of state parks, forests, fish, game, lakes, streams, certain plant life, and other outdoor

[9] *The term municipality under this section of the statutes is defined to include the state, any agency thereof, cities, villages, towns, counties, school districts, and regional planning commissions.*

resources; the authority to acquire conservation and scenic easements; and the authority to administer the federal grant program known as the Land and Water Conservation Fund within the state, as well as the park and open-space grant funds available under the State Outdoor Recreation Program (ORAP). The Secretary of the Department has, pursuant to federal planning guidelines, the responsibility of certifying to the U. S. Environmental Protection Agency (EPA) river basin, regional, and metropolitan plans for water quality management. Without such certification and subsequent acceptance by the EPA, local units of government within the watershed would lose their eligibility for federal grants in aid of the construction of sewerage facilities.

The Department also has the obligation to establish water quality standards and standards for floodplain and shoreland zoning and the authority to adopt, in the absence of satisfactory local action, shoreland and floodplain zoning ordinances, as well as the authority to prohibit the installation or use of on-site soil absorption sewage disposal systems and to approve the regulation of such systems as promulgated by the Wisconsin Division of Health. In addition, the Department has authority to regulate water diversions, shoreland grading, dredging, encroachments, and deposits in navigable waters; authority to regulate construction of neighboring ponds, lagoons, waterways, stream improvements, and pierhead and bulkhead lines; authority to regulate the construction, maintenance, and abandonment of dams; authority to regulate water levels of navigable lakes and streams and lake and stream improvements, including the removal of certain lake bed materials; and authority to require abatement of water pollution, to administer state financial aid programs for water resource protection, to assign priority for federal aid applications for sewage treatment plants, to review and approve water supply and sewerage systems, and to license well drillers and issue permits for high capacity wells. With such broad authority for the protection of the natural resources of the state and the Region, this Department will be extremely important to implementation of nearly all of the major elements of the comprehensive Milwaukee River watershed plan.

Wisconsin Department of Local Affairs and Development: This Department has limited authority to review subdivision plats; proposed municipal incorporations, consolidations, and annexations; and to provide technical assistance to local units of government in planning and planning-related matters.

Wisconsin Department of Transportation: This Department is broadly empowered to provide the state with an integrated transportation system. Within the Wisconsin Department of Transportation, the State Highway Commission is charged with the responsibility for administering all state and federal aid for highway improvement; for the planning, design, construction, and maintenance of all state highways; and for planning, laying out, revising, constructing, reconstructing, and maintaining the national interstate and defense highway system, the federal aid primary system, the federal aid secondary system, and the forest highway system, all subject to federal regulation and control. The State Highway Commission is also responsible for reviewing all county trunk highway systems. As such, the State Highway Commission, along with the respective County Highway Committees of the County Boards of Supervisors concerned, can play a role in full implementation of the Milwaukee River watershed plan with respect to the construction and reconstruction of bridges and other highway facilities within the watershed and the designation and marking of a system of scenic drives throughout the Milwaukee River watershed.

Wisconsin Department of Health and Social Services, Division of Health: This Division has the authority to review subdivision plats not served by public sanitary sewerage systems and to regulate private on-site soil absorption sewage disposal systems.

Wisconsin Soil Conservation Board: This Board has the obligation to review and to coordinate the programs of the County Soil and Water Conservation Districts; to apportion certain state and federal fund allotments; to administer federal watershed projects authorized under P. L. 566, as amended; and to approve federal participation in projects relating to the program responsibilities of county drainage boards, as set forth in Chapter 88 of the Wisconsin Statutes.

Federal Level Agencies

There exist at the federal level the following agencies which administer federal aid and assistance programs that can have important effects upon the implementation of the recommended Milwaukee River watershed plan because of the potential impact on the financing of both actual land acquisition and construction of specific facilities.

U. S. Department of Housing and Urban Development: This agency administers urban planning, flood insurance, urban beautification, park and open-space acquisition and development, and sewer and water facility construction grants. The park and open-space and sewer and water facility construction grant programs and the flood insurance program can be particularly important to implementation of the land use, outdoor recreation, flood control, and water quality control elements of the Milwaukee River watershed plan.

U. S. Environmental Protection Agency: This agency administers water quality management planning grants and sanitary sewage treatment plant and pollution control facility construction grants. The latter grants can be particularly important to implementation of the water quality control element of the Milwaukee River watershed plan. In addition, this agency is responsible for the ultimate enforcement of water quality standards on interstate waters, should the state not adequately enforce such standards. Under guidelines promulgated by this agency, river basin, regional, and metropolitan water quality management plans are required as a condition of the approval and award of federal grants-in-aid of the construction of sewerage facilities.

U. S. Department of the Interior, Bureau of Outdoor Recreation: This agency administers park and open-space acquisition and development grants through the Federal Land and Water Conservation Fund program. The program is administered in Wisconsin through the Wisconsin Department of Natural Resources. Grants under this program can be particularly important to implementation of the outdoor recreation and natural resource protection elements of the Milwaukee River watershed plan.

U. S. Department of the Interior, Geological Survey: This agency conducts continuing programs with respect to water resource appraisal and monitoring. The programs of the U. S. Geological Survey are particularly important to the implementation of the continuous stream gaging program recommended in the Milwaukee River watershed plan.

U. S. Department of Agriculture, Farmers Home Administration: This agency administers water and waste disposal construction grants and loans for rural areas, as well as resource conservation grants and loans. Such grants can be important to implementation of the water pollution control and water supply elements of the Milwaukee River watershed plan.

U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service: This agency administers park and recreation acquisition grants related to the conversion of land in agricultural use called GREENSPAN. In addition, this agency administers the Federal Rural Environmental Assistance Program (REAP), replacing the former Federal Agricultural Conservation Program (ACP). This program provides grants to rural landowners in partial support of carrying out approved soil, water, woodland, wildlife, and other conservation practices. These grants can be important to implementation of the water pollution control element of the Milwaukee River watershed plan.

U. S. Department of Agriculture, Soil Conservation Service: This agency administers resource conservation and development projects and watershed projects under federal P. L. 566 and provides technical and financial assistance through county soil and water conservation districts to landowners in the planning and construction of measures for land treatment, agricultural water management, and flood prevention and for public fish, wildlife, and recreational development. This agency also conducts detailed soil surveys and provides interpretations as a guide to utilizing soil survey data in local planning and development. Certain programs administered by this agency can be of particular importance to implementation of the agricultural land management and treatment measures, such as the construction of bench terraces, as recommended in the Milwaukee River watershed plan.

U. S. Department of the Army, Corps of Engineers: This agency has broad authority subject to U. S. Congressional approval to construct flood control facilities. While no structural flood control facilities are contained in the recommended Milwaukee River watershed plan, should the Waubeka Reservoir ever be incorporated into the plan, the Corps of Engineers could have a very important plan implementation role. Industries, under the provisions of the Federal Refuse Disposal Act of 1899, are required to obtain permits from the Corps of Engineers for any waste outfalls discharging to navigable waters.

PLAN ADOPTION AND INTEGRATION

Upon adoption of the Milwaukee River watershed plan by formal resolution of the Southeastern Wisconsin Regional Planning Commission, in accordance with Section 66.945(10) of the Wisconsin Statutes, the Commission will transmit a certified copy of the resolution adopting the watershed plan, together with the plan itself, to all local legislative bodies within the Milwaukee River watershed and to all of the aforesaid existing state, local, areawide, and federal agencies that have potential plan implementation functions.

Adoption, endorsement, or formal acknowledgement of the comprehensive watershed plan by the local legislative bodies and the existing local, areawide, state, and federal level agencies concerned is highly desirable not only to assure a common understanding between the several governmental levels and to enable their staffs to program the necessary implementation work but is, in some cases, required by the Wisconsin Statutes before certain planning actions can proceed, as in the case of city, village, and town plan commissions created pursuant to Section 62.23 of the Wisconsin Statutes. In addition, formal plan adoption may also be required for state and federal financial aid eligibility.

It is extremely important to understand that adoption of the recommended Milwaukee River watershed plan by any unit or agency of government pertains only to the statutory duties and function of the adopting agencies, and such adoption does not and cannot in any way preempt or commit action by another unit or agency of government acting within its own area of functional and geographic jurisdiction. Thus, adoption of the Milwaukee River watershed plan by a county would make the plan applicable as a guide, for example, to county park system development but not to any municipal park development within the County. To make the plan applicable as a guide to municipal park development would require its adoption by the municipality concerned.

Upon adoption or endorsement of the Milwaukee River watershed plan by a unit or agency of government, it is recommended that the policy-making body of the unit or agency direct its staff to review in detail the plan elements of the comprehensive watershed plan. Once such review is completed, the staff can propose to the policy-making body for its consideration and approval the steps necessary to fully integrate the watershed plan elements into the plans and programs of the unit or agency of government.

Local Level Agencies

1. It is recommended that the Milwaukee County Board formally adopt the comprehensive Milwaukee River watershed plan, including the land use elements, the natural resource protection elements, the park and outdoor recreation elements, the parkway and scenic drive elements, and the floodway evacuation element, by ordinance pursuant to Sections 27.04(2) and 66.945(12) of the Wisconsin Statutes after a report and recommendation by the County Park Commission, County Planning Commission, and County Highway Committee.

2. It is recommended that the Ozaukee County Board formally adopt the comprehensive Milwaukee River watershed plan, including the land use elements, the natural resource protection elements, the park and outdoor recreation elements, the scenic drive elements, the streamflow recordation element, and the floodway evacuation element, by ordinance pursuant to Sections 27.04(2) and 66.945(12) of the Wisconsin Statutes after a report and recommendation by the County Park Commission, the County Zoning Committee, and the County Highway Committee.

3. It is recommended that the Washington County Board formally adopt the comprehensive Milwaukee River watershed plan, including the land use elements, the natural resource protection elements, the park and outdoor recreation elements, the scenic drive element, the floodland evacuation element, and the streamflow recordation element, by ordinance pursuant to Sections 27.04(2) and 66.945(12) of the Wisconsin Statutes after a report by the County Park and Planning Commission and the County Highway Committee.

4. It is recommended that the Fond du Lac County Board formally adopt the comprehensive Milwaukee River watershed plan, including the land use elements, the natural resource protection elements, the park and outdoor recreation elements, the scenic drive element, and the streamflow recordation element, by ordinance pursuant to Section 27.04(2) of the Wisconsin Statutes after a report and recommendation by the County Parks and Development Committee.

5. It is recommended that the Sheboygan County Board formally adopt the comprehensive Milwaukee River watershed plan, including the land use elements, the natural resource protection elements, the park and outdoor recreation elements, and the scenic drive element, by ordinance pursuant to Section 27.04(2) of the Wisconsin Statutes after a report and recommendation by the County Parks, Property, and Aviation Committee; the County Resources Committee; and the County Highway Committee.

6. It is recommended that the Plan Commissions of all cities, villages, and towns in the watershed adopt the recommended Milwaukee River watershed plan, as it affects them, by resolution pursuant to Section 62.23(3)(b) of the Wisconsin Statutes and certify such adoption to their respective governing body.

7. It is recommended that the governing bodies of all municipal, water, and sanitary districts and utilities formally acknowledge the land use, natural resource protection, and water pollution abatement plan elements of the comprehensive Milwaukee River watershed plan and determine their utility service areas in accordance with such plan.

8. It is recommended that the County Soil and Water Conservation Districts of Milwaukee, Ozaukee, Washington, Fond du Lac, and Sheboygan Counties adopt those portions of the recommended Milwaukee River watershed plan affecting them, including the land use elements and the agricultural land treatment measures, so as to establish a broad, well-designed basis for the development of comprehensive conservation plans under Section 92.08(4) of the Wisconsin Statutes and to assist in establishing eligibility for tax relief and technical and financial assistance.

9. It is recommended that the Milwaukee Board of Harbor Commissioners endorse the recommended Milwaukee River watershed plan with respect to the flood control plan elements and in particular with respect to the establishment of policies regarding future bulkhead lines as they may encroach upon the floodway of the Lower Milwaukee River.

Areawide Agencies

1. It is recommended that the Metropolitan Sewerage Commission of the County of Milwaukee and the Sewerage Commission of the City of Milwaukee, acting jointly, adopt the recommended Milwaukee River watershed plan as such plan affects the work of those bodies, including the combined sewer overflow abatement plan element and the stream water quality management plan element, as such element recommends the connection of several industrial waste sources and the Thiensville sewer service area to the Milwaukee-metropolitan sewerage system.

2. It is recommended that the Fond du Lac, Milwaukee, Ozaukee, and Washington County Drainage Boards, as well as any other drainage board or district created within the watershed subsequent to the publication of this report, formally acknowledge the recommended Milwaukee River watershed plan, especially with respect to the land use elements, the natural resource protection elements, and the flood control elements.

3. It is recommended that any comprehensive river basin district or any cooperative contract agency or commission created within the watershed subsequent to the publication of this report formally acknowledge the recommended Milwaukee River watershed plan in regard to the exercise of their specific powers and duties.

State Level Agencies

1. It is recommended that the Wisconsin Natural Resources Board endorse the comprehensive Milwaukee River watershed plan,

certify the plan as an official river basin plan to the U. S. Environmental Protection Agency, and direct its staff in the Wisconsin Department of Natural Resources to integrate the recommended watershed plan elements into its broad range of agency responsibilities, as well as to assist in coordinating plan implementation activities over the next 20 years. In particular, it is recommended that the Natural Resources Board endorse the recommended environmental corridor protection plan elements and the regional recreational site plan elements, including the expansion of the existing Northern Unit of the Kettle Moraine State Forest to encompass the environmental corridor lands in the West Bend and Tri-Lakes areas of the watershed and the Lucas Lake multi-purpose recreational site, and direct its staff to integrate these plan elements into the long-range conservation and comprehensive outdoor recreation plans authorized by Section 23.09(7) of the Wisconsin Statutes and required by the Federal Land and Water Conservation Act.

It is further recommended that the Board, through its staff, coordinate the recommended Milwaukee River watershed plan with its activities relating to floodland and shoreland zoning. It is also recommended that the Board and its staff consider and give due weight to the recommended watershed plan in the exercise of their various water regulatory powers. It is further recommended that the Board adopt the detailed soils data and analyses prepared by the U. S. Soil Conservation Service as a guide in regulating soil absorption sewage disposal systems. Finally, it is recommended that the Board endorse the water pollution control plan recommendations of the Milwaukee River watershed plan and direct its staff to integrate these plan recommendations into its water quality control activities, including the issuance of amended pollution abatement orders to require local units of government to implement the recommendations contained in the Milwaukee River watershed plan.

2. It is recommended that the Wisconsin Department of Local Affairs and Development endorse the recommended Milwaukee River watershed plan and integrate the plan into its activities with respect to the provision of technical assistance to local units of government, with respect to reviewing subdivision plats, and with respect to administering federal urban planning grants.

3. It is recommended that the State Highway Commission of the Wisconsin Department of Transportation consider and give due weight to the recommended Milwaukee River watershed plan in the exercise of its various responsibilities governing the construction and reconstruction of highway facilities.

4. It is recommended that the Wisconsin Board of Health and Social Services endorse the land use elements and the water pollution control elements of the Milwaukee River watershed plan and direct its staff to follow the plan recommendations in the exercise of their subdivision plat review and approval powers created by Section 36.13(2)(m) of the Wisconsin Statutes. It is further recommended that the Board direct its staff to utilize the detailed soil survey prepared by the U. S. Department of Agriculture, Soil Conservation Service, as a guide in reviewing and objecting to subdivision plats, in accordance with Section 236.12 of the Wisconsin Statutes. It is further recommended that the Board adopt the detailed soils data and analyses as a guide in regulating soil absorption sewage disposal systems.

5. It is recommended that the Wisconsin Soil Conservation Board endorse the recommended Milwaukee River watershed plan, particularly the agricultural land use, environmental corridor preservation, and other natural resource protection plan elements, so as to coordinate the County Soil and Water Conservation District program and projects, as required in Section 92.04(4)(c) of the Wisconsin Statutes.

Federal Level Agencies

1. It is recommended that the U. S. Department of Housing and Urban Development formally acknowledge the Milwaukee River watershed plan and utilize such plan in its

administration and granting of federal aids for urban beautification, open-space land, park development, and sewer and water facilities and in the administration of its flood insurance program.

2. It is recommended that the U. S. Environmental Protection Agency formally accept the recommended Milwaukee River watershed plan upon State of Wisconsin certification, and utilize the plan recommendations in the administration and granting of federal aids for sewage treatment plants and related facilities.

3. It is recommended that the U. S. Department of the Interior, Bureau of Outdoor Recreation, formally acknowledge the Milwaukee River watershed plan and utilize the plan recommendations in its administration and granting of federal aids under the Land and Water Conservation Fund Act.

4. It is recommended that the U. S. Department of the Interior, Geological Survey, formally acknowledge the Milwaukee River watershed plan and continue, in cooperation with the various counties concerned, its entire water resources investigation program, including the maintenance and upgrading of its stream gaging program within the watershed.

5. It is recommended that the U. S. Department of Agriculture, Farmers Home Administration, formally acknowledge the Milwaukee River watershed plan and utilize the plan recommendations in its administration and granting of loans and grants-in-aid for rural water and waste disposal facilities and for watershed development programs.

6. It is recommended that the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, formally acknowledge the Milwaukee River watershed plan and utilize the plan recommendations in its administration of the cropland adjustment program and the rural environmental assistance program, with particular respect to the various agricultural land management measures and practices.

7. It is recommended that the U. S. Department of Agriculture, Soil Conservation Service, formally acknowledge the Milwaukee River watershed plan and utilize the plan recommendations in its administration and granting of federal aids for resource conservation and development and multiple-purpose watershed projects and in its provision of technical assistance to landowners and operators for land and water conservation practices.

8. It is recommended that the U. S. Department of the Army, Corps of Engineers, formally acknowledge the Milwaukee River watershed plan and resume and complete or terminate its suspended flood control study of the Milwaukee River watershed, giving due consideration and weight in the completion or termination of that study to the flood control recommendations contained in the comprehensive plan for the Milwaukee River watershed. If the Waubeka Reservoir should ever be reintroduced as a recommended plan element in the Milwaukee River watershed for flood control and other objectives, it is recommended that the Corps of Engineers cooperate with any local or state units and agencies of government in any requests for assistance in the construction of such a project.

SUBSEQUENT ADJUSTMENT OF THE PLAN

No plan can be permanent in all of its aspects or precise in all of its elements. The very definition and characteristics of areawide planning suggest that an areawide plan, such as a comprehensive watershed plan, to be viable and of use to local, state, and federal units and agencies of government, be continually adjusted through formal amendments, extensions, additions, and refinements to reflect changing conditions. The Wisconsin Legislature clearly foresaw this when it gave to regional planning commissions the power to "...amend, extend, or add to the master plan or carry any part or subject matter into greater detail..." in Section 66.945(9) of the Wisconsin Statutes.

Amendments, extensions, and additions to the Milwaukee River watershed plan will be forthcoming not only from the work of the Commission under the continuing regional planning programs but also from state agencies as they adjust and refine statewide plans and from federal agencies as national policies are established or modified or as new programs are created or as existing programs are expanded or curtailed. Adjustments must also come from local planning programs which, of necessity, must be prepared in greater detail and result in greater refinement of the watershed plan. This is particularly true with respect to the land use and natural resource protection elements of the watershed plan. Areawide adjustments may come from subsequent regional or state planning programs, which may include additional comprehensive or special-purpose planning efforts, such as the preparation of regional sanitary sewerage service plans, regional water supply plans, and regional or county park and open-space plans.

All of these adjustments and refinements will require the utmost cooperation by the local, areawide, state, and federal agencies of government, as well as coordination by the Southeastern Wisconsin Regional Planning Commission, which has been empowered under Section 66.945(8) of the Wisconsin Statutes to act as a coordinating agency for programs and activities of the local units of government. To achieve this coordination between local, state, and federal programs most effectively and efficiently and, therefore, to assure the timely adjustments of the watershed plan, it is recommended that all of the aforesaid state, areawide, and local agencies having various plan and plan implementation powers advise and transmit all subsequent planning studies, plan proposals and amendments, and plan implementation devices to the Southeastern Wisconsin Regional Planning Commission for consideration as to integration into, and adjustment of, the watershed plan. Of particular importance in this respect will be the continuing role of the Milwaukee River Watershed Committee in intergovernmental coordination.

LAND USE, NATURAL RESOURCE PROTECTION, PARK AND OUTDOOR RECREATION, AND PARKWAY AND SCENIC DRIVE PLAN ELEMENT IMPLEMENTATION

Introduction

The implementation of the land use, natural resource protection, park and outdoor recreation, and parkway and scenic drive plan elements of the comprehensive Milwaukee River watershed plan is of central importance to the realization of the overall watershed plan. These elements, moreover, require the most intricate implementation actions and the utmost cooperation between the local units of government and the areawide, state, and federal agencies concerned if the watershed development objectives are to be fully achieved. This is true not only because the land use, natural resource protection, park and outdoor recreation, and parkway and scenic drive plan elements are closely interrelated in nature and support and complement one another, but also because these elements are closely related to the flood control and water pollution abatement elements of the plan. If, for example, urban residential, commercial, and industrial growth is properly located within the watershed and is not allowed to further preempt the natural floodland areas or destroy the remaining wetlands and woodlands, a great deal will be achieved with respect to flood-damage control, as well as to natural resource protection. Similarly, if the recommended environmental corridors are protected and acquired for natural resource protection and conservancy purposes, this will, in turn, assure acquisition of many of the best park sites remaining within the watershed. Although all of the plan implementation recommendations are closely interrelated, this section has been divided, for convenience in presentation and use, into the following major subject areas: zoning, woodland and wetland management, land acquisition for natural resource protection, land acquisition for park and outdoor recreation, parkway development, and scenic drive designation.

Zoning Ordinances

Of all the land use plan implementation devices, the most readily available, most important, and most versatile is the application of the local police power to the control of land use development through the adoption of appropriate zoning ordinances, including zoning district regulations and zoning district delineations. The following zoning ordinances or amendments to existing zoning ordinances should be adopted by the appropriate county and local units of government within the watershed so as to provide a clear indication of the intent to implement the Milwaukee River watershed plan and thereby to provide a framework for other planning and plan implementation efforts.

1. It is recommended that the county zoning agencies of Fond du Lac, Ozaukee, Sheboygan, and Washington Counties, in coop-

eration with the town plan commissions and town zoning committees, formulate and recommend to their respective county board appropriate amendments to the county comprehensive and/or floodland and shoreland zoning ordinances, pursuant to Sections 59.97(3) and 59.971 of the Wisconsin Statutes, to provide district regulations, including exclusive agricultural use districts, and floodland and shoreland regulations similar to those provided in the SEWRPC Model Zoning Ordinance, together with changes to the zoning district maps, to implement the recommended watershed land use pattern. In particular, the county zoning agencies involved should carefully review the recently adopted county shoreland and floodland zoning regulations to determine if changes are in order to reflect the recommendations contained in the Milwaukee River watershed plan.

2. It is recommended that the county boards of Fond du Lac, Ozaukee, Sheboygan, and Washington Counties adopt appropriate amendments and changes to the zoning district maps, pursuant to Sections 59.97(3) and 59.971 of the Wisconsin Statutes, to provide district delineations, including floodplain and floodway regulatory areas, to implement the recommended watershed land use pattern. It is further recommended that the boards of all towns which have filed approval of the county zoning ordinance or which subsequently approve such a county zoning ordinance file a certified copy of the approval of such amendments and changes to the zoning district map, pursuant to Sections 59.97(2) and 59.97(3)(g) of the Wisconsin Statutes.

3. It is recommended that the plan commissions of all cities, villages, and those towns which have not filed approval of the county zoning ordinance formulate and recommend to their respective governing bodies new zoning ordinances or amendments to existing zoning ordinances in accordance with Section 60.74 or 62.23(7) of the Wisconsin Statutes so as to provide district regulations, including the exclusive use districts, and floodland and shoreland regulations similar to those provided in the SEWRPC Model Zoning Ordinance, together with appropriate zoning district map changes, to reflect the recommended watershed land use pattern.

4. It is recommended that the respective municipal governing bodies then adopt such zoning ordinances or amendments thereto, including such zoning district maps or changes thereto, pursuant to Section 60.74 or 62.23(7) of the Wisconsin Statutes. Zoning of lands in certain unincorporated areas should, as needs dictate, be supplemented jointly by the exercise of the extraterritorial zoning powers of the cities and villages with the towns, pursuant to Section 62. 23(7)(a) of the Wisconsin Statutes.

The task of delineating zoning district boundaries to reflect the land use plan recommendations in the comprehensive Milwaukee River watershed plan is as difficult as it is important. Proper delineation of the boundaries of the various zoning districts to achieve the land use pattern recommended in the watershed plan will require careful study and a thorough understanding not only of the local community plan recommendations by the local zoning agencies, but also of the watershed plan recommendations and their relationships to the local plans. In this process the primary environmental corridors must be broken down into several zoning districts as necessitated by the various types of natural resources found in such corridors. Moreover, the delineation of zoning districts to reflect immediately the recommended watershed land use plan would result initially in overzoning, which may, in turn, result in mixed and uneconomical future land use patterns. Therefore, the use of holding zones, such as exclusive agricultural districts, will be necessary to regulate community growth in both time and space in an orderly and economical manner.

The following recommendations are made to all zoning agencies within the watershed to assist them in the task of zoning ordinance preparation, including zoning district delineation.

<u>Residential Areas:</u> Not all of the areas shown as devoted to residential use in the recommended watershed land use plan should be initially placed in residential use districts. Only existing and platted, but not yet fully developed, residential areas and those areas that have immediate development potential and can be economically served by municipal utilities and facilities, such as sani-

tary sewer, public water supply, and schools, should be placed in exclusive residential districts related to the development densities indicated on the recommended watershed land use plan. The balance of the proposed future residential land use areas should be placed in exclusive agricultural districts so as to act as a holding zone for future development. The use of such holding districts is discussed in SEWRPC Planning Guide No. 3, Zoning Guide. Such holding districts should be rezoned into the appropriate residential zoning district or supporting land use district, such as business, neighborhood, or park districts, only when the community can economically and efficiently accommodate the proposed development. Certain residential areas may be initially zoned, as appropriate, for very low density "country estate" and related outdoor recreational uses. All residential zoning should be properly related to the inherent suitabilities of the underlying soil resource base.

Agricultural Areas: Areas shown as devoted primarily to agricultural use on the recommended watershed land use plan should usually be placed in an exclusive agricultural use district which essentially permits only agricultural uses. In such areas dwellings should be permitted only as accessory to the basic agricultural uses. Significant wetlands, woodlands, floodlands, and wildlife habitat areas that lie outside the delineated primary environmental corridor but within the agricultural use areas on the recommended watershed land use plan should be placed in conservancy districts.

Environmental Corridors: The environmental corridors shown on the recommended watershed land use plan should be placed immediately into one of several zoning districts, as dictated by consideration of existing development; the character of the specific resource values to be protected within the corridor; and the attainment of the outdoor recreation, open-space preservation, and resource conservation objectives of the watershed plan. Prime wildlife habitat areas, wetlands, woodlands, and undeveloped floodways and floodplains lying in the corridors should be placed in conservancy districts. Existing and potential park sites lying in the corridors should be placed in park districts which permit the development of appropriate private and public recreational facilities. The remaining area lying in the corridors may then be placed in exclusive agricultural use districts or in large estate-type residential use districts, depending upon the limitations of the soils for utilization of on-site disposal systems.

Other Outdoor Recreation Sites: The remaining outdoor recreation sites shown on the recommended watershed land use plan located outside the environmental corridors should be placed in exclusive agricultural, conservancy, or park districts so as to ensure preservation and availability for eventual public acquisition. It should be noted, however, that such zoning cannot be used in attempts to lower the land values of the parcels involved. Rather, such zoning should be used in an attempt to preserve the open character of the land, with public acquisition to occur at the determined fair market value within a reasonable period of time.

Floodlands: It is recommended that all counties, cities, villages, and towns within the watershed amend, as appropriate, their zoning ordinances to include special floodland regulations similar to those set forth in Appendix I of SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, as amended and improved through application in practice throughout the Southeastern Wisconsin Region. Such regulations, if properly adopted and enforced, will ensure the substantial maintenance in open uses of all undeveloped floodways and floodplains in the watershed. It should also be noted that such floodland regulations are required in addition to any basic zoning district regulations, such as agricultural districts, estate-type residential districts, park districts, and conservancy districts. Each county, city, and village in the watershed must, pursuant to Section 87.30 of the Wisconsin Statutes, formulate and adopt an effective and reasonable floodland zoning ordinance as soon as the necessary flood hazard data, such as that provided by the Milwaukee River watershed study, become available. Failing to do so may result in the Wisconsin Department of Natural Resources acting to exercise state floodplain zoning powers, pursuant to Section 87.30 of the Wisconsin Statutes. The adoption of floodland regulations in those communities having substantial amounts of urban development already in those communities having substantial amounts of urban development already in the floodlands will require special attention and should be so constructed as to carry out the flood abatement plan elements as discussed later in this chapter.

Shorelands: It is recommended that Fond du Lac, Ozaukee, Sheboygan, and Washington Counties review carefully their respective shoreland zoning regulations adopted pursuant to Section 59.971 of the Wisconsin Statutes, which regulations apply in unincorporated areas to all land lying within 1,000 feet of a lake, pond, or flowage and 300 feet from the bank of a river or stream or to the landward side of the floodplain, whichever is greater, to determine if changes are necessary to meet the land use development objectives contained in the comprehensive Milwaukee River watershed plan. A model of such special shoreland regulations has been set forth in Appendix I of SEWRPC Planning Guide No. 5 and has been amended and improved through application in practice throughout the Southeastern Wisconsin Region. The model ordinance seeks to regulate development in shoreland areas for the primary purpose of improving water quality. In this respect it should be noted that specific land use recommendations with respect to shoreland areas are available for all 19 major natural lakes in the Milwaukee River watershed in the series of lake use reports published under the Milwaukee River watershed planning program.[10]

Property Tax Policies: One of the valid criticisms often leveled against the use of exclusive agricultural and conservancy districts, as well as of restrictive floodland regulations, is that, in an urbanizing area, the assessed valuation of the restrictively zoned land may be so high as to reasonably preclude the maintenance of the land in predominantly rural uses. In addition, the mill rate applied to the assessed valuation is often rapidly rising in developing communities due to increased demands for urban services and, in particular, for school services. This is particularly true where communities have allowed substantially unregulated land development to occur, resulting in extensive urban sprawl. It is this kind of development that would be avoided if the watershed land use plan is implemented.

Section 70.32 of the Wisconsin Statutes directs local assessors to assess real estate at the full market value which could ordinarily be obtained at a private sale. Where such open lands are adjacent to, or within, a rapidly urbanizing area, and particularly so where poor land use regulations have permitted highly dispersed urban development, property tax assessments may reflect the public's sometimes exaggerated estimate of development potential. Even if the land is zoned for exclusive agricultural or conservancy use, the local assessor is allowed to, and commonly does, consider in the establishment of the market value of real property the reasonable probability of rezoning to permit more intensive use. Some lands zoned for agricultural or conservancy use realistically leave no potential for more intensive development, so that the market value and assessed value should both reflect that fact. Under present Wisconsin constitutional and statutory law, the most satisfactory way to relieve the owner of lands zoned for exclusive agricultural or conservancy use or for floodland use from the possibility of unrealistically high property assessment and resultant taxation where it exists is to remove the development potential. This may be accomplished in one of three ways:

1. The property owner may voluntarily grant an easement to a governmental unit, which easement would prohibit development for a period of at least 20 years;

2. The property owner may voluntarily place restrictive covenants upon the lands, which covenants would prohibit development and would be enforceable by a governmental unit in perpetuity or for some substantial time; or

3. A governmental unit may purchase the development rights.

All of these private or governmental actions will serve to permit and compel the local assessor to assess lands at their fair market value for agricultural, conservancy, and floodland uses rather than for potential urban uses. It is recommended that all cities, villages, and towns within the Milwaukee River watershed instruct their assessors that such potential tax relief exists for individual property owners upon their voluntary sale or relinquishment of potential development rights, where, in fact, the possibility of rezoning and development exist. It is further recommended that the Wisconsin Department of Revenue develop guidelines as to the extent to which assessments should be reduced if development potential is effectively removed in fact.

It is recognized that all of the three above methods of removing the immediate development potential represent techniques largely untried in the Southeastern Wisconsin Region, if not in the entire

[10] *Copies of all 19 lake use reports are available from the Commission Offices at a cost of $1.00 each.*

nation. At the present time, however, they represent the only satisfactory ways in which the inconsistencies between the Wisconsin taxing, land development, and open-space reservation policies can at least partially be overcome.[11] It is clear that the entire problem represented by premature land development and the effects of property taxation needs extensive study within Wisconsin. It is, therefore, recommended that the Wisconsin Department of Local Affairs and Development take the lead in initiating a legislative study designed to probe the inconsistencies now existing between property taxation and land development policies in Wisconsin and recommend changes to the State Legislature. Such a study should be conducted in cooperation with the Wisconsin Departments of Revenue, Administration, and Natural Resources, as well as local and county governments and concerned citizen groups, such as the Wisconsin Taxpayers Alliance. The study should review efforts by other states to overcome this property tax and land development problem and, in particular, the efforts being made in the States of New Jersey and California.[12]

[11] *For further discussion of this problem, see Chapter VI of SEWRPC Technical Report No. 6, Planning Law in Southeastern Wisconsin, 1966.*

[12] *In an attempt to at least partially resolve the property tax problems discussed in these paragraphs, several bills have recently been introduced in the Wisconsin Legislature. Senate Bill 58 (1971) would simply require all real property used for agriculture purposes to be classified for tax purposes as agriculture without regard to any effects on real value that changing land uses in the vicinity may have. Assembly Bill 225 (1971) also provides for the assessment of land utilized for agricultural or horticultural use on the basis of its value for such use rather than on the basis of its highest and best use value. This Bill provides for a "roll back tax" mechanism which would require a landowner converting agricultural land to nonagricultural use to pay the difference between his actual agriculturally based taxes and his full-value taxes over the past five years. This Bill further recognizes that a constitutional amendment would be necessary to provide for a nonuniform assessment of agricultural land. Assembly Bill 729 (1971) is aimed at providing tax relief for owners of land including significant wetland areas. This Bill provides for a permit procedure requiring those who wish to engage in any activity which may upset the ecological balance of a particular wetland to obtain a state permit. If a permit is denied, the landowner is eligible for local property tax relief of 50 percent; the state in turn would reimburse the local taxing jurisdiction for loss of revenues. Assembly Bill 847 (1971) is similar in concept to Assembly Bill 225 (1971), except that regional planning commissions are utilized to determine if a particular parcel of land should receive agricultural tax treatment.*

While the foregoing legislative proposals represent genuine efforts to resolve the conflict between property tax and land development policies in Wisconsin, enactment of any or all of these proposals should not preclude the conduct of the study recommended in the above paragraph.

Greenway Tax Law Proposal: The problems relating to the deterioration and destruction of woodlands within the watershed were discussed in Chapter XIII of Volume 1 of this report. In order to encourage private owners of woodlands to manage their stands on a balanced use and sustained yield basis and to provide an incentive for not changing the basic land use, it is recommended that the Wisconsin Department of Natural Resources take the lead in seeking the necessary state legislation to establish a new tax law program designed to provide for reduced property taxes on woodlands that are managed principally for aesthetic and scenic values, for wildlife conservancy, for limited production of forest products, and for watershed protection purposes.

This property tax law, which could be termed a "Greenway Tax Law," could be patterned after the existing Woodland Tax Law program. The principal feature of the proposed law would be to reduce the property tax rate on woodlands placed under the program in return for the property owners agreeing to undertake a sound woodland management program. Technical assistance in establishing the necessary management program could be provided by the Wisconsin Department of Natural Resources. The proposed law could also include a payment by the state to the local governments to help offset the reduced taxes. The law should also include a penalty clause for withdrawal of woodlands from the program.

Woodland and Wetland Management

The comprehensive Milwaukee River watershed plan includes recommendations for the institution on a large scale of sound woodland and wetland management practices in an effort to conserve and improve these important resources. Implementation of this plan element will largely depend on action by private landowners of woodland and wetland areas. Technical and financial assistance is available to qualified private landowners in such efforts. The Wisconsin Department of Natural Resources, Division of Forestry and Recreation, and Division of Fish, Game, and Enforcement, and the University Extension Service will provide to all landowners, upon request and at no cost, technical advice on woodland and wetland management. Many woodland and wetland management techniques and measures, such as tree planting, timber stand improvement, streambank protection, and establishment of wildlife cover, may be eligible for cost sharing through the Rural Environmental Assistance Program conducted by the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, in cooperation with local soil and water conservation districts, the U. S. Soil Conservation Service, the Wisconsin Department of Natural Resources, and the University Extension Service. Maximum use of such technical and financial assistance is essential to the implementation of this plan element.

Land Acquisition—Natural Resource Protection

The recommended Milwaukee River watershed plan places great emphasis upon the preservation, protection, and balanced use of the natural resource base, including the soils, surface and ground water, wetlands, woodlands, and wildlife habitat. Included in the plan are several recommendations for land acquisition to protect the natural resource base. These include the acquisition of all primary environmental corridors in those areas of the watershed designated in the plan to be developed for urban land uses by 1990; the acquisition of all other primary environmental corridors along the main stem of the Milwaukee River from Milwaukee to Kewaskum; the acquisition of selected remaining high-value wetland areas located in the primary environmental corridors; the acquisition of selected remaining high-value woodland areas located in the primary environmental corridors; and the acquisition of selected additional primary environmental corridor lands throughout the watershed. A schedule of land acquisition costs for implementation of the natural resource protection plan element is set forth in Table 122. It should again be stressed that important relationships exist between these land acquisition recommendations, which are intended primarily for natural resource protection purposes, and the park and outdoor recreation, flood control, pollution abatement, and water supply plan elements.

It is important to recognize that, while zoning is an extremely important land use plan implementation tool, the use of the police power to achieve plan implementation has some significant limitations from an equitable public policy, if not a legal, point of view. Questions relating to the confiscatory nature of the use of the police power inevitably arise when such power is extensively utilized for natural resource preservation objectives. Time and again attempts will be made by private landowners to convert their land to another use often through the filling of significant wetland areas and the clearing of significant woodland areas, which filling and clearing usually destroy the primary natural resource value of the land. Such attempts at land use conversion inevitably arise, particularly in areas undergoing rapid urbanization. Thus, local plan commissions and governing bodies are constantly faced with applications to convert land uses; to fill low-lying wetland areas; and to, in effect, destroy the natural resource base. From a public policy point of view, therefore, it seems essential to purchase for permanent preservation as much of the primary environmental corridor lands in the watershed as possible, not only to assure the permanent preservation and protection of these important remaining elements of the sustaining and underlying natural resource base but also to lend equity to the situation where landowners are faced with no real alternative uses for significant parcels of land, which parcels may, properly or improperly, be increasing in assessed valuation as development proceeds in the surrounding area.

Urban Environmental Corridors: It is recommended that Milwaukee, Ozaukee, Sheboygan, and Washington Counties, as well as the Wisconsin Department of Natural Resources, acquire, either through outright purchase of fee simple interests or through the purchase of development rights, all lands designated as primary environmental corridors which lie within, or adjacent to, areas of the watershed expected to become urban by 1990. In Milwaukee County it is recommended that the County Park Commission acquire those remaining undeveloped primary environmental corridor lands along the main stem of the Milwaukee River north to the Milwaukee-Ozaukee County line, totaling 248 acres. In Ozaukee County it is recommended that the County Park Commission acquire those urban environmental corridor lands located within the Cities of Cedarburg and Mequon; the Villages of Fredonia, Grafton, Saukville, and Thiensville; and the Towns of Cedarburg, Fredonia, Grafton, and Saukville, totaling 4,468 acres. In Washington County it is recommended that the County Park and Planning Commission acquire those urban corridors located in the Village of Kewaskum, the City of West Bend, and the Towns of Barton and Trenton and that the Wisconsin Department of Natural Resources

Table 122

SCHEDULE OF CAPITAL COSTS OF THE RECOMMENDED NATURAL RESOURCE PROTECTION PLAN ELEMENT OF THE MILWAUKEE RIVER WATERSHED PLAN BY COUNTY BY YEAR: 1971-1990

		Milwaukee County		Ozaukee County				
Calendar Year	Project Year	Urban Environmental Corridor[a] (County)	Total	Urban Environmental Corridor[a] (County)	High-Value Wetlands[b] (State)	Main Stem Environmental Corridor[c] (County)	Selected Additional Environmental Corridor[d] (County)	Total
1971	1	$ 124,000	$ 124,000	$ 893,600	$ 57,530	$ --	$ --	$ 951,130
1972	2	124,000	124,000	893,600	57,530	--	--	951,130
1973	3	124,000	124,000	893,600	57,530	--	--	951,130
1974	4	124,000	124,000	893,600	57,530	--	--	951,130
1975	5	124,000	124,000	893,600	57,530	--	--	951,130
1976	6	124,000	124,000	893,600	57,530	--	--	951,130
1977	7	124,000	124,000	893,600	57,530	--	--	951,130
1978	8	124,000	124,000	893,600	57,530	--	--	951,130
1979	9	124,000	124,000	893,600	57,530	--	--	951,130
1980	10	124,000	124,000	893,600	57,530	--	--	951,130
1981	11	--	--	--	57,530	62,860	83,000	203,390
1982	12	--	--	--	57,530	62,860	83,000	203,390
1983	13	--	--	--	57,530	62,860	83,000	203,390
1984	14	--	--	--	57,530	62,860	83,000	203,390
1985	15	--	--	--	57,530	62,860	83,000	203,390
1986	16	--	--	--	57,530	62,860	83,000	203,390
1987	17	--	--	--	57,530	62,860	83,000	203,390
1988	18	--	--	--	57,530	62,860	83,000	203,390
1989	19	--	--	--	57,530	62,860	83,000	203,390
1990	20	--	--	--	57,530	62,860	83,000	203,390
Total		$1,240,000	$1,240,000	$8,936,000	$1,150,600	$628,600	$830,000	$11,545,200
Annual Average		$ 62,000	$ 62,000	$ 446,800	$ 57,530	$ 31,430	$ 41,500	$ 577,260

		Washington County						Fond du Lac County			
Calendar Year	Project Year	Urban Environmental Corridor[a] (County-State)	High-Value Wetlands[b] (State)	High-Value Woodlands[e] (State)	Main Stem Environmental Corridor[c] (County)	Selected Additional Environmental Corridor[d] (County)	Total	High-Value Wetlands[b] (State)	High-Value Woodlands[e] (State)	Selected Additional Environmental Corridor[d] (County)	Total
1971	1	$ 806,600	$ 94,765	$ 6,160	$ --	$ --	$ 907,525	$ 80,335	$ 82,915	$ 54,750	$ 218,000
1972	2	806,600	94,765	6,160	--	--	907,525	80,335	82,915	54,750	218,000
1973	3	806,600	94,765	6,160	--	--	907,525	80,335	82,915	54,750	218,000
1974	4	806,600	94,765	6,160	--	--	907,525	80,335	82,915	54,750	218,000
1975	5	806,600	94,765	6,160	--	--	907,525	80,335	82,915	54,750	218,000
1976	6	806,600	94,765	6,160	--	--	907,525	80,335	82,915	54,750	218,000
1977	7	806,600	94,765	6,160	--	--	907,525	80,335	82,915	54,750	218,000
1978	8	806,600	94,765	6,160	--	--	907,525	80,335	82,915	54,750	218,000
1979	9	806,600	94,765	6,160	--	--	907,525	80,335	82,915	54,750	218,000
1980	10	806,600	94,765	6,160	--	--	907,525	80,335	82,915	54,750	218,000
1981	11	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
1982	12	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
1983	13	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
1984	14	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
1985	15	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
1986	16	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
1987	17	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
1988	18	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
1989	19	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
1990	20	--	94,765	6,160	176,540	93,700	371,165	80,335	82,915	54,750	218,000
Total		$8,066,000	$1,895,300	$123,200	$1,765,400	$937,000	$12,786,900	$1,606,700	$1,658,300	$1,095,000	$4,360,000
Annual Average		$ 403,300	$ 94,765	$ 6,160	$ 88,270	$ 46,850	$ 639,345	$ 80,335	$ 82,915	$ 54,750	$ 218,000

		Sheboygan County					Watershed Total					
Calendar Year	Project Year	Urban Environmental Corridor[a] (County)	High-Value Wetlands[b] (State)	High-Value Woodlands[e] (State)	Selected Additional Environmental Corridor[d] (County)	Total	Urban Environmental Corridor[a] (County-State)	High-Value Wetlands[b] (State)	High-Value Woodlands[e] (State)	Main Stem Environmental Corridor[c] (County)	Selected Additional Environmental Corridor[d] (County)	Total
1971	1	$ 219,600	$ 10,240	$ 29,960	$ --	$ 259,800	$ 2,043,800	$ 242,870	$ 119,035	$ --	$ 54,750	$ 2,460,455
1972	2	219,600	10,240	29,960	--	259,800	2,043,800	242,870	119,035	--	54,750	2,460,455
1973	3	219,600	10,240	29,960	--	259,800	2,043,800	242,870	119,035	--	54,750	2,460,455
1974	4	219,600	10,240	29,960	--	259,800	2,043,800	242,870	119,035	--	54,750	2,460,455
1975	5	219,600	10,240	29,960	--	259,800	2,043,800	242,870	119,035	--	54,750	2,460,455
1976	6	219,600	10,240	29,960	--	259,800	2,043,800	242,870	119,035	--	54,750	2,460,455
1977	7	219,600	10,240	29,960	--	259,800	2,043,800	242,870	119,035	--	54,750	2,460,455
1978	8	219,600	10,240	29,960	--	259,800	2,043,800	242,870	119,035	--	54,750	2,460,455
1979	9	219,600	10,240	29,960	--	259,800	2,043,800	242,870	119,035	--	54,750	2,460,455
1980	10	219,600	10,240	29,960	--	259,800	2,043,800	242,870	119,035	--	54,750	2,460,455
1981	11	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
1982	12	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
1983	13	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
1984	14	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
1985	15	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
1986	16	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
1987	17	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
1988	18	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
1989	19	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
1990	20	--	10,240	29,960	157,600	197,800	--	242,870	119,035	239,400	389,050	990,355
Total		$2,196,000	$204,800	$599,200	$1,576,000	$4,576,000	$20,438,000	$4,857,400	$2,380,700	$2,394,000	$4,438,000	$34,508,100
Annual Average		$ 109,800	$ 10,240	$ 29,960	$ 78,800	$ 228,800	$ 1,021,900	$ 242,870	$ 119,035	$ 119,700	$ 221,900	$ 1,725,405

[a] INCLUDES THE ACQUISITION IN MILWAUKEE COUNTY OF 248 ACRES AT AN ESTIMATED AVERAGE COST OF $5,000 PER ACRE; IN OZAUKEE COUNTY OF 4,468 ACRES, IN SHEBOYGAN COUNTY OF 1,098 ACRES, AND IN WASHINGTON COUNTY OF 4,033 ACRES, ALL AT AN ESTIMATED AVERAGE COST OF $2,000 PER ACRE.

[b] INCLUDES THE ACQUISITION IN FOND DU LAC COUNTY OF 5,470 ACRES, IN OZAUKEE COUNTY OF 4,112 ACRES, IN SHEBOYGAN COUNTY OF 775 ACRES, AND IN WASHINGTON COUNTY OF 5,683 ACRES, AT AN ESTIMATED AVERAGE COST OF $200 PER ACRE FOR WETLAND ACREAGE AND AT AN ESTIMATED AVERAGE COST OF $500 PER ACRE FOR ADJACENT OPEN LANDS.

[c] INCLUDES THE ACQUISITION IN OZAUKEE COUNTY OF 898 ACRES AND IN WASHINGTON COUNTY OF 2,522 ACRES, ALL AT AN ESTIMATED AVERAGE COST OF $700 PER ACRE.

[d] INCLUDES THE ACQUISITION IN FOND DU LAC COUNTY OF 2,190 ACRES, IN OZAUKEE COUNTY OF 1,660 ACRES, IN SHEBOYGAN COUNTY OF 3,152 ACRES, AND IN WASHINGTON COUNTY OF 1,874 ACRES, ALL AT AN AVERAGE ESTIMATED COST OF $500 PER ACRE.

[e] INCLUDES THE ACQUISITION IN FOND DU LAC COUNTY OF 2,369 ACRES, IN SHEBOYGAN COUNTY OF 856 ACRES, AND IN WASHINGTON COUNTY OF 176 ACRES, ALL AT AN ESTIMATED AVERAGE COST OF $700 PER ACRE.

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND SEWRPC.

acquire those urban environmental corridor lands located to the west and south of the City of West Bend in the Towns of Barton and West Bend and attach such acquisitions to the Northern Unit of the Kettle Moraine State Forest. The urban environmental corridor lands to be acquired within Washington County total 4,033 acres. In Sheboygan County it is recommended that the Resources Committee of the County Board acquire those urban environmental corridor lands in the Villages of Cascade and Random Lake and the Town of Lyndon, totaling 1,098 acres. It is further recommended that the cities, villages, and towns wherein urban environmental corridor land is located cooperate with the various county park agencies and the Wisconsin Department of Natural Resources in the acquisition of such environmental corridors by preserving such corridor lands in open-space use through appropriate zoning and official mapping, and, where feasible, through acquisition by dedication during the land subdivision and development process.

It is recommended that, because of the possible loss of such corridors to various forms of urban development, the above-designated urban corridors be reserved immediately and acquired as soon as possible. First priority in land acquisition, as recommended in the Milwaukee River watershed plan, should be given to the designated urban environmental corridors. In this connection purchase of less than fee interest of such corridor lands may be considerably cheaper and would result in more rapid preservation and proper use of the designated riverine areas. Such acquisition of less than fee interest may be in the form of scenic easement; conveyances of development rights to assure continuance of very low-density residential, private park, and related open-space uses; and grants of various public uses and development rights for construction and use of park and outdoor recreation facilities.

Milwaukee River Main Stem Corridors: It is recommended that Ozaukee and Washington Counties, together with the Wisconsin Department of Natural Resources, acquire those remaining primary environmental corridors outside the urban corridors lying along the main stem of the Milwaukee River. In Ozaukee County it is recommended that the Ozaukee County Park Commission acquire those remaining main stem corridors in the Towns of Saukville and Fredonia, totaling 898 acres. It is recommended that the Washington County Park and Planning Commission acquire those remaining main stem corridors located in the Town of Trenton and that the Wisconsin Department of Natural Resources acquire those remaining main stem corridors located in the Towns of Barton and Kewaskum and attach such lands to the Northern Unit of the Kettle Moraine State Forest. The remaining main stem corridor lands to be acquired within Washington County total 2,522 acres. The purchase for public use of these remaining main stem corridor lands, together with the purchase of the urban corridors, will result in eventual public ownership of the entire remaining undeveloped floodlands of the main stem of the Milwaukee River from Milwaukee through Kewaskum.

High-Value Wetlands: It is recommended that the Wisconsin Department of Natural Resources acquire those high resource value wetlands identified for public acquisition in the Milwaukee River watershed plan. Such acquisition, totaling 16,040 acres, would include acquisitions at the Jackson Marsh and Wayne Marsh areas in Washington County, the Cedarburg Bog and Huiras Lake areas in Ozaukee County, the Kettle Moraine Lake area in Fond du Lac County, and the Adell Swamp area in Sheboygan County.

High-Value Woodlands: It is recommended that the Wisconsin Department of Natural Resources acquire those high resource value woodlands identified for public acquisition in the Milwaukee River watershed plan. Such acquisition, totaling 3,401 acres, would include expansion of the existing Northern Unit of the Kettle Moraine State Forest in Fond du Lac, Sheboygan, and Washington Counties.

Selected Additional Environmental Corridors: It is recommended that Fond du Lac, Ozaukee, Sheboygan, and Washington Counties acquire, either through outright purchase of fee simple interest or through the purchase of development rights, all lands designated as selected additional primary environmental corridors in the comprehensive Milwaukee River watershed plan. In Ozaukee County it is recommended that the County Park Commission acquire those adiitional corridor lands designated in the recommended plan along Cedar Creek in the Town of Cedarburg and minor tributaries to the North Branch of the Milwaukee River in the Town of Fredonia, totaling 1,660 acres. In Washington County it is recommended that the County Park and Planning Commission acquire those selected additional environmental corridors located along Cedar Creek in the Town of Jackson; along the North Branch of the Milwaukee River in the Town of Farmington; and along the main stem of the Milwaukee River north of Kewaskum, totaling 1,874 acres. In Fond du Lac County it is recommended that the County Parks and Development Committee acquire those designated selected additional environmental corridors located along the main stem of the Milwaukee River in the Town of Auburn and along the West Branch of the Milwaukee River in the Town of Ashford, totaling 2,190 acres. In Sheboygan County it is recommended that the Resources Committee acquire those designated selected additional environmental corridor lands along the North Branch of the Milwaukee River in the Towns of Scott, Sherman, and Lyndon; along Silver Creek in the Town of Sherman; and along Melius Creek in the Town of Scott, totaling 3,152 acres. It is further recommended that the cities, villages, and towns wherein selected additional environmental corridor land is located cooperate with the various county park agencies in the acquisition of such corridors through preservation in open use by appropriate zoning and official mapping measures. It is further recommended that the acquisition of such selected additional environmental corridor lands primarily be programmed for the latter half of the 20-year plan implementation period.

Land Acquisition and Development for Park and Outdoor Recreation

The recommended Milwaukee River watershed plan, in addition to the above natural resource protection proposals, includes recommendations for regional park development and the public acquisition and development of certain high-value park sites. It should be noted that many of the recommended park and outdoor recreation sites lie within the environmental corridors recommended for acquisition under the natural resource protection plan element. Acquisition of these corridors, therefore, will ordinarily result in certain lands being acquired and, therefore, available for ultimate public park development. One new major regional park site is recommended for immediate public acquisition and full development within the 20-year plan implementation period. In addition, an existing regional park site is recommended to undergo a major expansion to provide for a multi-use capacity. Each of these two major park developments is discussed below. A schedule of capital costs by county for implementing the outdoor recreation element of the Milwaukee River watershed plan is set forth in Table 123.

Lucas Lake-Paradise Valley Park Site: It is recommended that the Washington County Park and Planning Commission develop the Lucas Lake-Paradise Valley park site as a major multiple-purpose outdoor recreation area. It is further recommended that if the Washington County Park and Planning Commission acts to acquire the park site, it also acts to acquire, in cooperation with the City of West Bend, the remaining urban environmental corridor lands located to the west of the City of West Bend and utilize such lands as part of a permanent urban park and open-space system in the West Bend area. If Washington County does not act within a period of one year after plan adoption to acquire the park site, it is recommended that the site be acquired and developed by the Wisconsin Department of Natural Resources as a third major state recreation area in the Northern Unit of the Kettle Moraine State Forest. The total site area for the proposed Lucas Lake-Paradise Valley Park, if developed as a state recreation area, is about 1,500 acres, including adjacent environmental corridor lands. Of this total, about 350 acres would actually be developed for active outdoor recreation purposes either as a state or county park facility.

Hawthorne Hills Park Site: It is recommended that the Ozaukee County Park Commission expand the existing Hawthorne Hills Park in the Town of Saukville. Such expansion would require the acquisition of 324 acres of land in addition to the 293 acres of land currently in public ownership. Land for this park site expansion would be acquired under the natural resource protection plan element.

Selected Additional High-Value Park Sites: It is recommended that the Fond du Lac, Ozaukee, Sheboygan, and Washington County park agencies acquire and develop, as demand dictates, additional high-value outdoor recreation sites for county parks, as indicated in the Milwaukee River watershed plan. Of the total of 18 recommended additional high-value outdoor recreation sites with a combined area of 4,449 acres, 17 having a combined area of 4,388 acres, contain 3,560 acres that are located in the primary environmental corridors recommended for acquisition in the natural resource protection plan element and would be acquired if that plan element were fully implemented.[13]

---

[13]*The estimated land acquisition costs set forth in Table 123 do not include the primary environmental corridor portions of the 17 sites located in the corridors.*

Table 123

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED OUTDOOR RECREATION PLAN ELEMENT OF THE MILWAUKEE RIVER WATERSHED PLAN BY COUNTY BY YEAR: 1971-1990

		MILWAUKEE COUNTY				OZAUKEE COUNTY			
CALENDAR YEAR	PROJECT YEAR	LAND ACQUISITION[a] (COUNTY)	PARK AND RECREATION FACILITY CONSTRUCTION[b] (COUNTY)	OPERATION AND MAINTENANCE[c] (COUNTY)	TOTAL	LAND ACQUISITION[a] (COUNTY-LOCAL)	PARK AND RECREATION FACILITY CONSTRUCTION[b] (COUNTY-LOCAL)	OPERATION AND MAINTENANCE[c] (COUNTY-LOCAL)	TOTAL
1971	1	$ 160,000	$ --	$ --	$ 160,000	$49,500	$ --	$ --	$ 49,500
1972	2	160,000	197,895	--	357,895	--	172,284	--	172,284
1973	3	160,000	197,895	8,400	366,295	--	172,284	8,188	180,472
1974	4	160,000	197,895	16,800	374,695	--	172,284	16,376	188,660
1975	5	160,000	197,895	25,200	383,095	--	172,284	24,564	196,848
1976	6	160,000	197,895	33,600	391,495	--	172,284	32,752	205,036
1977	7	160,000	197,895	42,000	399,895	--	172,284	40,940	213,224
1978	8	160,000	197,895	50,400	408,295	--	172,284	49,128	221,412
1979	9	160,000	197,895	58,800	416,695	--	172,284	57,316	229,600
1980	10	140,000	197,895	67,200	405,095	--	172,284	65,504	237,788
1981	11	--	197,895	75,600	273,495	--	288,488	73,692	362,180
1982	12	--	197,895	84,000	281,895	--	239,884	93,600	333,484
1983	13	--	197,895	92,400	290,295	--	239,884	113,508	353,392
1984	14	--	197,895	100,800	298,695	--	239,884	133,416	373,300
1985	15	--	197,895	109,200	307,095	--	239,884	153,324	393,208
1986	16	--	197,895	117,600	315,495	--	239,884	173,232	413,116
1987	17	--	197,895	126,000	323,895	--	239,884	193,140	433,024
1988	18	--	197,895	134,400	332,295	--	239,884	213,048	452,932
1989	19	--	197,895	142,800	340,695	--	239,884	232,956	472,840
1990	20	--	197,895	150,400	348,295	--	239,884	252,864	492,748
TOTAL		$1,580,000	$3,760,005	$1,435,600	$6,775,605	$49,500	$3,998,000	$1,927,548	$5,975,048
ANNUAL AVERAGE		$ 79,000	$ 188,000	$ 71,780	$ 338,780	$ 2,475	$ 133,267	$ 96,377	$ 298,752

		WASHINGTON COUNTY				FOND DU LAC COUNTY			
CALENDAR YEAR	PROJECT YEAR	LAND ACQUISITION[a] (COUNTY-LOCAL)	PARK AND RECREATION FACILITY CONSTRUCTION[b] (STATE-COUNTY-LOCAL)	OPERATION AND MAINTENANCE[c] (STATE-COUNTY-LOCAL)	TOTAL	LAND ACQUISITION[a] (COUNTY-LOCAL)	PARK AND RECREATION FACILITY CONSTRUCTION[b] (COUNTY-LOCAL)	OPERATION AND MAINTENANCE[c] (COUNTY-LOCAL)	TOTAL
1971	1	$ 26,850	$ --	$ --	$ 26,850	$ 13,500	$ --	$ --	$ 13,500
1972	2	26,850	81,447	--	108,297	13,500	27,890	--	41,390
1973	3	26,850	81,447	4,658	112,955	13,500	22,895	2,489	38,884
1974	4	26,850	81,447	9,316	117,613	13,500	22,895	4,978	41,373
1975	5	26,850	81,447	13,974	122,271	13,500	22,895	7,467	43,862
1976	6	26,850	81,447	18,632	126,929	13,500	22,895	9,956	46,351
1977	7	26,850	81,447	23,290	131,587	13,500	22,895	12,445	48,840
1978	8	26,850	81,447	27,948	136,245	13,500	22,895	14,934	51,329
1979	9	26,850	81,447	32,606	140,903	13,500	22,895	17,423	53,818
1980	10	26,850	81,447	37,264	145,561	13,500	22,895	19,912	56,307
1981	11	26,850	283,554	41,922	352,326	--	22,895	22,401	45,296
1982	12	26,850	231,047	66,790	324,687	--	22,895	24,890	47,785
1983	13	26,850	231,047	91,658	349,555	--	22,895	27,379	50,274
1984	14	26,850	231,047	116,526	374,423	--	22,895	29,868	52,763
1985	15	26,850	231,047	141,394	399,291	--	22,895	32,357	55,252
1986	16	26,850	231,047	166,262	424,159	--	22,895	34,846	57,741
1987	17	26,850	231,047	191,130	449,027	--	22,895	37,335	60,230
1988	18	26,850	231,047	215,998	473,895	--	22,895	39,824	62,719
1989	19	26,850	231,047	240,866	498,763	--	22,895	42,313	65,208
1990	20	26,850	231,047	265,734	523,631	--	22,895	44,802	67,697
TOTAL		$537,000	$3,096,000	$1,705,968	$5,338,968	$135,000	$440,000	$425,619	$1,000,619
ANNUAL AVERAGE		$ 26,850	$ 154,800	$ 85,298	$ 266,948	$ 6,750	$ 22,000	$ 21,281	$ 50,031

		SHEBOYGAN COUNTY				WATERSHED TOTAL			
CALENDAR YEAR	PROJECT YEAR	LAND ACQUISITION[a] (COUNTY-LOCAL)	PARK AND RECREATION FACILITY CONSTRUCTION[b] (COUNTY-LOCAL)	OPERATION AND MAINTENANCE[c] (COUNTY-LOCAL)	TOTAL	LAND ACQUISITION[a] (COUNTY-LOCAL)	PARK AND RECREATION FACILITY CONSTRUCTION[b] (STATE-COUNTY-LOCAL)	OPERATION AND MAINTENANCE[c] (STATE-COUNTY-LOCAL)	TOTAL
1971	1	$ 19,425	$ --	$ --	$ 19,425	$ 269,275	$ --	$ --	$ 269,275
1972	2	19,425	46,236	--	65,661	219,775	525,752	--	745,527
1973	3	19,425	46,236	4,474	70,135	219,775	520,757	28,209	768,741
1974	4	19,425	46,236	8,948	74,609	219,775	520,757	56,418	796,950
1975	5	19,425	46,236	13,422	79,083	219,775	520,757	84,627	825,159
1976	6	19,425	46,236	17,896	83,557	219,775	520,757	112,836	853,368
1977	7	19,425	46,236	22,370	88,031	219,775	520,757	141,045	881,577
1978	8	19,425	46,236	26,844	92,505	219,775	520,757	169,254	909,786
1979	9	19,425	46,236	31,318	96,979	219,775	520,757	197,463	937,995
1980	10	19,425	46,236	35,792	101,453	199,775	520,757	225,672	946,204
1981	11	19,425	46,252	40,266	105,943	46,275	839,084	253,881	1,139,240
1982	12	19,425	43,736	44,740	107,901	46,275	735,457	314,020	1,095,752
1983	13	19,425	43,736	49,214	112,375	46,275	735,457	374,159	1,155,891
1984	14	19,425	43,736	53,688	116,849	46,275	735,457	434,298	1,216,030
1985	15	19,425	43,736	58,162	121,323	46,275	735,457	494,437	1,276,169
1986	16	19,425	43,736	62,636	125,797	46,275	735,457	554,576	1,336,308
1987	17	19,425	43,736	67,110	130,271	46,275	735,457	614,715	1,396,447
1988	18	19,425	43,736	71,584	134,745	46,275	735,457	674,854	1,456,586
1989	19	19,425	43,736	76,058	139,219	46,275	735,457	734,993	1,516,725
1990	20	19,425	43,736	80,532	143,693	46,275	735,457	794,332	1,576,064
TOTAL		$388,500	$856,000	$765,054	$2,009,554	$2,690,000	$12,150,005	$6,259,789	$21,099,794
ANNUAL AVERAGE		$ 19,425	$ 42,800	$ 38,253	$ 100,478	$ 134,500	$ 607,500	$ 312,989	$ 1,054,990

[a] INCLUDES THE ACQUISITION IN MILWAUKEE COUNTY OF 316 ACRES OF LOCAL PARK LAND AT AN AVERAGE ESTIMATED COST OF $5,000 PER ACRE; IN OZAUKEE COUNTY OF 99 ACRES OF ADDITIONAL HIGH-VALUE PARK LAND, IN WASHINGTON COUNTY OF 1,074 ACRES OF ADDITIONAL HIGH-VALUE PARK LAND, IN FOND DU LAC COUNTY OF 270 ACRES OF ADDITIONAL HIGH-VALUE PARK LAND, AND IN SHEBOYGAN COUNTY OF 777 ACRES OF ADDITIONAL HIGH-VALUE PARK LAND, ALL AT AN AVERAGE ESTIMATED COST OF $500 PER ACRE.

[b] INCLUDES THE DEVELOPMENT IN OZAUKEE COUNTY OF 324 ACRES OF REGIONAL PARK LAND AND IN WASHINGTON COUNTY OF 350 ACRES OF REGIONAL PARK LAND ALL AT AN ESTIMATED COST OF $1,500 PER ACRE, AND THE DEVELOPMENT IN MILWAUKEE COUNTY OF 752 ACRES OF NEIGHBORHOOD PARKS, IN OZAUKEE COUNTY OF 470 ACRES OF NEIGHBORHOOD PARKS AND 1,162 ACRES OF COMMUNITY PARKS, IN WASHINGTON COUNTY OF 110 ACRES OF NEIGHBORHOOD PARKS AND 2,021 ACRES OF COMMUNITY PARKS, IN FOND DU LAC COUNTY OF 1 ACRE OF NEIGHBORHOOD PARK AND 435 ACRES OF COMMUNITY PARKS, IN SHEBOYGAN COUNTY OF 5 ACRES OF LOCAL PARKS AND 831 ACRES OF COMMUNITY PARKS, ALL AT AN ESTIMATED AVERAGE COST OF $5,000 PER ACRE FOR NEIGHBORHOOD PARKS AND $1,000 PER ACRE FOR COMMUNITY PARKS. NO DEVELOPMENT COSTS HAVE BEEN ASSIGNED TO THE ADDITIONAL HIGH-VALUE PARK SITES RECOMMENDED TO BE ACQUIRED UNDER THE OPTIMUM OUTDOOR RECREATION PLAN. IT WAS ASSUMED THAT DEVELOPMENT OF THESE SITES WOULD BE DEFERRED UNTIL AFTER THE INITIAL 20-YEAR PLAN IMPLEMENTATION PERIOD.

[c] BASED ON ESTIMATED AVERAGE COSTS OF $100 PER ACRE OF DEVELOPED REGIONAL PARK LAND AND $200 PER ACRE OF DEVELOPED NEIGHBORHOOD OR COMMUNITY PARK LAND.

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND SEWRPC.

Other Additional High-Value Outdoor Recreation Sites: It is recommended that the county park agencies or the cities, villages, and towns concerned acquire and develop, as the demand dictates, the 22 additional recommended local potential park sites in the watershed. Of these 22 sites, 20 would be acquired if the recommended environmental corridor acquisition under the natural resource protection plan element of the Milwaukee River watershed plan is fully carried out. In some cases these additional potential outdoor recreation sites would make logical additions to existing county park systems; in other cases these sites would more appropriately make additions to existing city, village, or town park systems. The local units of government involved in the acquisition of these other additional potential outdoor recreation sites are: the City of Mequon and the Towns of Cedarburg, Fredonia, Grafton, and Saukville in Ozaukee County; the Towns of Farmington, Polk, Trenton, and West Bend in Washington County; the Towns of Auburn and Osceola in Fond du Lac County; and the Towns of Scott and Sherman in Sheboygan County. Acquisition of these other outdoor recreation sites would total 4,423 acres, of which 3,092 acres are located within the primary environmental corridors.[14]

Private Park Development: The foregoing outdoor recreation land acquisition and development recommendations provide for meeting the entire anticipated outdoor recreation demand through public action. It is, however, fully recognized that private recreation development has been and will continue to play an important role in meeting outdoor recreation demand within the Milwaukee River watershed. The future extent of such private outdoor recreation development cannot, however, be reliably forecast. It is known that, at the present time, about 13 percent of the developed recreation land in the watershed devoted to the five major outdoor recreation acitivities upon which the 1990 forecast demand for outdoor recreation land is based is in private ownership and operation. This level of private activity may continue in the future. To the extent that it does, it will reduce the need to publicly acquire and develop the park and related open-space land.

Park Land Preservation: It is not economically desirable or financially feasible to acquire all of the aforementioned recommended park lands and natural resource environmental corridor lands immediately. Certain police powers that are available to local units of government should, therefore, be used to protect from development those areas recommended for eventual public acquisition. In addition to preserving those natural resource areas and park lands recommended to be eventually acquired by the use of exclusive agricultural, conservancy, and park districts under zoning ordinances and by sound floodland zoning regulations, the official mapping powers possessed by local units of government should also be utilized for this purpose. Such powers, as well as recommended mapping survey procedures, are shown in SEWRPC Planning Guide No. 2, Official Mapping Guide, 1964.

It is, therefore, recommended that all affected cities, villages, and towns in the watershed prepare and adopt, pursuant to Section 62.23(6) of the Wisconsin Statutes, official maps showing thereon as park sites all park sites and as parkways all corridors recommended for acquisition in the Milwaukee River watershed plan. Such official maps should be prepared for both the area encompassed within the corporate limits of the municipalities and the area within the extraterritorial subdivision plat approval jurisdictional area and should be adopted by an ordinance similar to that set forth in Appendix A of SEWRPC Planning Guide No. 2, Official Mapping Guide.

Milwaukee River Parkway Pleasure Drive

It is recommended that the Milwaukee County Park Commission construct and maintain the recommended Milwaukee River parkway pleasure drive from Lincoln Memorial Drive near the McKinley Marina to and along the Milwaukee River valley to a junction with the existing Estabrook Parkway Drive at Capitol Drive. This new segment of parkway drive should be constructed along standards similar to those utilized by the Milwaukee County Park Commission on its other parkway pleasure drives. The total cost of constructing the proposed parkway pleasure drive extension is estimated at $576,000 (see Table 124). Completion of this parkway pleasure drive will provide an important link between the lakefront and the existing Estabrook Park and Milwaukee River Parkway Drives and will provide for a continuous parkway pleasure drive facility from the lakefront to Good Hope Road. Construction of this parkway pleasure drive and appurtenant parkland facilities would serve to implement recommendations made by the Milwaukee River Technical Study Committee for upper river park development.

[14] *The estimated land acquisition costs set forth in Table 123 do not include the primary environmental corridor portions of the 20 sites located in the corridors.*

Table 124

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED PARKWAY AND SCENIC DRIVE PLAN ELEMENT OF THE MILWAUKEE RIVER WATERSHED PLAN BY COUNTY BY YEAR: 1971-1990

CALENDAR YEAR	PROJECT YEAR	PARKWAY PLEASURE DRIVE MILWAUKEE COUNTY			PRIMARY AND SECONDARY SCENIC DRIVE--SIGNING AND MARKING[c]						PARKWAY AND SCENIC DRIVE TOTAL
		ROADWAY FACILITY CONSTRUCTION[a]	PARKWAY MAINTENANCE[b]	TOTAL	MILWAUKEE COUNTY	OZAUKEE COUNTY	WASHINGTON COUNTY	FOND DU LAC COUNTY	SHEBOYGAN COUNTY	TOTAL	
1971	1	$ --	$ --	$ --	$--	$ --	$ --	$ --	$ --	$ --	$ --
1972	2	--	--	--	--	384	283	212	126	1,005	1,005
1973	3	--	--	--	--	384	283	212	126	1,005	1,005
1974	4	--	--	--	--	384	283	212	126	1,005	1,005
1975	5	--	--	--	--	384	283	212	126	1,005	1,005
1976	6	--	--	--	--	384	283	212	126	1,005	1,005
1977	7	--	--	--	--	384	281	212	126	1,003	1,003
1978	8	--	--	--	--	--	--	--	--	--	--
1979	9	--	--	--	--	--	--	--	--	--	--
1980	10	115,200	--	115,200	60	--	--	--	--	60	115,260
1981	11	115,200	2,304	117,504	60	--	--	--	--	60	117,564
1982	12	115,200	4,608	119,808	--	--	--	--	--	--	119,808
1983	13	115,200	6,912	122,112	--	--	--	--	--	--	122,112
1984	14	115,200	9,216	124,416	--	--	--	--	--	--	124,416
1985	15	--	11,520	11,520	--	--	--	--	--	--	11,520
1986	16	--	11,520	11,520	--	--	--	--	--	--	11,520
1987	17	--	11,520	11,520	--	--	--	--	--	--	11,520
1988	18	--	11,520	11,520	--	384	283	212	126	1,005	12,525
1989	19	--	11,520	11,520	--	384	283	212	126	1,005	12,525
1990	20	--	11,520	11,520	60	384	283	212	126	1,065	12,585
TOTAL		$576,000	$92,160	$668,160	$180	$3,456	$2,545	$1,908	$1,134	$9,223	$677,383
ANNUAL AVERAGE		$ 28,800	$ 4,608	$ 33,408	$ 9	$ 173	$ 127	$ 95	$ 57	$ 461	$ 33,869

[a]ASSUMES 0.48 MILE OF PARKWAY COMPLETED PER YEAR AT $240,000 PER MILE.

[b]BASED ON MAINTENANCE COSTS OF $4,800 PER MILE OF NEWLY COMPLETED PARKWAY.

[c]ASSUMES THE INSTALLATION OF TWO SIGNS PER MILE AT $20 PER SIGN FOR THE FIRST SIX YEARS AND 50 PERCENT REPLACEMENT OF SIGNS AFTER 10 YEARS.

SOURCE- SEWRPC.

Milwaukee River Scenic Drives

It is recommended that the county highway committees of Fond du Lac, Milwaukee, Ozaukee, Sheboygan and Washington Counties, together with the Wisconsin Department of Transportation, coordinate the establishment over existing state, county, and local streets and highways of the recommended system of Milwaukee River scenic drives. It is anticipated that the establishment of this scenic drive system will consist primarily of the design, preparation, and placement of appropriate signs identifying the scenic drive route along its total 153-mile length, an effort similar in nature to the marking of the existing Kettle Moraine Scenic Drive. The total estimated cost of signing and marking the scenic drive system in the Milwaukee River watershed over the next 20 years is $9,223 (see Table 124).

FLOOD CONTROL PLAN ELEMENT IMPLEMENTATION

The major flood abatement recommendation contained in the Milwaukee River watershed plan is the institution of sound floodland zoning regulations throughout the watershed and the acquisition for public park and open-space use of all of the undeveloped floodlands of the main stem of the Milwaukee River. These basic land use recommendations are supported by certain flood control plan elements, including floodland land use controls, floodway clearance, flood insurance, bridge construction, streamflow recordation, reservoir land protection, floodway encroachment-bulkhead line establishment, and dam investigation.

Floodland Land Use Controls

It is recommended that all counties, cities, villages, and towns within the watershed amend, as appropriate, their zoning ordinances to include special floodland regulations similar to those set forth in Appendix I of SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide. Such regulations can take the shape of overlay regulations or, in the alternative, can comprise special floodway and floodplain zoning districts. Either of these two basic approaches can be utilized to assure that the basic objective of floodland zoning is achieved; namely, the reservation in essentially open uses of the floodway and floodplain lands. The essence of such floodland zoning would be to prohibit further urban development in the floodway[15] and regulate urban development in the floodplain so as to reduce the flood hazard and preserve the existing floodwater storage capacity. In this connection it is important to recognize that the watershed plan recommends public acquisition of such undeveloped floodways and floodplains throughout the urban areas of the watershed and along the entire main stem of the Milwaukee River from Milwaukee to Kewaskum. It is recognized that zoning alone may be sufficient in most instances to achieve the basic objective of maintaining in open-space uses the necessary floodways and floodplains. From a long-range public policy point of view, however, it is considered more sound to eventually purchase for permanent public preservation and protection all such undeveloped floodway and floodplain lands, particularly in urbanizing areas. Not only will the public agencies avoid troublesome attempts to seek permission to fill and utilize floodplain lands, such as low-lying wetlands, but also the public acquisition of such lands will provide for future park lands. In addition, proper maintenance of such lands can be assured. The soundness of a long-range policy of purchasing riverine lands has been long demonstrated in Milwaukee County, where public parkway development has provided a focus for high-value adjacent residential development.

In addition to the zoning of floodlands as recommended above, it is recommended that other land use control and related measures be undertaken within the Milwaukee River watershed. These measures range from corrective measures dealing with obstructions in the channels and floodways to regulations requiring floodproofing of existing structures.

It is recommended that Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties formally request the Wisconsin Department of Natural Resources to survey periodically the bed of the Milwaukee River and to institute appropriate legal action to cause the removal of materials or structures, pursuant to Sections 30.11, 30.12, and 30.13 of the Wisconsin Statutes. It is further recommended that any local unit of government lying along the Milwaukee River and its tributary streams report to the Department of Natural Resources, in writing, every violation which has or may occur relative to structures or deposits in navigable waters and to extension beyond duly established pierhead lines, pursuant to Section 30.14(1) of the Wisconsin Statutes.

It is recommended that all cities, villages, and towns in the Milwaukee River watershed direct their local municipal engineers and building or housing inspectors to inspect periodically and determine whether any structure lying in the floodway or floodplain is in need of extensive repair or is so old or so dangerous, unsafe, unsanitary, or otherwise so unfit for human habitation as to be beyond repair. Upon such findings, municipalities may cause the razing of such structure, pursuant to Section 66.05 of the Wisconsin Statutes, or institute action pursuant to Chapter 280 of the Wisconsin Statutes.

It is recommended that all counties, cities, villages, and towns in the watershed undertake to include in their zoning, building, housing, subdivision, and sanitary ordinances, as appropriate, regulations dealing with the control of seepage, sewer backup relief, and protection from overland flood flow for dwellings located in the floodlands. Such floodproofing regulations should supplement sound floodway and floodplain regulations in the zoning ordinances to prohibit further urban development of floodlands. To assist private property owners in the undertaking of floodproofing of existing structures in floodlands, cities, villages, and towns in the watershed may wish to consider adopting a policy of establishing, upon the request of affected property owners, bench marks related to the elevation of the 100-year recurrence interval flood on, or in close proximity to, all major structures located within the boundaries of the 100-year recurrence interval floodplain. Such a policy would assist private property owners in determining the floodproofing measures necessary for their particular structure and would serve to eliminate any uncertainties that could lead to excessive costs for floodproofing or to inadequate floodproofing.

---

[15] *The floodway is defined as those floodlands, including the channel, required to carry and discharge the one hundred (100)-year recurrence interval flood. If development and fill are prohibited in the floodplain, the floodway may be delineated as that area subject to inundation by the ten (10)-year recurrence interval flood. The floodplain is defined as those floodlands, excluding the floodway, subject to inundation by the one hundred (100)-year recurrence interval flood or, where such data is not available, the maximum flood of record.*

It is recommended that other supplemental preventive measures be taken, including, as appropriate, the posting of flood warning signs or floodland boundary signs along the 100-year recurrence interval flood boundary and the design and installation of municipal utilities and facilities in such a way as to discourage the development of floodlands.

Floodway Clearance

It is recommended that the Milwaukee County Park Commission, the Ozaukee County Park Commission, and the Washington County Park and Planning Commission, in conjunction with the local units of government concerned and, in particular, the Cities of Glendale and Mequon, establish a program for the eventual voluntary removal of all existing structures in the floodways of the watershed. This program would consist of regulation by the local unit of government and acquisition by the local unit of government or the county for park and open-space use. A total of 471 homes and other major structures are located within such floodways and would require removal over a long period of time. The floodland land use controls discussed above should be designed to render all existing structures in the floodways nonconforming uses. It is not recommended that condemnation powers be utilized to effect the removal of any existing structures within the floodways. Rather, all floodway properties should be zoned for nonconforming use status with the properties being purchased for the eventual public use only if offered for such use by the individual homeowners. Even though this recommendation is to establish a program for the voluntary removal of any existing structures in the floodways, it is important that the three county park agencies, together with the affected local units of government, particularly in the Cities of Glendale and Mequon, establish such a program as a matter of public policy so that owners of such homes would have a real alternative to selling in the private real estate market.

It is recognized that zoning regulations based upon what the courts have termed the police power—that is, the power of local government to regulate the private use of land to promote public health, safety and welfare without payment of compensation—alone may be sufficient to eventually result in the voluntary clearance of all structures within the floodways. Because the public as a whole was, however, through the local and state units of government, a party to the development of such floodway lands through approval of subdivision plats and the issuance of building permits, considerations of public policy and of equity would seem to require that the public as a whole now be willing to provide an alternative to those who happen to own floodway lands at this particular moment in time. In addition, the establishment of lineal park strips along the river will serve to enhance the adjacent residential development. Thus, over a long period of time, it would seem essential that public policy be established to provide for eventual public ownership of all floodway lands in urban areas.

Flood Insurance

It is recommended that those cities and villages along the main stem of the Milwaukee River having substantial floodplain lands already developed for urban purposes seek to qualify for flood insurance under the National Flood Insurance Program administered by the U. S. Department of Housing and Urban Development. Although flood insurance is available only to individual homeowners and small businesses, the initiative to become eligible for the sale of such federally subsidized flood insurance must be taken by each individual municipality. It is important to note that, as a condition for eligibility under the federally subsidized national flood insurance program, a local community must also adopt adequate land use control measures not only for those areas already developed in the floodways and floodplains but to prevent the development of new structures on floodways and floodplains now in undeveloped use. Thus, while the program is intended to reduce losses on existing development in the floodplain, it is, more importantly, also intended to discourage the injudicious use of floodplains not yet developed.

Bridge Construction

It is recommended that any public or private body constructing or financing new bridges or replacing existing bridges over the perennial stream channel system of the Milwaukee River watershed design and construct such bridge in accordance with the water control facility objectives and standards set forth in Chapter II of this volume and with the accompanying design methodology and criteria. The cost of bridge replacement and construction is not included in the recommended watershed plan, since it is assumed that any structures requiring replacement will have served their useful life and will, in any case, require replacement for traffic safety and transportation system construction, operation, and maintenance purposes.

Stream Flow Recordation

It is recommended that the U. S. Geological Survey continue to operate the continuous recording stream gaging station at Milwaukee (Estabrook Park). It is further recommended that Washington County finance 50 percent of the cost of operation and maintenance of the existing continuous recording stream gaging station at Fillmore and finance 50 percent of the cost of converting, operating, and maintaining the proposed continuous recording stream gaging station at Kewaskum. The Kewaskum gage is currently a noncontinuous recording gaging station consisting of a staff gage. It is further recommended that Fond du Lac County finance 50 percent of the cost of operation and maintenance of the existing continuous recording stream gaging station at New Fane. Finally, it is recommended that Ozaukee County finance 50 percent of the cost of establishing, operating, and maintaining a continuous recording stream gaging station at Waubeka and 50 percent of the cost of reestablishing, operating, and maintaining a continuous recording stream gaging station on Cedar Creek at Cedarburg. To accomplish the cooperative financing of the New Fane, Fillmore, Kewaskum, Waubeka, and Cedarburg stream gaging stations, it is recommended that interagency agreements be executed between Fond du Lac, Ozaukee, and Washington Counties, the Southeastern Wisconsin Regional Planning Commission, and the U. S. Geological Survey.

Reservoir Land Protection

Although the proposed Waubeka multiple-purpose reservoir is not recommended to be included in the comprehensive Milwaukee River watershed plan, it is recommended that the county zoning agencies of Ozaukee, Sheboygan, and Washington Counties take appropriate steps to protect the reservoir site itself from encroachment by intensive urban land uses, thus preserving the reservoir site in essentially open land uses and providing flexibility to meet changing water quality management and flood control needs in the watershed beyond the design year of the plan. This recommendation would be automatically carried out if the basic land use zoning plan implementation measures, as described earlier in this chapter, are followed. In the event that the Waubeka Reservoir, which is the only economically feasible and aesthetically acceptable structural flood control alternative in the watershed, should ever be reinstituted as a recommended watershed plan element, it is recommended that an attempt be made to seek the necessary enabling legislation to create a comprehensive river basin district. Such an areawide river basin authority could be made responsible not only for construction of the Waubeka Reservoir but also for implementation of the natural resource protection, park and outdoor recreation, and water pollution abatement plan elements should there be sufficient evidence to indicate a lack of interest on the part of local units of government in pursuing vigorously the recommended plan implementation actions. It is further recommended that, should the Waubeka Reservoir be reinstituted as a flood control plan element, the U. S. Army Corps of Engineers give due consideration and weight to the comprehensive Milwaukee River watershed plan findings, analyses, and recommendations and cooperate with either the Milwaukee River Flood Control Board or any future comprehensive river basin authority in implementation of the reservoir element.

Floodway Encroachment/Bulkhead Line Establishment

Although the basic plan recommendation is to preserve in essentially open land uses the floodways and floodplains of the watershed, it is recognized that bulkhead lines or encroachment lines have already been established in several areas of the watershed and, most importantly, in the lower reaches of the Milwaukee River downstream from the North Avenue Dam (see Appendix O, Volume 1, of this report). It is extremely important that the establishment of any future bulkhead lines be carefully coordinated with the recommended comprehensive Milwaukee River watershed plan recommendations. It is recommended, therefore, that the Milwaukee Harbor Commission, the Wisconsin Department of Natural Resources, and any cities, villages, or towns or private landowners within the watershed seeking to establish new or change old bulkhead lines refer such proposals to the Regional Planning Commission for review and comment prior to execution.[16] Upon receipt of such a referral, the Regional Planning Commission will determine the effect on flood flows of the proposed encroachment through utilization of the flood-flow simulation model developed under the Milwaukee River watershed study and will issue comments thereon.

---

[16] *It should be noted in this respect that Assembly Bill 686 (1971), introduced into the Legislature on April 14, 1971, would require all municipalities and the Wisconsin Department of Natural Resources to consider the effect on flood flow before establishing or approving a bulkhead line.*

In this connection it should be noted that one such referral has already been made to the Regional Planning Commission prior to plan adoption. This referral involves the establishment of a new bulkhead line to accommodate the proposed Pere Marquette Park development by the Milwaukee County Park Commission on the west bank of the Milwaukee River between W. Kilbourn Avenue and W. State Street in the City of Milwaukee (see Figure 0-1, page 506, Volume 1, of this report). In response to a request by the Milwaukee County Park Commission, the Regional Planning Commission analyzed the proposed bulkhead change and determined that the additional encroachment proposed would not have any significant effect upon anticipated future flood flows. It is recommended, therefore, that the proposed Pere Marquette bulkhead line be approved by the Common Council of the City of Milwaukee, the Milwaukee Harbor Commission, and the Wisconsin Department of Natural Resources. In addition, it is important to note that the effect of all existing and approved bulkhead lines in the City of West Bend (see Figure 0-2, Volume 1, of this report) on the 100-year recurrence interval flood stage has been incorporated into the flood flow simulation model developed under the watershed study.

Engineering Investigations of Selected Dams

It is recommended that the City of Milwaukee and the City of West Bend undertake detailed engineering investigations of the North Avenue Dam and the Woolen Mills Dam, respectively. Such investigations should include soundings of the upstream pool and boreholes in the superstructure, foundation, and embankments, as described in detail in Chapter V, Volume 1, of this report. A schedule of capital costs for implementing this plan subelement is set forth in Table 125.

Table 125

SCHEDULE OF CAPITAL COSTS OF THE RECOMMENDED SITE INVESTIGATIONS AND ANALYSIS OF STABILITY OF THE NORTH AVENUE AND WOOLEN MILLS DAMS IN THE CITIES OF MILWAUKEE AND WEST BEND, RESPECTIVELY: 1971-1990

CALENDAR YEAR	PROJECT YEAR	COST OF SITE INVESTIGATION AND ANALYSIS OF STABILITY OF THE NORTH AVENUE DAM*	COST OF SITE INVESTIGATION AND ANALYSIS OF STABILITY OF THE WOOLEN MILLS DAM*
1971	1	$ --	$ --
1972	2	12,400	6,700
1973	3	--	--
1974	4	--	--
1975	5	--	--
1976	6	--	--
1977	7	--	--
1978	8	--	--
1979	9	--	--
1980	10	--	--
1981	11	--	--
1982	12	--	--
1983	13	--	--
1984	14	--	--
1985	15	--	--
1986	16	--	--
1987	17	--	--
1988	18	--	--
1989	19	--	--
1990	20	--	--
TOTAL		$12,400	$6,700
ANNUAL AVERAGE		$ 620	$ 335

*FOR A DETAILED BREAKDOWN OF THE REQUIRED WORK ITEMS AND ITEMIZED ESTIMATED COSTS, SEE TABLES 22 AND 23 OF VOLUME 1 OF THIS REPORT.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

WATER POLLUTION ABATEMENT PLAN ELEMENT IMPLEMENTATION

The pollution abatement facility plan elements of the recommended comprehensive Milwaukee River watershed plan include in the lower watershed the completion of the long-range relief sewer construction program currently being conducted by the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee and the construction of a combination deep tunnel mined storage/flow-through treatment system to collect, convey, and adequately treat all combined sewer overflows emanating in the 5,800-acre combined sewer service area of the Milwaukee River watershed. With respect to the upper watershed, the plan recommends the provision of specified levels of secondary, tertiary, and advanced waste treatment at 11 existing and one proposed municipal sewage treatment plants, the abandonment of one existing municipal sewage treatment plant and connection of its service area to the Milwaukee metropolitan sewerage system, and the provision of sanitary sewerage service at nine major lakes in the upper watershed. Finally, the plan also recommends the institution of algae control operations, as necessary, at eight major lakes in the upper watershed; the institution of weed harvesting operations, as necessary, at 13 major lakes in the upper watershed; the institution of improved agricultural land and livestock management practices for soil and water conservation purposes in the tributary drainage areas of 12 major lakes in the watershed, including, as appropriate, the construction of bench terraces; the regulation of the installation of on-site soil absorption sewage disposal systems; the conduct of stream basin surveys on a regular basis; and a continuing water quality monitoring program. Schedules of capital costs for implementing the water pollution abatement plan element of the Milwaukee River plan are set forth by county in Tables 126, 127, 128, 129, and 130.

Table 126

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED WATER POLLUTION ABATEMENT PLAN ELEMENT OF THE MILWAUKEE RIVER WATERSHED FOR MILWAUKEE COUNTY BY YEAR: 1971-1990

CALENDAR YEAR	PROJECT YEAR	STREAM WATER QUALITY IMPROVEMENTS — ABATEMENT OF COMBINED SEWER OVERFLOWS THROUGH DEEP TUNNEL MINED STORAGE/FLOW-THROUGH TREATMENT SYSTEM: ENGINEERING FEASIBILITY STUDY[a]	FACILITY CONSTRUCTION[b]	OPERATION AND MAINTENANCE[c]
1971	1	$ --	$ --	$ --
1972	2	400,000	--	--
1973	3	--	7,380,000	--
1974	4	--	7,380,000	100,000
1975	5	--	7,380,000	200,000
1976	6	--	7,380,000	300,000
1977	7	--	7,380,000	400,000
1978	8	--	4,100,000	495,000
1979	9	--	--	495,000
1980	10	--	--	495,000
1981	11	--	--	495,000
1982	12	--	--	495,000
1983	13	--	--	495,000
1984	14	--	--	495,000
1985	15	--	--	495,000
1986	16	--	--	495,000
1987	17	--	--	495,000
1988	18	--	--	495,000
1989	19	--	--	495,000
1990	20	--	--	495,000
TOTAL		$400,000	$41,000,000	$7,435,000
ANNUAL AVERAGE		$ 20,000	$ 2,050,000	$ 371,750

[a] THE TOTAL COST OF CONDUCTING THE ENGINEERING FEASIBILITY STUDY FOR THE ENTIRE 17,200-ACRE MILWAUKEE COMBINED SEWER SERVICE AREA IS ESTIMATED AT $1.2 MILLION. THIS COST INCLUDES SUBSURFACE EXPLORATION AS WELL AS MORE DETAILED ENGINEERING, ECONOMIC, AND FINANCIAL ANALYSES AND THE PREPARATION OF A FINAL REPORT. THE PRO RATA SHARE OF CONDUCTING THE FEASIBILITY STUDY FOR THE 5,800-ACRE COMBINED SEWER SERVICE AREA IN THE MILWAUKEE RIVER WATERSHED IS ESTIMATED AT $400,000.

[b] THE TOTAL COST OF CONSTRUCTING THE NECESSARY DEEP TUNNEL MINED STORAGE/FLOW-THROUGH TREATMENT SYSTEM FOR THE ENTIRE 17,200-ACRE MILWAUKEE COMBINED SEWER SERVICE AREA IS ESTIMATED AT $121.5 MILLION. THE PRO RATA SHARE OF CONSTRUCTING THE NECESSARY FACILITIES FOR THE 5,800-ACRE COMBINED SEWER SERVICE AREA IN THE MILWAUKEE RIVER WATERSHED IS ESTIMATED AT $41 MILLION.

[c] THE TOTAL ANNUAL COST OF OPERATING AND MAINTAINING THE DEEP TUNNEL MINED STORAGE/FLOW-THROUGH TREATMENT SYSTEM FOR THE ENTIRE 17,200-ACRE MILWAUKEE COUNTY SEWER SERVICE AREA IS ESTIMATED AT $1,460,000. THE PRO RATA SHARE OF ANNUALLY OPERATING AND MAINTAINING THE NECESSARY FACILITIES FOR THE 5,800-ACRE COMBINED SEWER SERVICE AREA IN THE MILWAUKEE RIVER WATERSHED IS ESTIMATED AT $495,000.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Lower Milwaukee River Watershed

It is recommended that the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee, acting jointly, work as rapidly as possible toward completion of the long-range relief sewer construction program in Milwaukee County. Completion of this relief sewer program, together with necessary main and relief sewer construction programs by local municipalities served by the joint Commissions, should eliminate all of the separate sanitary sewer overflows to stream courses in the lower Milwaukee River watershed.

It is recommended that the Sewerage Commission of the City of Milwaukee assume responsibility for construction of a combination deep tunnel mined storage/flow-through treatment system to collect, convey, and adequately treat all combined sewer overflows emanating in the 5,800-acre combined sewer service area of the Milwaukee River watershed. The construction of such a system should, as appropriate, be expanded to include the entire 17,200-acre combined sewer service area in Milwaukee County. Responsibility for the construction of such a system necessarily rests under existing enabling legislation with the Sewerage Commission of the City of Milwaukee rather than the Metropolitan Sewerage Commission of Milwaukee County. The latter Commission by law can operate only outside cities of the first class.

Table 127

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED WATER POLLUTION ABATEMENT PLAN ELEMENT FOR OZAUKEE COUNTY BY YEAR: 1971-1990

CALENDAR YEAR	PROJECT YEAR	STREAM WATER QUALITY IMPROVEMENTS: SECONDARY WASTE TREATMENT AT FREDONIA		SECONDARY AND ADVANCED WASTE TREATMENT AT SAUKVILLE		SECONDARY AND ADVANCED WASTE TREATMENT AT CEDARBURG-GRAFTON		CONNECTION OF THIENSVILLE TO MILWAUKEE-METROPOLITAN SEWERAGE SYSTEM		TOTAL	
		FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE
1971	1	$ --	$ --	$ --	$ --	$ --	$ --	$ --	$ --	$ --	$ --
1972	2	13,700	--	16,500	--	228,350	--	--	--	258,550	--
1973	3	109,600	--	132,000	--	1,826,800	--	--	--	2,068,400	--
1974	4	13,700	19,800	16,500	31,800	228,350	258,000	219,500	--	478,050	309,600
1975	5	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1976	6	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1977	7	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1978	8	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1979	9	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1980	10	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1981	11	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1982	12	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1983	13	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1984	14	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1985	15	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1986	16	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1987	17	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1988	18	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1989	19	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
1990	20	--	19,800	--	31,800	--	258,000	--	52,800	--	362,400
TOTAL		$137,000	$336,600	$165,000	$540,600	$2,283,500	$4,386,000	$219,500	$844,800	$2,805,000	$6,108,000
ANNUAL AVERAGE		$ 6,850	$ 16,830	$ 8,250	$ 27,030	$ 114,175	$ 219,300	$ 10,975	$ 42,240	$ 140,250	$ 305,400

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table 128

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED WATER POLLUTION ABATEMENT PLAN ELEMENT OF THE MILWAUKEE RIVER WATERSHED PLAN FOR WASHINGTON COUNTY BY YEAR: 1971-1990

		STREAM WATER QUALITY IMPROVEMENTS							
		SECONDARY WASTE TREATMENT AT NEWBURG		SECONDARY AND ADVANCED WASTE TREATMENT AT JACKSON		SECONDARY AND ADVANCED WASTE TREATMENT AT KEWASKUM		SECONDARY AND ADVANCED WASTE TREATMENT AND INSTREAM AERATION AT WEST BEND	
CALENDAR YEAR	PROJECT YEAR	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE
1971	1	$ --	$ --	$ --	$ --	$ --	$ --	$ --	$ --
1972	2	9,200	--	55,600	--	46,500	--	119,845	--
1973	3	70860	0 --	444,800	--	372,000	--	479,380	--
1974	4	9,200	13,600	55,600	51,600	46,500	58,800	479,380	--
1975	5	--	13,600	--	51,600	--	58,800	119,845	288,000
1976	6	--	13,600	--	51,600	--	58,800	--	288,000
1977	7	--	13,600	--	51,600	--	58,800	--	288,000
1978	8	--	13,600	--	51,600	--	58,800	--	288,000
1979	9	--	13,600	--	51,600	--	58,800	--	288,000
1980	10	--	13,600	--	51,600	--	58,800	--	288,000
1981	11	--	13,600	--	51,600	--	58,800	--	288,000
1982	12	--	13,600	--	51,600	--	58,800	--	288,000
1983	13	--	13,600	--	51,600	--	58,800	--	288,000
1984	14	--	13,600	--	51,600	--	58,800	--	288,000
1985	15	--	13,600	--	51,600	--	58,800	--	288,000
1986	16	--	13,600	--	51,600	--	58,800	--	288,000
1987	17	--	13,600	--	51,600	--	58,800	--	288,000
1988	18	--	13,600	--	51,600	--	58,800	--	288,000
1989	19	--	13,600	--	51,600	--	58,800	--	288,000
1990	20	--	13,600	--	51,600	--	58,800	--	288,000
TOTAL		$92,000	$231,200	$556,000	$877,200	$465,000	$999,600	$1,198,450	$4,608,000
ANNUAL AVERAGE		$ 4,600	$ 11,560	$ 27,800	$ 43,860	$ 23,250	$ 49,980	$ 59,923	$ 230,400

		LAKE WATER QUALITY IMPROVEMENTS									
		WATER QUALITY MANAGEMENT PLAN FOR BIG CEDAR LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR GREEN LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR LITTLE CEDAR LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR LUCAS LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR SILVER LAKE[a]	
CALENDAR YEAR	PROJECT YEAR	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE
1971	1	$ 8,500	$ 3,150	$ --	$ --	$ 5,400	$ 1,200	$44,100	$ 300	$ --	$ --
1972	2	--	3,150	--	--	--	1,200	--	300	--	--
1973	3	--	3,150	--	--	--	1,200	--	300	--	--
1974	4	--	3,150	--	--	--	1,200	--	300	--	--
1975	5	403,900	3,150	52,480	--	32,000	1,200	--	300	88,350	--
1976	6	622,240	3,150	419,840	--	164,490	1,200	--	300	706,800	--
1977	7	622,240	13,150	52,480	16,750	1,067,920	1,200	--	300	88,350	7,950
1978	8	622,240	29,100	--	16,750	133,490	18,250	--	300	--	7,950
1979	9	622,240	39,100	--	16,750	--	18,250	--	300	--	7,950
1980	10	622,240	49,100	--	16,750	--	18,250	--	300	--	7,950
1981	11	363,900	49,100	--	16,750	--	18,250	--	300	--	7,950
1982	12	--	49,100	--	16,750	--	18,250	--	300	--	7,950
1983	13	--	49,100	--	16,750	--	18,250	--	300	--	7,950
1984	14	--	49,100	--	16,750	--	18,250	--	300	--	7,950
1985	15	--	49,100	--	16,750	--	18,250	--	300	--	7,950
1986	16	--	45,950	--	16,750	--	17,050	--	--	--	7,950
1987	17	--	45,950	--	16,750	--	17,050	--	--	--	7,950
1988	18	--	45,950	--	16,750	--	17,050	--	--	--	7,950
1989	19	--	45,950	--	16,750	--	17,050	--	--	--	7,950
1990	20	--	45,950	--	16,750	--	17,050	--	--	--	7,950
TOTAL		$3,887,500	$624,600	$524,800	$234,500	$1,403,300	$239,650	$44,100	$4,500	$883,500	$111,300
ANNUAL AVERAGE		$ 194,375	$ 31,230	$ 26,240	$ 11,725	$ 70,165	$ 11,982	$ 2,205	$ 225	$ 44,175	$ 5,565

		LAKE WATER QUALITY IMPROVEMENTS						TOTAL STREAM AND LAKE WATER QUALITY IMPROVEMENTS	
		WATER QUALITY MANAGEMENT PLAN FOR SMITH LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR TWELVE LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR WALLACE LAKE[a]			
CALENDAR YEAR	PROJECT YEAR	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE
1971	1	$ 5,400	$ 850	$ 3,350	$ 500	$ 7,950	$ 350	$ 74,700	$ 6,350
1972	2	10,000	850	19,200	500	--	350	260,345	6,350
1973	3	10,000	850	19,200	500	--	350	1,398,980	6,350
1974	4	--	850	--	500	--	350	590,680	130,350
1975	5	--	850	--	500	35,315	350	731,890	418,350
1976	6	--	850	--	500	282,520	350	2,195,890	418,350
1977	7	--	850	--	500	35,315	5,500	1,866,305	458,200
1978	8	--	850	--	500	--	5,500	755,730	491,200
1979	9	--	850	--	500	--	5,500	622,240	501,200
1980	10	--	850	--	500	--	5,500	622,240	511,200
1981	11	--	850	--	500	--	5,500	363,900	511,200
1982	12	--	850	--	500	--	5,500	--	511,200
1983	13	--	850	--	500	--	5,500	--	511,200
1984	14	--	850	--	500	--	5,500	--	511,200
1985	15	--	850	--	500	--	5,500	--	511,200
1986	16	--	--	--	--	--	5,150	--	504,850
1987	17	--	--	--	--	--	5,150	--	504,850
1988	18	--	--	--	--	--	5,150	--	504,850
1989	19	--	--	--	--	--	5,150	--	504,850
1990	20	--	--	--	--	--	5,150	--	504,850
TOTAL		$25,400	$12,750	$41,750	$7,500	$361,100	$77,350	$9,482,900	$8,028,150
ANNUAL AVERAGE		$ 1,270	$ 637	$ 2,087	$ 375	$ 18,055	$ 3,867	$ 474,145	$ 401,407

[a] FOR A DETAILED BREAKDOWN OF THE COMPONENT LAKE WATER QUALITY MANAGEMENT PLAN ELEMENT COSTS, SEE TABLE 106.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table 129

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS
OF THE RECOMMENDED WATER POLLUTION ABATEMENT PLAN
ELEMENT OF THE MILWAUKEE RIVER WATERSHED PLAN FOR
FOND DU LAC COUNTY BY YEAR: 1971-1990

		STREAM WATER QUALITY IMPROVEMENTS		LAKE WATER QUALITY IMPROVEMENTS											
		SECONDARY AND ADVANCED WASTE TREATMENT AT CAMPBELLSPORT		WATER QUALITY MANAGEMENT PLAN FOR AUBURN LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR FOREST LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR KETTLE MORAINE LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR LONG LAKE[a]		WATER QUALITY MANAGEMENT PLAN FOR MAUTHE LAKE[a]		TOTAL STREAM AND LAKE WATER QUALITY IMPROVEMENTS	
CALENDAR YEAR	PROJECT YEAR	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE	FACILITY CONSTRUCTION	OPERATION AND MAINTENANCE
1971	1	$ --	$ --	$ 2,100	$ 300	$ 3,350	$ 400	$ 6,200	$ 900	$ 4,150	$ 600	$ 3,350	$ 650	$ 19,150	$ 2,850
1972	2	31,570	--	34,000	300	--	400	--	900	93,000	600	20,000	650	178,570	2,850
1973	3	252,560	--	34,000	300	--	400	--	900	93,000	600	20,000	650	399,560	2,850
1974	4	31,570	44,700	--	300	--	400	--	900	--	600	--	650	31,570	47,550
1975	5	--	44,700	--	300	39,090	400	93,410	900	--	600	--	650	132,500	47,550
1976	6	--	44,700	--	300	312,720	400	747,280	900	--	600	--	650	1,060,000	47,550
1977	7	--	44,700	--	300	39,090	17,400	93,410	24,100	--	600	--	650	132,500	87,750
1978	8	--	44,700	--	300	--	17,400	--	24,100	--	600	--	650	--	87,750
1979	9	--	44,700	--	300	--	17,400	--	--	--	600	--	650	--	87,750
1980	10	--	44,700	--	300	--	17,400	--	24,100	--	600	--	650	--	87,750
1981	11	--	44,700	--	300	--	17,400	--	24,100	--	600	--	650	--	87,750
1982	12	--	44,700	--	300	--	17,400	--	24,100	--	600	--	650	--	87,750
1983	13	--	44,700	--	300	--	17,400	--	24,100	--	600	--	650	--	87,750
1984	14	--	44,700	--	300	--	17,400	--	24,100	--	600	--	650	--	87,750
1985	15	--	44,700	--	300	--	17,400	--	24,100	--	600	--	650	--	87,750
1986	16	--	44,700	--	--	--	17,000	--	23,200	--	--	--	--	--	84,900
1987	17	--	44,700	--	--	--	17,000	--	23,200	--	--	--	--	--	84,900
1988	18	--	44,700	--	--	--	17,000	--	23,200	--	--	--	--	--	84,900
1989	19	--	44,700	--	--	--	17,000	--	23,200	--	--	--	--	--	84,900
1990	20	--	44,700	--	--	--	17,000	--	23,200	--	--	--	--	--	84,900
TOTAL		$315,700	$759,900	$70,100	$4,500	$394,250	$244,000	$940,300	$338,300	$190,150	$9,000	$43,350	$9,750	$1,953,850	$1,365,450
ANNUAL AVERAGE		$ 15,785	$ 37,995	$ 3,505	$ 225	$ 19,713	$ 12,200	$ 47,015	$ 16,915	$ 9,507	$ 450	$ 2,167	$ 488	$ 97,692	$ 68,272

[a]FOR DETAILED BREAKDOWN OF THE COMPONENT LAKE WATER QUALITY MANAGEMENT PLAN ELEMENT COSTS, SEE TABLE 106.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table 130

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED WATER POLLUTION ABATEMENT PLAN ELEMENT OF THE MILWAUKEE RIVER WATERSHED PLAN FOR SHEBOYGAN COUNTY BY YEAR: 1971-1990

Calendar Year	Project Year	Stream Water Quality Improvements				Lake Water Quality Improvements						Total Stream and Lake Water Quality Improvements	
		Secondary Waste Treatment and Stream-Flow Augmentation at Cascade		Secondary and Tertiary Waste Treatment at Random Lake		Water Quality Management Plan for Crooked Lake[a]		Water Quality Management Plan for Ellen Lake[a]		Water Quality Management Plan for Random Lake[a]			
		Facility Construction	Operation and Maintenance	Facility Construction	Operation and Maintenance	Facility Construction	Operation and Maintenance	Facility Construction	Operation and Maintenance	Facility Construction	Operation and Maintenance	Facility Construction	Operation and Maintenance
1971	1	$ --	$ --	$ 32,900	$ --	$ 2,100	$ 300	$ 3,350	$ 650	$ 66,200	$ 900	$ 104,550	$ 1,850
1972	2	--	--	263,200	--	55,000	300	12,200	650	52,400	900	382,800	1,850
1973	3	12,700	--	32,900	25,000	55,000	300	13,000	650	83,840	900	197,440	26,850
1974	4	12,700	--	--	25,000	--	300	73,580	650	83,840	900	170,120	26,850
1975	5	101,600	--	--	25,000	--	300	662,220	650	83,840	900	847,660	26,850
1976	6	--	26,500	--	25,000	--	300	--	47,950	83,840	900	83,840	100,650
1977	7	--	26,500	--	25,000	--	300	--	47,950	83,840	6,850	83,840	106,600
1978	8	--	26,500	--	25,000	--	300	--	47,950	52,400	6,850	52,400	106,600
1979	9	--	26,500	--	25,000	--	300	--	47,950	--	6,850	--	106,600
1980	10	--	26,500	--	25,000	--	300	--	47,950	--	6,850	--	106,600
1981	11	--	26,500	--	25,000	--	300	--	47,950	--	6,850	--	106,600
1982	12	--	26,500	--	25,000	--	300	--	47,950	--	6,850	--	106,600
1983	13	--	26,500	--	25,000	--	300	--	47,950	--	6,850	--	106,600
1984	14	--	26,500	--	25,500	--	300	--	47,950	--	6,850	--	106,600
1985	15	--	26,500	--	25,000	--	300	--	47,950	--	6,850	--	106,600
1986	16	--	26,500	--	25,000	--	--	--	47,300	--	5,950	--	104,750
1987	17	--	26,500	--	25,000	--	--	--	47,300	--	5,950	--	104,750
1988	18	--	26,500	--	25,000	--	--	--	47,300	--	5,950	--	104,750
1989	19	--	26,500	--	25,000	--	--	--	47,300	--	5,950	--	104,750
1990	20	--	26,500	--	25,000	--	--	--	47,300	--	5,950	--	104,750
Total		$127,000	$397,500	$329,000	$450,000	$112,100	$4,500	$764,350	$719,250	$590,200	$96,800	$1,922,650	$1,668,050
Annual Average		$ 6,350	$ 19,875	$ 16,450	$ 22,500	$ 5,605	$ 225	$ 38,218	$ 35,963	$ 29,510	$ 4,840	$ 96,133	$ 83,403

[a] FOR A DETAILED BREAKDOWN OF THE COMPONENT LAKE WATER QUALITY MANAGEMENT PLAN ELEMENT COSTS, SEE TABLE 106.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

It is recognized, however, that the two Commissions share a common staff and often act jointly in matters of importance throughout the City of Milwaukee and the Metropolitan Sewerage District.

The first step in implementation of this recommended plan element would be the undertaking of a preliminary engineering study to determine with greater precision and detail the configuration of the recommended deep tunnel mined storage/flow-through treatment system as required to serve and adequately handle the combined sewer overflows. It is estimated that such an engineering feasibility study could be completed within a 12-month period and would cost, with respect to the entire 17,200-acre combined sewer service area, an estimated $1.2 million. Such a study would include subsurface exploration, including geophysical logging and geohydrologic testing. In addition, such a study would include the analyses of subsurface data collection; the collection and analysis of data for sewer capacity, hydrologic and hydraulic loadings, and water quality characteristics of combined sewer overflows; a review of applicable sewage treatment methods; the preparation of sewer layouts and costs estimates; and the preparation of a construction schedule.

It is recommended that the Wisconsin Department of Natural Resources order, as appropriate, the connection of the following eight industrial waste outfalls, which now discharge directly to Lincoln Creek or to the Milwaukee River within Milwaukee County, to the Milwaukee metropolitan sewerage system; Automatic Auto Wash; City of Milwaukee Fifth District Police Station; Milwaukee School Board, Marshall High School; Modern Car Wash, Inc.; Pure Oil Capitol Court Auto Wash; Pure Oil Car Wash; Wisco 99 Car Wash; and Wisconsin Gas Company, North Service Center. In addition, it is recommended that the Department order, as appropriate, improved waste treatment of inorganic wastes before discharge to the municipal storm sewer system at the following five industrial waste sources: Delta Oil Products Corp., Ricketson Color Division; Outboard Marine Corp., Evinrude Motors Division; Interstate Drop Forge Company; Paul J. Schmidt Trucking; and Sealtest Foods, Division of Dairy Products, Kraftco Corporation.

Upper Milwaukee River Watershed

It is recommended that the Villages of Adell and Fredonia and the Newburg Sanitary District continue to provide secondary waste treatment and post-chlorination for disinfection at their existing sewage treatment facilities. It is further recommended that the Adell treatment facility continue to discharge its effluent to a seepage pond rather than to the stream system.

It is recommended that the Village of Cascade establish a municipal sanitary sewerage system and construct a sewage treatment plant to provide secondary waste treatment and post-chlorination for disinfection of effluent. It is further recommended that the Village of Cascade either provide for streamflow augmentation, utilizing a single small capacity well, or, in the alternative, discharge its effluent to a seepage pond rather than to the stream system. Finally, it is recommended that the Village of Cascade contract with the Town of Lyndon Sanitary District No. 1 for the treatment of sewage emanating from the urban development around Lake Ellen.

It is recommended that the Village of Random Lake provide secondary waste treatment, tertiary waste treatment for 95 percent BOD removal, and post-chlorination for disinfection of effluent at the existing sewage treatment facility. It is also recommended that the Village of Random Lake provide sewer service to the remaining unsewered urban development located on the north and east shores of Random Lake, either through eventual annexation or through a contract agreement between the Village and a town sanitary district organized for that purpose in the Town of Sherman.

It is recommended that the Villages of Campbellsport, Jackson, Kewaskum, and Saukville provide secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination for disinfection of effluent at their existing municipal sewage treatment facilities. The Jackson sewage treatment facility, however, would be proposed to be relocated at a new site about 0.5 mile east of the present plant site in order to accommodate the wastes emanating from the Libby, McNeill, & Libby industrial plant and to provide a more rational sewer service area.

It is recommended that the City of Cedarburg and the Village of Grafton jointly construct an advanced waste treatment facility near the confluence of the Milwaukee River and Cedar Creek and continue to operate their existing sewage treatment facilities as secondary treatment plants, with advanced waste treatment (90 percent phosphorus removal) to be provided at the jointly operated facility. The implementation of this plan recommendation would require either the execution of a voluntary intergovernmental cooperation agreement, pursuant to Section 66.30 of the Wisconsin Statutes, between the City of Cedarburg and the Village of Grafton or, in the alternative, the creation of a metropolitan sewerage district, which district would provide the sewage treatment plant operation necessary for all three plants. As noted earlier in this chapter, there is currently no valid enabling legislation in the Wisconsin Statutes to provide for the creation of new metropolitan sewerage districts. It is anticipated, however, that remedial legislation will be forthcoming in the near future to make this particular form of institutional structure available for use in plan implementation. Under either alternative it may be desirable to include portions of the Towns of Cedarburg and Grafton in order to provide rational sewer service to the entire Cedarburg-Grafton urbanizing areas.

It is recommended that the City of West Bend provide secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination for disinfection at the existing West Bend sewage treatment plant. In addition, instream aeration should be provided by the City of West Bend at specified locations along the Milwaukee River and in the Newburg Pond. It is recommended that the Wisconsin Department of Natural Resources approve the installation of the required aeration facilities under its water regulatory powers. It is further recommended that the Town of Trenton grant any needed change in zoning to permit the City of West Bend to install the aeration facilities. In addition, it is recommended that the City of West Bend contract to provide for sewage treatment for sewage emanating from urban development around Big Cedar, Little Cedar, Silver, and Wallace Lakes. Such contracts should be consumated with the Big Cedar, Little Cedar, Silver, and Wallace Lake Sanitary Districts which have already been formed within the area. In the alternative, it is recommended that consideration be given to the establishment of a metropolitan sewerage district to provide for sewerage service to the entire West Bend and surrounding lakes area. The establishment of such a metropolitan sewerage district would, of course, be subject to obtaining the necessary state legislation to provide the mechanism for the establishment of such new districts.

It is recommended that the Village of Thiensville enter into a contract with the Metropolitan Sewerage District of Milwaukee to provide for sewage treatment. Such action would enable the eventual elimination of the existing Thiensville sewage treatment plant. Furthermore, it is recommended that the Village of Thiensville and the City of Mequon jointly construct the recommended trunk sewer to connect the Thiensville sewer service area and a portion of the City of Mequon to the Milwaukee metropolitan sewerage system.

It is recommended that the several county soil and water conservation districts concerned, together with the University Extension Service, the U. S. Soil Conservation Service, and the U. S. Agricultural Stabilization and Conservation Service, undertake, as appropriate, strengthened programs of education and technical service to provide for the institution of agricultural land management practices to over 65,000 acres of additional agricultural land in the Milwaukee River watershed located outside the subwatersheds of the major lakes concerned. Such agricultural land management practices should be instituted on a voluntary basis and should take maximum advantage of the federal technical and financial assistance available.

It is recommended that the 13 major industrial waste sources in the upper watershed existing in 1967 and identified in Volume 1 of this report fully comply with any outstanding and future pollution abatement orders issued by the Wisconsin Department of Natural Resources. It should be noted in this regard that the following firms have already complied with outstanding orders and implemented the plan recommendations: Kiekhaefer Corporation (improved inplant pretreatment of wastes); Line Materials Industries, West Bend Company, and Badger Worsted Mills, Inc., (connection to municipal sanitary sewerage systems); and Foremost Foods, Inc., Krier Preserving Company, and River Road Cheese Factory (improved private waste treatment facilities). Two sources—DeSoto Chemical Coatings, Inc. and Passini Cheese Company, Inc.—are no longer in business and, therefore, no longer constitute waste sources. With respect to the remaining industrial waste sources, it is recommended that Federal Foods, Level Valley Dairy, and Justro Feed Corporation provide, as appropriate, improved private waste treatment facilities and that Libby, McNeill, & Libby connect to the proposed new Village of Jackson sewage treatment facility.

Establishment of Lake Sewerage Systems

The provision of sanitary sewerage systems is recommended in the Milwaukee River watershed plan at nine major lakes: Big Cedar, Ellen, Forest, Green, Kettle Moraine, Little Cedar, Random, Silver, and Wallace Lakes. At three of the nine lakes—Forest, Green, and Kettle Moraine—the recommended sanitary sewerage system provides for the treatment of wastes at a new sewage treatment plant providing secondary waste treatment and post-chlorination for disinfection of effluent. At the six remaining lakes—Big Cedar, Ellen, Little Cedar, Random, Silver, and Wallace—waste treatment would be provided at existing or proposed sewage treatment plants discussed under the recommended stream water quality management plan element.

It is recommended that the Big Cedar Lake Sanitary District, the Little Cedar Lake Sanitary District, the Silver Lake Sanitary District, and the Wallace Lake Sanitary District contract with the City of West Bend to provide for treatment of sewage emanating in the respective sanitary districts. In the alternative, it is recommended that the aforementioned sanitary districts, together with the town boards of the Towns of Barton, Polk, Trenton, and West Bend and the City of West Bend, seek to establish a metropolitan sewerage district to provide for the necessary areawide sewerage system. It is further recommended that the underlying sanitary districts assume basic responsibility for constructing the trunk, lateral, and branch sewers to collect wastes within the various districts.

It is recommended that the Sanitary District No. 1 in the Town of Lyndon contract with the Village of Cascade to provide for the treatment of sewage emanating in the sanitary district at the proposed Village of Cascade sewage treatment plant. In the alternative, it is recommended that the Village of Cascade and the Sanitary District No. 1 in the Town of Lyndon together seek the establishment of a metropolitan sewerage district to provide for such areawide sewage treatment.

It is recommended that the Town of Sherman establish a sanitary district around the north and east shores of Random Lake to provide an entity which could contract with the Village of Random Lake to provide for the treatment of sewage emanating from the proposed sanitary district. In the alternative, it is recommended that the Village of Random Lake annex such urban development around the north and east shores of Random Lake to provide for total sewer service around the lake.

It is recommended that the town boards of the Towns of Auburn, Farmington, and Osceola create, pursuant to Section 60.301 and 30.315 of the Wisconsin Statutes, sanitary districts to serve existing urban development around Forest, Green, and Kettle Moraine Lakes, respectively. Such districts should be charged with the responsibility of implementing the recommended lake sanitary sewerage system plan elements included in the Milwaukee River watershed plan.

Lake Algae Control and Weed Harvesting

The comprehensive Milwaukee River watershed plan recommended provision, as necessary, of continuing programs for chemical control of nuisance algal blooms at Big Cedar, Ellen, Forest, Little Cedar, Mauthe, Smith, Twelve, and Wallace Lakes and the provision, as necessary, of continuing programs for the machine harvesting of aquatic weed growths at Auburn, Big Cedar, Crooked, Ellen, Forest, Kettle Moraine, Little Cedar, Long, Lucas, Mauthe, Random, Smith, and Twelve Lakes.

The provision of lake improvement programs, such as those recommended above, can be accomplished in several ways, depending upon the local governmental structure. Cities are empowered, pursuant to Sections 62.11(5) and 62.23(18) of the Wisconsin Statutes, to make improvements on lakes for the protection and welfare of public health and wildlife. Villages, under Sections 61.34 and 61.35 of the Wisconsin Statutes, have similar powers to carry on improvement programs for lakes. Towns are specifically given authority in Section 60.29(29) of the Wisconsin Statutes to make improvements in any lake situated in the town. Alternatively, towns may, through Sections 60.301 and 60.315 of the Wisconsin Statutes, establish sanitary districts for a variety of purposes, including lake improvement.

Accordingly, it is recommended that the Big Cedar Lake Sanitary District undertake the recommended algae control and weed harvesting programs for Big Cedar Lake; the Town of Lyndon Sanitary District No. 1 undertake the recommended algae control and weed harvesting programs for Lake Ellen; the sanitary district recommended to be created for sewerage purposes in the Town of Auburn undertake the recommended algae control and weed harvesting programs for Forest Lake; the Little Cedar Lake Sanitary District undertake the algae control and weed harvesting programs for Little Cedar Lake; the sanitary district recommended to be created for sewerage purposes in the Town of Osceola undertake the recommended weed harvesting program for Kettle Moraine Lake; the sanitary district recommended to be created for sewerage purposes in the Town of Sherman, together with the Village of Random Lake, cooperatively undertake the recommended weed harvesting program for Random Lake; and the Wallace Lake Sanitary District undertake the recommended algae control program for Wallace Lake.

It is further recommended that a sanitary district be created in the Town of Auburn to undertake the weed harvesting program for Auburn Lake; that a sanitary district be created in the Towns of Auburn and Scott to undertake the recommended weed harvesting program for Crooked Lake; that a sanitary district be created in the Town of Osceola to undertake the recommended weed harvesting program for Long Lake; that a sanitary district be created in the Town of West Bend to undertake the recommended weed harvesting program for Lucas Lake; that a sanitary district be created in the Town of Barton to undertake the recommended algae control and weed harvesting programs for Smith Lake; and that a sanitary district be created in the Town of Farmington to undertake the recommended algae control and weed harvesting programs for Twelve Lake. Finally, it is recommended that the Wisconsin Department of Natural Resources undertake the recommended algae control and weed harvesting programs for Mauthe Lake, which lake lies entirely within properties owned by the Department as part of the Northern Unit of the Kettle Moraine State Forest.

Responsibility for these lake improvement programs would thus be placed with the appropriate general-purpose local unit of government when cities and villages are involved, with appropriate sanitary districts when unincorporated areas are involved, and with the Wisconsin Department of Natural Resources when the Kettle Moraine State Forest is involved. In the alternative to the creation of sanitary districts, it is recommended that the town governments undertake the recommended lake improvement programs.

Soil and Water Conservation Practices

The comprehensive Milwaukee River watershed plan recommends that, in addition to the continuing programs for the institution of sound soil and water conservation practices throughout the watershed, specific attention be given to the provision of bench terracing or other appropriate agricultural land management measures on those agricultural lands subject to erosion within the tributary watersheds of the following 12 lakes: Auburn, Big Cedar, Crooked, Ellen, Little Cedar, Long, Lucas, Mauthe, Random, Smith, Twelve, and Wallace. The basic institutional mechanism recommended for achieving this objective is the appropriate county soil and water conservation district, together with technical assistance provided by the U. S. Soil Conservation Service and cooperating agencies.

It is accordingly recommended that Fond du Lac, Ozaukee, Sheboygan, and Washington Soil and Water Conservation District Supervisors, pursuant to Section 92.09(1) of the Wisconsin Statutes, formulate proposed land use regulations for the purpose of conserving soil resources, controlling erosion, and reducing water pollution in the Milwaukee River watershed. Such regulations should specifically include provisions for bench terracing on those agricultural lands subject to erosion within the tributary watersheds of the aforementioned lakes. Such special land use regulations may also include, as appropriate, the construction of upland water control structures, such as terrace outlets, erosion control dams, ponds, and diversion channels, and the institution of sound soil and water conservation practices, such as contour farming; grassed waterways; reforestation; contour stripcropping; and seeding and planting of lands with plants, trees, and grasses. It should be noted that such special land use regulations require not only a recommendation by the county soil and water conservation district supervisors after public hearings and approval by the county board but also will require a referendum in which two-thirds of the land occupiers affected approve the regulations.

It is further recommended that the U. S. Soil Conservation Service provide staff technical assistance, as necessary, in the implementation of this watershed plan recommendation. It is also recommended that the U. S. Agricultural and Stabilization Service, through its Rural Environmental Assistance Program, give priority to any proposals dealing with cost-sharing for the construction of the recommended bench terraces or other appropriate agricultural land management practices. Finally, it should be noted that the town boards of the Towns of Auburn, Barton, Farmington, Lyndon, Osceola, Polk, Scott, Sherman, and Trenton could seek authority, under Section 60.18(21) of the Wisconsin Statutes, should they desire to appropriate money under Section 60.29(44), for the purpose of assisting in the construction of the recommended bench terraces as a natural resource conservation project.

Septic Tank Sewage Disposal Systems

It is recommended that Fond du Lac County and Sheboygan County, as well as all cities and villages within the watershed not already having done so, adopt sanitary codes, pursuant to Sections 59.07(51), 62.11(5), and 140.09 of the Wisconsin Statutes, that would prohibit the installation of septic tank sewage disposal systems on soils within the watershed that have "very severe limitations" for such systems, as established in the regional and watershed soils survey, and prohibit septic tank sewage disposal systems on soils that have "severe limitations" for such systems, as established in the regional and watershed soils survey, unless such limitations are overcome at the time of development.[17] These units of government should further regulate the installation of such systems on soils not having such limitations so as to prevent any further installation of systems that are periodically inoperative or which drain directly into surface waters of the watershed.

By way of supplementing such local regulations, it is also recommended that the Wisconsin Department of Natural Resources, pursuant to Section 144.025(2)(q) of the Wisconsin Statutes, similarly prohibit and regulate the installation of septic tank sewage disposal systems. In addition, it is recommended that the Wisconsin Division of Health fully utilize the regional soil survey and interpretive analyses and prohibit, under Chapters H62 and H65 of the Wisconsin Administrative Code, the subdivision of land for urban development, where such development will result in health problems created by the inability of the soils to absorb properly the sewage effluent.

Stream Basin Survey

It is recommended that the Wisconsin Department of Natural Resources, pursuant to its pollution control powers under Section 144.025 of the Wisconsin Statutes, continue to conduct periodic surveys of the Milwaukee River basin, including the collection and analyses of water samples, the monitoring of major sources of pollution, and the preparation of pollution control orders addressed each stream polluter. Such surveys, as continuing inventory efforts, should be made within the watershed at regular intervals of no more than five years. It is further recommended that the Department of Natural Resources reevaluate any

[17] *Ozaukee and Washington Counties have already adopted county sanitary codes.*

pollution control orders outstanding in the Milwaukee River basin and issue amended orders, as appropriate, to ensure implementation of the water pollution abatement plan element of the Milwaukee River watershed plan. Finally, it is recommended that the Department relate all future pollution control orders to the specific water pollution abatement elements contained in the Milwaukee River watershed plan.

Water Quality Monitoring Program

It is recommended that the Wisconsin Department of Natural Resources and the Southeastern Wisconsin Regional Planning Commission continue the cooperative water quality monitoring program previously inaugurated within the Region, increasing the sampling program to include monthly sampling and at selected locations and continuous sampling during one week of the summer season at selected locations. The cost of conducting this program is set forth in Table 131. This water quality monitoring program should be fully coordinated with the ongoing stream gaging efforts so that, in particular and insofar as possible, stream flow data is collected simultaneously with water quality data.

WATER SUPPLY PLAN ELEMENT IMPLEMENTATION

The recommended water supply plan element of the Milwaukee River watershed plan consists of management recommendations regarding the shallow sand and gravel, shallow dolomite, and deep sandstone aquifers and the establishment of municipal water supply systems at several locations throughout the watershed.

Ground Water Supply Management

It is recommended that the various municipalities in the watershed utilizing the shallow sand and gravel, the shallow dolomite, and the deep sandstone aquifers for water supply carefully consider the plan recommendations concerning well location and spacing, as set forth in Chapter VI of this volume, so as to achieve proper utilization of these three important aquifers. In addition, it is recommended that the county and local units of government in the watershed and in the Region carefully protect the recharge areas of these aquifers from improper land use development which might reduce the amount of recharge water reaching the aquifers or which might result in

Table 131

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED WATER RESOURCES MONITORING PROGRAM FOR THE MILWAUKEE RIVER WATERSHED BY COUNTY BY YEAR: 1971-1990

Calendar Year	Project Year	Milwaukee County: Two Water Quality Stations and One Stream Gaging Station		Ozaukee County: Five Water Quality Stations and Two Stream Gaging Stations		Washington County: Four Water Quality Stations and Two Stream Gaging Stations		Fond du Lac County: One Water Quality Station and One Stream Gaging Station		Total: Twelve Water Quality Stations and Six Stream Gaging Stations	
		Facility Construction	Operation and Maintenance[a]	Facility Construction[b]	Operation and Maintenance[a]	Facility Construction[c]	Operation and Maintenance[a]	Facility Construction	Operation and Maintenance[a]	Facility Construction	Operation and Maintenance
1971	1	$ --	$ 2,800	$6,000	$ 6,000	$6,000	$ 5,600	$ --	$ 2,400	$12,000	$ 16,800
1972	2	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1973	3	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1974	4	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1975	5	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1976	6	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1977	7	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1978	8	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1979	9	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1980	10	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1981	11	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1982	12	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1983	13	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1984	14	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1985	15	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1986	16	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1987	17	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1988	18	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1989	19	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
1990	20	--	2,800	--	6,000	--	5,600	--	2,400	--	16,800
Total		$ --	$56,000	$6,000	$120,000	$6,000	$112,000	$ --	$48,000	$12,000	$336,000
Annual Average		$ --	$ 2,800	$ 300	$ 6,000	$ 300	$ 5,600	$ --	$ 2,400	$ 600	$ 16,800

[a] Includes an estimated $400 annual operation and maintenance cost for each water quality monitoring station and an estimated $2,000 annual operation and maintenance cost for each continuous recording stream gaging station.

[b] Includes the reestablishment of the discontinued (1970) Cedarburg gage as a continuous recording stream gaging station.

[c] Includes the replacement of an existing staff gage at Kewaskum with a continuous recording stream gaging station.

Source- Harza Engineering Company and SEWRPC.

pollution of the aquifers. Such aquifers must be carefully protected from pollution through septic tank sewage disposal systems, dumps, and improperly located and operated sanitary landfills, urban and agricultural runoff, and excessive drawdowns. Implementation of the natural resource base protection plan element, as described earlier in this chapter, would achieve the necessary protection of the deep sandstone aquifer recharge areas, which lie to a considerable extent within the primary environmental corridors, by a combination of public acquisition and regulation.

Municipal Water Supply Systems

It is recommended that the Villages of Bayside, River Hills, and Thiensville and the City of Mequon jointly create a municipal water supply system to serve the combined area of these four municipalities. It is further recommended that this municipal water supply system utilize Lake Michigan as its source of water. The cost schedule for constructing the recommended water supply system is set forth in Table 132. It is recommended that the four units of government involved execute a voluntary intergovernmental cooperation agreement, pursuant to Section 66.30 of the Wisconsin Statutes, to effect the desired water supply system. Under this approach, each of the four local units of government would become a signatory to the intergovernmental agreement establishing a joint commission, which commission would, in turn, plan, build, maintain, and operate the necessary water supply intake, water treatment facilities, and primary transmission facilities. The contractual agreement would specify all of the necessary arrangements, including such matters as membership on the governing body, financing, and a method by which any ensuing conflicts could be arbitrated and resolved. This cooperative approach has the advantage of avoiding the creation of a special-purpose unit of government and relying instead upon the abilities and the resources of the existing general-purpose local units of government. It is further recommended that the Wisconsin Department of Natural Resources and the Wisconsin Public Service Commission approve the creation of such a joint utility to serve the four communities.

Table 132

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED WATER SUPPLY PLAN ELEMENT OF THE MILWAUKEE RIVER WATERSHED PLAN BY COUNTY BY YEAR: 1971-1990

		MILWAUKEE AND OZAUKEE COUNTIES	
		BAYSIDE-RIVER HILLS-MEQUON-THIENSVILLE WATER SUPPLY SYSTEM	
CALENDAR YEAR	PROJECT YEAR	FACILITY CONSTRUCTION°	OPERATION AND MAINTENANCE
1971	1	$ --	$ --
1972	2	530,800	--
1973	3	2,123,200	--
1974	4	2,123,200	--
1975	5	530,800	156,600
1976	6	--	156,600
1977	7	--	156,600
1978	8	--	156,600
1979	9	--	156,600
1980	10	--	156,600
1981	11	--	156,600
1982	12	--	156,600
1983	13	--	156,600
1984	14	--	156,600
1985	15	--	156,600
1986	16	--	156,600
1987	17	--	156,600
1988	18	--	156,600
1989	19	--	156,600
1990	20	--	156,600
TOTAL		$5,308,000	$2,505,600
ANNUAL AVERAGE		$ 265,400	$ 125,280

°INCLUDES WATER INTAKE; TREATMENT FACILITIES, AND MAJOR TRANSMISSION MAINS ONLY, DOES NOT INCLUDE A COMPLETE DISTRIBUTION NETWORK.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

It is recommended that individual municipal water utilities be established for the Villages of Cascade and Jackson and the unincorporated Villages of Newburg and Waubeka. All of these recommended utilities would utilize the ground water aquifer as the major source of water supply. Municipal water utilities could be created in the Villages of Cascade and Jackson. The existing Newburg Sanitary District could undertake the establishment of the water supply system for the unincorporated Village of Newburg. A sanitary district could be formed in the Town of Fredonia to provide the necessary water supply system for the unincorporated Village of Waubeka. It is recommended that the Wisconsin Department of Natural Resources and the Wisconsin Public Service Commission approve the creation of these water supply systems.

RELATIONSHIP OF WATERSHED PLAN TO REPORT OF THE MILWAUKEE RIVER TECHNICAL STUDY COMMITTEE

The Milwaukee River, and in particular the Milwaukee River in Milwaukee County and below the North Avenue Dam, was the subject of a technical study conducted by the Milwaukee River Technical Study Committee in the mid-1960's and summarized in a report entitled, The Milwaukee River:

an Inventory of its Problems, an Appraisal of its Potentials. This Technical Study Committee was appointed by the Mayor of the City of Milwaukee on July 5, 1963, for the purpose of preparing general recommendations as to the establishment of a sound development program for the Milwaukee River and river frontage lands in the City of Milwaukee. The Committee consisted of key staff members of the City and County of Milwaukee. The Committee's report was published in 1968.

The Committee's work focused primarily on the lower Milwaukee River downstream of the North Avenue Dam and dealt largely with aesthetic problems and the ways and means by which this major river could be revitalized and become a greater asset to the central business district of the major city in the Southeastern Wisconsin Region. As such, the Technical Study Committee made many detailed recommendations concerning aesthetic and related matters. Such recommendations included the development of a detailed river area master plan by the City of Milwaukee Plan Commission, with such plan focusing on very detailed land use considerations, regulatory controls for signs and waterfront structures, and the development of promenade and arcaded walks and planting and landscaping along the riverfront; the encouragement of the development of additional outdoor cafes and riverside restaurants together with picturesque shops and additional riverside apartments; the maintenance of an effective surface debris removal program and the development of a weed control program; and the development of public boat landings and pleasure craft moorings to encourage recreational boating both upstream and downstream of the North Avenue Dam. Most of these very detailed recommendations were directed at existing public agencies, particularly in the City of Milwaukee, and could be implemented utilizing powers now available to such agencies.

Although the great majority of the Milwaukee River Technical Study Committee recommendations, then, concerned very detailed land use and aesthetic considerations which go beyond the scope and depth of the more comprehensive, areawide Milwaukee River Watershed Study, some of the questions raised by the Committee and some of the resulting recommendations of the Committee do have implications for the watershed as a whole and do relate to the recommended comprehensive plan for the entire watershed. These include the following:

1. The Committee recommended that the North Avenue Dam be restudied for its hydraulic control effects. It was determined in the watershed study that the North Avenue Dam, if restored to its full operational potential, would have negligible effects upon major flood events on the Milwaukee River. An inspection of the dam made during the course of the watershed study found that the dam was generally in good repair and safe condition. It is recommended in the watershed plan, however, that more detailed engineering investigations be undertaken to more fully ascertain the soundness of this important dam. Such investigations should be undertaken by the owner of the dam, that is, by the City of Milwaukee through its Department of Public Works.

2. The Committee recognized the potential need to provide for upstream flood control measures. As discussed in detail in Chapter IV of this volume, seven major alternative flood control plan elements—six structural alternatives and one nonstructural alternative—were subject to detailed analysis in the comprehensive watershed study, including reservoir alternatives, diversion channel alternatives, dike-floodwall alternatives, and, finally, a structure removal and floodproofing plan element. None of the structural flood control mechanisms, however, were recommended for inclusion in the final comprehensive watershed plan.

3. The Committee recommended that a study be made of the possible use of the existing North Avenue flushing tunnel as a diversion channel to relieve floodwater accumulation. An investigation of the hydraulic capacity of the existing channel of the Milwaukee River from the North Avenue Dam to the confluence with the Menomonee River was completed as a part of the watershed study and, as described in Chapter XII of Volume 1 and Chapter IV of Volume 2 of this report, it was determined that if that reach were to experience a rare flood event consisting of the 100-year recurrence interval discharge of 16,700 cfs and a high Lake Michigan level of Elevation 583 feet Mean Sea Level (2.4 feet City of Milwaukee datum), the resulting peak

stages would cause only minor local overbank flooding. Additional flood flow relief, as might be provided by a modification of the flushing tunnel is, therefore, not needed.

4. The Committee recommended that efforts be expanded to control upstream pollution sources. The watershed plan contains a series of detailed recommendations, as outlined in Chapter V of this volume, designed to control the pollution from the major municipal waste sources, from the relatively few existing industrial waste sources, and from agricultural runoff in the upper watershed, as well as from both separate and combined sewer overflows in the lower watershed.

5. The Committee recommended that consideration be given to greater use of the flushing tunnel operation. It was determined in the watershed study that the flushing tunnel must continue to be operated at least until the water pollution control recommendations contained in the watershed plan are fully carried out. Alternatives for low flow augmentation which would have greatly reduced the needed time of operation for the flushing tunnel were evaluated in the planning process; such alternatives were not, however, included in the recommended comprehensive watershed plan.

6. The Committee recommended that study be given to the installation of cascade steps at the North Avenue Dam to increase the amount of oxygen in the lower river. The watershed study recommendations for the upper Milwaukee River watershed, if fully carried out, would result in maintaining the dissolved oxygen levels in the entire river system above the state standards and would render unnecessary the installation of such cascade steps on the North Avenue Dam.

7. The Committee encouraged the exploration of new ideas for the resolution of the combined sewer overflow pollution problem. The watershed study has recommended a far-reaching program for control of pollution from combined sewer overflows, including the construction of deep tunnel intercepting sewers and a mined storage area under the Milwaukee Harbor, combined with flow-through treatment procecures prior to discharge of the combined sewer overflows to Lake Michigan.

8. The Committee recommended that the dock elevation requirement set by City ordinance be raised from the present level of 2'-10" (Milwaukee datum) to 4'-0". Hydrologic and hydraulic analyses completed as part of the watershed study indicated that the Milwaukee-Metropolitan Sewerage Commission's recommended flood protection elevation of 586.6 feet Mean Sea Level (4.0 feet City of Milwaukee datum), as established in 1952, is sufficient to provide without a freeboard provision, against the 100-year recurrence interval flood event for riverine properties along the Milwaukee River from the harbor to the Cherry Street Bridge. It is recommended, however, that flood protection elevations in excess of 584.6 feet MSL be used upstream of the Cherry Street Bridge, such elevations being determined from hydraulic data set forth in Appendices F and G of this volume.

9. The Committee made several recommendations concerning the reclamation of the upper Milwaukee River above the North Avenue Dam to Estabrook Park. The recommended comprehensive plan for the Milwaukee River watershed includes the development of a continuous Milwaukee River parkway along the Milwaukee River to Estabrook Park and assigns jurisdiction for the development of the parkway and adjacent related lands to the Milwaukee County Park Commission.

10. The Committee recommended the creation of a Milwaukee River Advisory Board to assist and advise the City of Milwaukee Plan Commission and county agencies in the revitalization efforts for the Milwaukee River in Milwaukee County. This Advisory Board would be composed of civic and business interests from the City of Milwaukee and the cities and villages along the Milwaukee River upstream from the City of Milwaukee in Milwaukee County as well as public officials who served on the Technical Study Committee. The water-

shed study recommendations include the retention of the existing Milwaukee River Watershed Committee to provide for a continuing public body to monitor development in the watershed and to advise the Regional Planning Commission as to any needed changes in plan implementation recommendations. In addition, the watershed study recommends that consideration be given to the formation of a comprehensive river basin district to provide for plan implementation should the county and local units of government which are charged with the responsibility for plan implementation evidence a lack of interest in pursuing vigorously the necessary plan implementation actions. It is suggested, therefore, that the Milwaukee River Watershed Committee could perform the "public watchdog" function suggested by the Technical Study Committee for a special Milwaukee River Advisory Board. In addition, it is recognized that the Greater Milwaukee Committee, a committee of leading citizens in the Milwaukee metropolitan area, has evidenced special interest in the revitalization of the Milwaukee River particularly in Milwaukee County, and it is suggested that this ongoing Committee could be given the function of a "private watchdog" agency to sustain public interest in the revitalization of the Milwaukee River and to sustain pressure on public agencies and private interests toward watershed plan implementation through the preparation of more detailed plans at the local level. In this respect, it should be emphasized that implementation of the watershed plan will require the preparation of more detailed development plans particularly along the river itself and particularly in the developed and developing areas of the river. Local plan commissions, such as the City of Milwaukee Plan Commission, must pursue vigorously the preparation, adoption, and implementation of such detailed master development plans.

RELATIONSHIP OF THE WATERSHED PLAN TO ENVIRONMENTAL IMPACT STATEMENTS

Section 102(c) of the National Environmental Policy Act of 1969 requires the preparation by appropriate officials of detailed statements which assess the impact on the environment of nearly all development proposals and projects which in any way involve federal participation. Such statements must be addressed at an assessment of the environmental impact of the proposed project, at any unavoidable adverse environmental effects, at alternatives to the proposed project, at the relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity, and at any irreversible and irretrievable commitments of natural resources caused by the proposed project. Such environmental impact statements are intended to provide an additional basis for the review of proposed capital improvement projects and are important in assuring that the decision-making process with respect to federally aided public works of improvement includes adequate considerations of the potential effect of the project on the environment. The inventory data, extensive analyses, alternative plan elements, and recommended comprehensive plan for the Milwaukee River watershed presented in summary form in the two volumes of this planning report constitute, in effect, a comprehensive environmental impact statement. As a comprehensive design for the preservation and protection of the natural resource base and for the maintenance and enhancement of the overall quality of the environment within the Milwaukee River watershed, the plan should provide the basis for the preparation of future environmental impact statements with respect to specific proposals for land and water resource related public works construction within the watershed. Moreover, each such future environmental impact statement should be carefully related to the recommended comprehensive watershed plan and should demonstrate how the particular project under consideration would assist in achieving the objectives, principles, and standards which underlie and have formed the basis for the recommended comprehensive watershed plan.

FINANCIAL AND TECHNICAL ASSISTANCE

Upon adoption of the various land use, natural resource protection, park and outdoor recreation, parkway and scenic drive, flood control, and pollution abatement watershed plan elements and any necessary schedules of capital costs, it becomes necessary for the areawide governmental agencies concerned and the local units of government within the watershed to utilize effectively all sources of financial and technical assistance available for the timely execution of the recommended plan elements. In addition to current tax revenue sources, such as property taxes, fees, fines, public utility earnings, highway aids, educational aids, and state collected taxes, the areawide agencies and local units of government can also make use of other revenue sources, such as borrowing, special taxes and assessments, state and federal grants, and gifts. Various types of technical assistance useful in plan implementation are also available from county, state, and federal agencies. The type of assistance extends from the technical advice on land and water management practices provided by the U. S. Soil Conservation Service to the educational, advisory, and review services offered by the University of Wisconsin and the Regional Planning Commission itself.

Borrowing

Areawide agencies and local units of government are normally authorized to borrow so as to effectuate their powers and discharge their duties. Chapter 67 of the Wisconsin Statutes generally empowers counties, cities, villages, and towns to borrow money and to issue municipal obligations not to exceed 5 percent of the equalized assessed valuation of its taxable property, with certain exceptions, including school bonds and revenue bonds. Such borrowing powers, which are related directly to implementation of the comprehensive Milwaukee River watershed plan, include:

1. Counties may issue bonds for county park and related open-space land acquisition and development.

2. Cities and villages may borrow and issue bonds for the construction of water supply and distribution systems, sanitary sewerage systems, and sewage treatment plants and for park and related open-space land acquisition and development.

3. Towns may issue bonds for acquiring river fronts, lakeshores, woodlots, and scenic and historic sites.

Section 60.307 of the Wisconsin Statutes specifically authorizes town sanitary districts to borrow money and to issue bonds for the construction or extension of storm sewer, sanitary sewer, and water supply systems. Sections 66.202 and 59.96(7) of the Wisconsin Statutes authorize metropolitan sewerage districts to borrow money and to issue bonds for the construction of sanitary sewerage facilities. Farm drainage boards are authorized under Section 88.12 of the Wisconsin Statutes to issue bonds for any and all of their functions. In addition, the powers of cooperative contract commissions created under Section 66.30 of the Wisconsin Statutes were recently clarified[18] to include borrowing by the contracting bodies of such commissions for acquiring, constructing, and equipping areawide projects.

Federal Loans: Federal advances and loan programs are available not only for the planning and construction of public works but also for resource conservation. A brief description of those federal loan programs of significance to Milwaukee River watershed plan implementation are:

1. Interest free advances for public works planning are available to local units of government from the U. S. Department of Housing and Urban Development to assist in planning essential public works and community facilities. These advances are to be repaid when construction begins.

2. Long-term construction loans are available to local units of government under 50,000 population and their agencies from the U. S. Department of Housing and Urban Development for needed public facilities for which financing is not available elsewhere on reasonable terms.

3. Resource conservation and development loans are available to local units of government and soil and water conservation districts from the U. S. Department of Agriculture for planning and carrying out a balanced program of resource conservation development and utilization.

4. Low interest forestry loans are available to farmers and farm associations from the U. S. Farmers Home Administration for reforestation and the establishment of forestry practices and programs.

5. Recreation loans are available to farmers from the U. S. Stabilization and Conservation Service for purchasing and developing land and water recreation resources and facilities, including private camping

[18] *Chapter 238, Laws of Wisconsin, 1965.*

grounds, swimming areas, tennis courts, cottages, lakes, docks, nature trails, and shooting preserves.

6. Rural water and sewer development loans are available to rural units of government from the U. S. Farmers Home Administration for developing water supply and waste disposal systems. To qualify, such rural units of government must have less than 5,500 population and be unable to obtain financial assistance elsewhere.

Special Taxes and Assessments

Counties and cities have special assessment powers for park and parkway acquisition and improvements under Sections 27.065 and 27.10(4), respectively, of the Wisconsin Statutes. Counties are empowered under Section 27.06 of the Wisconsin Statutes to levy a mill tax to be collected into a separate fund and to be paid out only upon order of the county park commission for the purchase of land and other commission expenses. Farm drainage boards, town sanitary districts, metropolitan sewerage districts, cities, and villages also have taxing and special assessment powers under Sections 88.06, 63.06, 60.309, 59.96(9), and 62.18(16) of the Wisconsin Statutes. Although soil and water conservation districts have no taxing, bonding, or assessment powers, such districts may recover the cost and expenses, with interest, of performing work or operations, as authorized by a court under Section 92.11 of the Wisconsin Statutes.

Park and Open-Space Land and Development Grants

Several federal grant programs are available to state and local units of government, and one state grant program is available to local units of government for the financing of park land acquisition and development. In general, the local units of government and agencies in the Region are eligible for these grants; however, the eligibility of individual projects is based upon certain planning and other prerequisites and must be determined for each specific project. The following is a brief description of these programs.

State Local Park Aids Program (ORAP): This program, administered by the Wisconsin Department of Natural Resources, provides grants to all local units of government in amounts up to 50 percent of the cost of acquiring and developing recreational lands and rights-in-land to be used for local park and open-space systems. Such state funds can also be used to help match federal funds.

Federal Open-Space Land Program: This program, administered by the U. S. Department of Housing and Urban Development, provides grants to the state and local units of government in amounts up to 50 percent of the cost of acquisition and development of land for parks and open spaces.

Federal Land and Water Conservation Fund: This program, administered by the U. S. Department of the Interior, Bureau of Outdoor Recreation, through the Wisconsin Department of Natural Resources, provides grants to state and local units of government in amounts up to 50 percent of the cost of acquisition and improvement of outdoor recreation areas.

Federal Cropland Adjustment Program (Greenspan): This program, administered by the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, provides grants to local units of government in amounts up to 50 percent of the cost of acquisition and conservation of cropland to park and recreation purposes.

Federal Urban Beautification Program: This program, administered by the U. S. Department of Housing and Urban Development, provides grants to local units of government in amounts up to 50 percent of the cost of improving and beautifying publicly owned or controlled land.

Water Supply and Sewerage System Grants

Several state and federal grant programs are available to local units of government for the financing of water systems, sewer facilities, storm water drainage systems, and sewage treatment facilities. A brief description of these programs follows.

State Water Pollution Prevention and Abatement Program: This program, administered by the Wisconsin Department of Natural Resources, provides financial assistance in amounts up to one-fourth of the total cost of approved pollution prevention and abatement projects. Such monies can be used to help match available federal funds.

Federal Water and Sewer Facilities Program: This program, administered by the U. S. Department of Housing and Urban Development, provides grants up to 50 percent to local units of government, including sewer and water districts, toward the cost of constructing water supply, treatment, storage, and transmission systems; sanitary sewer collection and transmission systems; and storm water collection and transmission systems.

Federal Water Pollution Control Program: This program, administered by the U. S. Environmental Protection Agency, Water Quality Office, provides grants up to 55 percent to local units of government toward the cost of constructing sewage treatment works and intercepting sewers that prevent the discharge of untreated or inadequately treated sewage into any waters. Projects must be in conformance with an approved areawide system plan.

Federal Farmers Home Administration Programs: A number of programs administered by the U. S. Department of Agriculture, Farmers Home Administration, provide grants toward the cost of developing domestic water supply and waste collection and disposal systems to rural units of government up to 5,500 population, if these units of government are unable to obtain credit at reasonable terms.

Soil and Water Conservation Grants

There are several programs available for conservation and protection of the agricultural lands and environmental corridors recommended in the Milwaukee River watershed plan for preservation. A brief description of these programs follows.

State Soil and Water Conservation Program: This program, administered by the State Soil Conservation Board, provides grants to the county soil and water conservation districts in amounts up to 50 percent toward the cost of approved soil and water conservation projects.

Federal Rural Environmental Assistance Program: This program, administered by the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, provides grants in amounts up to 50 percent of the total project cost to farmers for carrying out approved soil, water, woodland, and wildlife conservation practices.

Federal Resource Conservation and Development Program: This program, administered by the U. S. Department of Agriculture, Soil Conservation Service, provides cost sharing up to 100 percent for flood control and sediment control works and up to 50 percent for construction of water conservation works, structural recreation works, and improved land use measures.

Federal Cropland Adjustment Program: This program, also administered by the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, provides grants in amounts up to 50 percent of the cost to farmers to divert cropland to protective conservation uses for 5- to 10-year periods, the cost being based upon the value of the crops which would be produced. This program also provides cost sharing up to 50 percent toward the cost of carrying out good conservation practices, such as establishment of vegetative cover, forest cover, good wildlife habitat, and preservation of natural beauty.

Federal Multiple-Purpose Watershed Program: This program, administered by the U. S. Department of Agriculture. Soil Conservation Service, through the State Soil Conservation Board, provides cost sharing up to 100 percent to qualified sponsors, such as soil and water conservation, flood control, drainage, or irrigation districts, for flood prevention works and up to 50 percent towards agricultural water management, public recreation, fish and wildlife development, acquisition of certain recreational land rights, and agricultural land planning and treatment.

State Water Quality Regulation Enforcement Program: This program, administered by the Wisconsin Department of Natural Resources, provides annual grants to counties in amounts up to $1,000 in partial support of the cost of administering and enforcing county water protection or shoreland use regulations.

Federal Water Resources Investigation Program

The U. S. Department of the Interior, Geological Survey, administers a cooperative water resources investigation program that provides federal matching funds in amounts up to 50 percent of the cost of projects under the program. This program includes the installation, calibration, operation, and maintenance of stream gage recording stations.

General Works Projects—U. S. Army Corps of Engineers

Substantial federal financial and technical assistance is available for the construction of approved flood control works under the general works projects program carried out by the U. S. Army Corps of Engineers upon U. S. Congressional approval of a particular project. After feasibility studies and public hearings, the U. S. Army Corps of Engineers will undertake the construction of such flood control works as levees, dams, and reservoirs. All lands, easements, and necessary rights-of-way and other costs in accordance with established cost sharing policies, however, must be provided by the local unit of government. In addition, the local unit of government must agree to maintain and to operate all facilities constructed under the program in accordance with regulations prescribed by the Secretary of the Army. Although the Milwaukee River watershed plan contains no recommendations for such structural flood control facilities, should the Waubeka Reservoir be reintroduced as a recommended plan element, the U. S. Army Corps of Engineers should be requested to evaluate the proposed project, giving due weight to the comprehensive watershed plan recommendations.

Gifts

Donations of lands, interests in lands, or monies from private individuals and corporations should not be overlooked as sources of possible assistance in regional plan implementation, particularly with respect to park acquisition and environmental corridor preservation. The potential contributions, both in leadership and funds, from private groups should not be underestimated. Such gifts, either in lands, interests in lands, or monies, may, moreover, be used toward the local contribution in obtaining various state and federal grants.

Technical Assistance

Certain federal, state, regional, and county agencies provide various levels and types of technical assistance useful in watershed plan implementation to local units of government upon request. Limited guidance and assistance is usually provided without cost, or such assistance may be provided for a nominal fee. In some cases the local unit of government may contract with the agency for more extensive technical assistance services. A summary of the various levels and types of assistance available by agency follows.

Federal Agencies: The U. S. Department of Agriculture, Soil Conservation Service, provides technical assistance to local units of government and soil and water conservation districts for resource conservation, development, and utilization programs. The Soil Conservation Service also provides technical assistance to local units of government in the adaptation of the detailed operational soil survey and interpretive analyses to urban planning and development problems under a "Memorandum of Understanding" with the Commission.

The U. S. Department of Agriculture, Farmers Home Administration, provides technical and management assistance to farmers and farm associations for forestry programs, soil improvement, fish production, and recreation enterprise.

The U. S. Department of the Interior, Bureau of Outdoor Recreation, provides limited technical assistance and advice to local units of government and private interests in recreational resource planning and programming.

The U. S. Environmental Protection Agency provides technical assistance and advice on request at no cost to state and local units of government and private firms relative to water quality problems.

State Agencies: The University of Wisconsin Extension, through the county agents and extension specialists, provides important educational and technical assistance to farmers and to local units of government in public affairs, soil and water conservation, and outdoor recreation. An example of such university assistance having a direct relationship to watershed plan implementation is the educational services on the use and adaptation of the detailed operational soil survey and interpretive analyses being provided under the previously cited "Memorandum of Understanding" between the University and the Commission. Since the work of the Commission is entirely advisory, the importance of organized educational efforts directed at achieving public understanding and acceptance of the regional plans cannot be overestimated. The University Extension can, in this respect, fulfill an indirect, yet most important, plan implementation function.

The Wisconsin Department of Natural Resources provides advice on water problems; fish management; and forest planting, protection, management, and harvesting and will contract with counties to prepare outdoor recreation plans which would establish county eligibility under the Federal Land and Water Conservation Program.

The Wisconsin Department of Natural Resources provides plan review services and supervision of the operation of public water supply and sewage treatment facilities and is authorized to provide technical assistance to local units of government and private groups in their efforts to initiate or engage in specific types of development, such as parks, recreation, resource development, water supply, and sewage disposal. The Department was recently authorized to extend assistance to local units of government for the purpose of securing uniformity of water resource protection regulations.

The State Soil Conservation Board is authorized to provide assistance to landowners and the county soil and water conservation districts in carrying out soil and water conservation practices.

Areawide Agencies: The Southeastern Wisconsin Regional Planning Commission, through its Community Assistance Division, provides limited educational, advisory, and review services to the local units of government, including participation in educational programs, such as workshops; provision of speakers; sponsorship of regional planning conferences; publication of bimonthly newsletters; selection of staff and consultants; preparation of planning programs; special base and soil mapping; preparation of suggested zoning, official mapping, and land division ordinances; information regarding federal and state aid programs; and the review of local planning programs, plan proposals, ordinances, and most state and federal grant applications. In addition, the Commission is empowered to contract with local units of government under Section 66.30 of the Wisconsin Statutes to make studies and offer advice on land use, transportation, community facilities, and other public improvements.

County Agencies: The County Soil and Water Conservation Districts are authorized to cooperate in furnishing technical assistance to landowners or occupiers and any public or private agency in preventing soil erosion and floodwater and sedimentation damage and in furthering water conservation and development.

Those counties with park or planning staffs provide certain technical services related to park design and general community planning and development problems to local units of government and private groups.

SUMMARY

This chapter has described the various means available and has recommended specific procedures for implementation of the recommended comprehensive Milwaukee River watershed plan. The most important recommended plan implementation action are summarized in the following paragraphs by level of government, responsible agency or unit of government, and plan elements.

State Level

Wisconsin Department of Natural Resources: It is recommended that the State Natural Resources Board and the Department of Natural Resources:

1. Endorse the comprehensive Milwaukee River watershed plan and direct its integration into the various conservation, park and outdoor recreation, environmental protection, water control, and technical and financial assistance programs conducted by various divisions of the Department.

2. Certify the Milwaukee River watershed plan to the U. S. Environmental Protection Agency as a river basin plan for state and federal planning purposes.

3. Conduct periodic water pollution control surveys of the Milwaukee River basin and reevaluate, amending as necessary, and enforce outstanding pollution control orders in accordance with pollution abatement recommendations, as set forth in the Milwaukee River watershed plan.

4. Endorse the recommended water pollution abatement plan element for the lower Milwaukee River watershed which seeks to abate the pollution from the combined sewer overflows and reflect such endorsement in amended pollution abatement orders to the City of Milwaukee Sewerage Commission.

5. Cooperate with towns, villages, and cities of the watershed in the establishment of utility or sanitary districts, as necessary, to provide sanitary sewerage systems and sewage treatment facilities at nine major lakes: Big Cedar, Ellen, Forest, Green, Kettle Moraine, Little Cedar, Random, Silver, and Wallace Lakes.

6. Seek additional state-enabling legislation relative to the establishment of areawide or metropolitan sewerage districts so that: a) a feasible alternative exists for the establishment of an areawide sanitary sewerage system in the Cedarburg-Grafton area of the watershed and b) a feasible alternative exists for the establishment of areawide sanitary sewerage systems and sewage treatment plants, where necessary, at the nine major lakes noted above.

7. Give due weight to the recommended Milwaukee River watershed plan in the exercise of the Department's various water regulatory functions, including approval of the establishment of bulkhead lines and the undertaking of channel improvements.

8. Encourage counties and local units of government in the watershed to follow the watershed plan recommendations relative to floodland and shoreland zoning when review is made of floodland and shoreland zoning ordinances prepared by such local units of government, pursuant to Sections 59.971 and 87.30 of the Wisconsin Statutes.

9. Adapt the regional soil survey and analyses as a guide in regulating the installation of soil absorption sewage disposal systems within the watershed, prohibiting the installation of such systems on soils within the watershed that have very severe limitations for the absorption of sewage effluent, as determined by the detailed operational soil surveys.

10. Endorse and integrate the environmental corridors and other high-value wetlands and woodlands shown on the recommended Milwaukee River watershed plan into the state long-range conservation and outdoor recreation plans as a guide to park and related open-space development and to resource conservation and management practices within the watershed.

11. Acquire those urban environmental corridor and Milwaukee River main stem environmental corridor lands located to the north and west of the City of West Bend and in the Tri-Lakes area of the watershed and attach such acquisitions to the Northern Unit of the Kettle Moraine State Forest. Expand the boundaries of the Northern Unit of the Kettle Moraine State Forest as soon as practicable to include such future land acquisitions.

12. Establish a new State Recreation Area at the Lucas Lake-Paradise Valley park site southwest of the City of West Bend, located on lands purchased under the foregoing environmental corridor acquisition recommendation, in order to provide a third major state recreation area in the Northern Unit of the Kettle Moraine State Forest.

13. Acquire those recommended high-value woodland areas in environmental corridors totaling 3,401 acres as expansions to the existing Northern Unit of the Kettle Moraine State Forest in Fond du Lac, Sheboygan, and Washington Counties.

14. Acquire those recommended high-value wetland areas in environmental corridors totaling 16,040 acres around the Jackson Marsh and Wayne Marsh areas in Washington County, the Cedarburg Bog and Huiras Lake areas in Ozaukee County, the Kettle Moraine Lake area in Fond du Lac County, and the Adell Swamp area in Sheboygan County.

15. Assign the highest appropriate priorities to all LAWCON or ORAP local park aid applications for land located within the urban environmental corridors and along the main stem of the Milwaukee River.

16. Approve only such applications for state and federal aids in partial support of the construction and improvement of municipal pollution prevention and abatement facilities that are located and designed in general accordance with the recommended Milwaukee River watershed plan.

17. Recommend to the State Legislature that consideration be given to the establishment of a Greenway Tax Law patterned after the well-established Forest Crop Law and directed toward providing property tax incentives for private landowners who retain and manage high-value woodlands throughout the watershed and the state.

18. Increase the amount of technical aid and assistance to private landowners relative to the proper management of woodland and wetland resources.

19. Approve the creation of a municipal water utility to serve the Villages of Bayside, River Hills, and Thiensville and the City of Mequon and individual water supply systems to serve the Village of Cascade and Jackson and the unincorporated Villages of Newburg and Waubeka.

Wisconsin Department of Local Affairs and Development: It is recommended that the Wisconsin Department of Local Affairs and Development:

1. Endorse the comprehensive Milwaukee River watershed plan and direct its integration into the various functions of the Department.

2. Give due weight to the recommended Milwaukee River watershed land use plan element in reviewing proposed annexations, incorporations, and consolidations.

3. Promote implementation of the Milwaukee River watershed plan in its program of providing technical assistance to local units of government.

4. Take the lead in initiating a legislative study designed to probe the inconsistencies now existing between property taxation and land development policies in Wisconsin and recommend appropriate remedial action.

Wisconsin Department of Transportation: It is recommended that the Department of Transportation:

1. Give due weight to the recommended Milwaukee River watershed plan in its transportation facility planning and construction activities, with particular respect to the replacement of bridge structures in the stream valleys of the watershed so that the flood control objectives of the watershed plan are achieved.

2. Coordinate the establishment, signing and marking, and maintenance of the recommended system of Milwaukee River scenic drives in cooperation with the five county highway committees concerned.

Wisconsin Department of Health and Social Services, Division of Health: It is recommended that the Health and Social Services Board and the State Division of Health:

1. Endorse the comprehensive Milwaukee River watershed plan, with particular respect to the land use plan element and the rational urban service areas implied therein in the exercise of its subdivision review and approval powers.

2. Adopt the regional soil survey and analyses as a guide in reviewing subdivision plats so as to prohibit the installation of soil absorption sewage disposal systems on soils that have very severe limitations for such systems, thereby delaying the subdivision of land covered by such soils until such time as public sanitary sewerage service becomes available.

Wisconsin Soil Conservation Board: It is recommended that the Wisconsin Soil Conservation Board:

1. Endorse the comprehensive Milwaukee River watershed plan, with particular respect to the recommended land use plan element, including the agricultural land use and environmental corridor recommendations, as a guide in the coordination of County Soil and Water Conservation Districts projects.

2. Apportion appropriate federal and state funds to the County Soil and Water Conservation Districts within the watershed to enable them to implement agricultural land management programs which serve to implement the recommended watershed plan.

Local Level

Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington County Boards of Supervisors: It is recommended that the County Boards of the five major constituent counties comprising the Milwaukee River watershed, upon the recommendation of the appropriate agencies and committees:

1. Adopt the recommended Milwaukee River watershed plan, as it applies to each county, as a guide to the future development of the Milwaukee River watershed portion of the county.

2. Support the establishment of the Milwaukee River Watershed Committee by the Southeastern Wisconsin Regional Planning Commission as a continuing intergovernmental advisory body concerned with watershed plan adjustment and implementation.

3. Consider the establishment of a county park and planning commission and reassign, as appropriate, all county zoning, subdivision plat review, and park and recreation functions (Fond du Lac, Sheboygan, and Ozaukee).[19]

4. Officially adopt the comprehensive park and parkway elements of the Milwaukee River watershed plan upon recommendation of the appropriate county park and planning agencies.

5. Adopt the recommended "Schedules of Capital Costs" set forth herein for plan implementation and allocate annually the monies as so scheduled, including the purchase of land designated as urban environmental corridor, main stem environmental corridor, and selected additional environmental corridor.

6. Amend the county comprehensive zoning ordinance or the county floodland and shoreland zoning ordinance, as it applies to riverine areas, to provide for the eventual elimination of flood-vulnerable structures located in the floodways of the Milwaukee River through nonconforming use provisions and to provide, in addition, for sound floodland use regulations (Fond du Lac, Ozaukee, Sheboygan, and Washington Counties).

7. Continue the operation and maintenance of streamflow gages and establish new gages (Fond du Lac, Ozaukee, and Washington Counties).

8. Amend the county zoning ordinance, as it applies to the entire watershed, to provide for the recommended exclusive residential, agricultural, conservancy, and park districts (Fond du Lac, Sheboygan, and Washington Counties).

[19] *Parentheses indicate that the recommended action is only applicable to the named unit or units of government.*

9. Review and amend, as appropriate, the recently adopted county shoreland zoning ordinances to ensure that the objectives of the recommended Milwaukee River watershed plan will be achieved (Fond du Lac, Ozaukee, Sheboygan, and Washington Counties).

10. Adopt soil and conservation land use regulations, as formulated by the soil and water conservation district supervisors.

11. Adopt a county sanitary code, applicable on a county-wide basis, to provide for the regulation of the design and installation of septic tank sewage disposal systems utilizing detailed soil survey data (Fond du Lac and Sheboygan Counties).

12. Report to the Wisconsin Department of Natural Resources any alleged encroachments on the navigable channels of the Milwaukee River system.

13. Create or amend the county subdivision control ordinance to prohibit further land division and development in the floodways and floodplains of the Milwaukee River watershed and to provide park land dedication or fees in lieu of dedication.

14. Support attempts to seek additional state-enabling legislation relative to the establishment of areawide or metropolitan sewerage districts.

15. Establish, in cooperation with the Wisconsin Department of Transportation and upon recommendation of the respective county highway committee, the establishment of a Milwaukee River scenic drive system.

Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington County Park and Planning Agencies: It is recommended that the Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington County park and planning agencies:

1. Recommend to the county board adoption of the recommended natural resource protection, park and outdoor recreation, and parkway and scenic drive plan elements of the Milwaukee River watershed plan.

2. Formulate and petition the county board to adopt appropriate amendments to the

existing county zoning ordinances to effectuate the watershed land use plan element (Fond du Lac, Ozaukee, Sheboygan, and Washington Counties).

3. Formulate detailed county plans for the ultimate acquisition of all recommended urban environmental corridors, rural environmental corridors along the main stem of the Milwaukee River, and selected additional environmental corridors.

4. Include in the detailed county park plan measures for the ultimate removal on a voluntary basis of existing residences located in the floodways of the Milwaukee River and its major tributaries.

5. Expand the existing Hawthorne Hills County Park into a major regional outdoor recreation area (Ozaukee County).

6. Acquire and ultimately develop all additional high-value outdoor recreation sites, as set forth in the recommended watershed plan (Fond du Lac, Ozaukee, Sheboygan, and Washington Counties).

7. Request the Wisconsin Department of Natural Resources by resolution to expand the boundaries of the Northern Unit of the Kettle Moraine State Forest to include urban and main stem environmental corridor lands south of the Village of Kewaskum and west of the City of West Bend Washington County); develop a major state recreation area at the Lucas Lake-Paradise Valley park site (Washington County); acquire additional high-value wetlands (Fond du Lac, Ozaukee, Sheboygan, and Washington Counties); acquire additional high-value woodlands (Fond du Lac, Sheboygan, and Washington Counties).

8. Develop the recommended Milwaukee River parkway pleasure drive from Lincoln Memorial Drive near the McKinley Marina to and along the Milwaukee River valley to a junction with the existing Estabrook Parkway Drive (Milwaukee County).

Soil and Water Conservation Districts: It is recommended that the Soil and Water Conservation Districts of Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties:

1. Adopt the recommended Milwaukee River watershed plan as it affects each respective district and request those federal and state agencies existing in the district to provide such assistance as would serve to implement the recommended land use, natural resource protection, and water pollution abatement plan elements.

2. Formulate, as appropriate, soil and water conservation regulations necessary to assist in implementation of the recommended watershed land use and natural resource protection plan elements.

Common Councils, Village Boards, and Town Boards: It is recommended that, upon referral to, and upon recommendation of, the local plan commissions, each common council, village board, and town board within the watershed, as appropriate and as noted:

1. Support the establishment of the Milwaukee River Watershed Committee as a continuing intergovernmental coordinating body concerned with the Milwaukee River watershed plan adjustment and implementation.

2. Adopt the recommended Milwaukee River watershed plan as a guide to the future development of the community as that plan effects each community.

3. Amend existing or adopt new local zoning ordinances so as to provide land use regulations similar to those contained in the SEWRPC Model Zoning Ordinance and adopt changes to the zoning district maps, as appropriate, to reflect the recommended land use plan element of the Milwaukee River watershed plan. Include in such ordinances floodland and shoreland regulations, as appropriate and as necessary, to achieve the objectives of the Milwaukee River watershed plan. Such regulations should include provisions for the discontinuance of nonconforming uses in the floodways of the watershed.

4. Instruct local assessors that tax relief is available for owners of land zoned for agricultural and conservancy use in accordance with the recommended Milwaukee River watershed plan.

5. Amend or adopt land division ordinances, as appropriate, prohibiting further land division and development in the floodways and floodplains of the perennial channel system of the Milwaukee River watershed and assuring park plan dedication or fees in lieu of dedication.

6. Prepare and adopt or amend official maps showing, as appropriate, park and parkway land use plan elements.

7. Include floodway and floodplain regulations in local building, housing, subdivision, and sanitary ordinances.

8. Consider and give due weight to the rational urban service areas implied in the Milwaukee River watershed plan in all deliberations concerning proposed annexations, consolidations, and incorporations.

9. Establish an intergovernmental cooperative sewerage commission or metropolitan sewerage commission to provide for a joint advanced waste treatment facility to serve the Cedarburg-Grafton area (City of Cedarburg, Village of Grafton, Towns of Cedarburg and Grafton).

10. Contract with the Metropolitan Sewerage District of Milwaukee County to provide for sewage treatment services and abandon the existing municipal sewage treatment plant (Village of Thiensville).

11. Establish a municipal sanitary sewerage system and provide contractual sewer service to the Lake Ellen area (Village of Cascade and Town of Lyndon Sanitary District No. 1).

12. Provide for tertiary waste treatment and provide sewer service to remaining developed areas around Random Lake (Village of Random Lake).

13. Provide for continued secondary waste treatment and post-chlorination for disinfection of effluent (Villages of Adell and Fredonia and the Newburg Sanitary District).

14. Provide for advanced waste treatment (90 percent phosphorus removal) and post-chlorination for disinfection of effluent (Villages of Campbellsport, Jackson, Kewaskum, and Saukville).

15. Provide for advanced waste treatment (90 percent phosphorus removal), post-chlorination for disinfection of effluent, and instream aeration and provide contractual sewer service to the Tri-Lakes and Wallace Lakes sewer service areas or form metropolitan sewerage district (City of West Bend).

16. Establish such sanitary or utility districts, as necessary, to implement the recommendations governing the establishment of sanitary sewerage systems at the following major lakes: Forest, Green, and Kettle Moraine (Towns of Auburn, Farmington, and Osceola).

17. Establish such sanitary or utility districts, as necessary, to implement the recommendations governing the conduct of weed harvesting and algae control programs at the following major lakes: Auburn, Crooked, Long, Lucas, Smith, and Twelve (Towns of Auburn, Scott, Osceola, West Bend, Barton, and Farmington).

18. Assist the county park agencies in the acquisition of all lands lying within the urban environmental corridors, the rural environmental corridors along the main stem of the Milwaukee River, and in selected additional environmental corridors.

19. Acquire and develop all other potential outdoor recreation sites as recommended in the Milwaukee River watershed plan and not recommended for county level acquisition and development.

20. Approve county official maps governing park and parkway acquisition adopted pursuant to the recommendations contained herein.

21. Establish a joint municipal water utility (City of Mequon, Villages of Bayside, River Hills, and Thiensville).

22. Establish municipal water supply systems (Village of Cascade and Jackson and unincorporated Villages of Newburg and Waubeka).

Plan Commissions of the Cities, Villages, and Towns within the Watershed: It is recommended that the plan commissions of all cities, villages, and towns within the watershed:

1. Adopt the watershed plan elements and certify such adoption to the governing body.

2. Formulate and recommend to their governing body amendments to their existing land use control ordinances to effectuate the land use plan elements of the watershed plan.

3. Prepare for submission to the governing body detailed local plans relative to the acquisition of urban environmental corridors, rural environmental corridors along the main stem of the Milwaukee River, and selected additional environmental corridors, as well as selected high-value and other potential outdoor recreation sites.

Municipal Water and Sanitary Districts: It is recommended that any municipal water and sanitary district now existing or hereinafter created within the watershed:

1. Acknowledge the recommended watershed plan, thereafter determining proper utility service areas in accordance with such plan, and adopt and adhere to utility extension policies that are consistent with the rational urban service area implied by the plan.

2. Implement the recommendations governing the establishment of sanitary sewerage systems at the following major lakes: Big Cedar, Ellen, Little Cedar, Silver, and Wallace (Big Cedar Lake Sanitary District, Town of Lyndon Sanitary District No. 1, Little Cedar Lake Sanitary District, Silver Lake Sanitary District, and Wallace Lake Sanitary District).

3. Design and install public water supply and sewerage systems so as to preclude service by such systems to proposed development located in floodplains, on soils having very severe or severe limitations for urban development, or within the recommended regional environmental corridors in prime agricultural areas.

Areawide Level

Metropolitan Sewerage District of the County of Milwaukee: It is recommended that the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee, acting as agents for the Metropolitan Sewerage District of the County of Milwaukee:

1. Adopt the recommended Milwaukee River watershed plan, including the land use and water control elements, and thereafter determine the proposed sewer service areas in accordance with the plan.

2. Complete the long-range trunk and relief sewer construction program in Milwaukee County in order to abate the pressing water pollution problems in the Milwaukee River watershed caused by separate sanitary sewer overflows.

3. Contract with the Village of Thiensville to provide sewage treatment service for sewage emanating from the Thiensville sewer service area, thus enabling abandonment of the Thiensville sewage treatment plant.

4. Undertake responsibility for implementation of the plan recommendation dealing with the abatement of pollution caused by combined sewer overflows in the Milwaukee River watershed (Sewerage Commission of the City of Milwaukee).

Federal Level

U. S. Department of Housing and Urban Development: It is recommended that the U. S. Department of Housing and Urban Development:

1. Acknowledge the comprehensive Milwaukee River watershed plan and use such plan as a guide in the administration and granting of federal aids for urban beautification, open-space acquisition, park development, and sewer and water facilities and in the administration of the national flood insurance program.

2. Assign the highest appropriate priorities to all applications for urban beautification, open-space acquisition, and park development grants that are in partial support of the acquisition and development of those sites recommended for public use in the plan.

3. Approve only those applications for sewer and water facility grants that are located and designed in accordance with the land use and water pollution abatement elements of the Milwaukee River watershed plan.

U. S. Environmental Protection Agency: It is recommended that the U. S. Environmental Protection Agency:

1. Accept the recommended Milwaukee River watershed plan upon state certification thereof and utilize the plan as a guide in the administration and granting of federal aids for the construction of sewage treatment plants and related facilities within the watershed.

U. S. Department of the Interior, Geological Survey: It is recommended that the U. S. Department of the Interior, Geological Survey:

1. Continue to maintain a cooperative program of water resources investigation in the watershed, including the expansion of a continuous stream gaging program within the watershed.

U. S. Department of Agriculture, Farmers Home Administration: It is recommended that the U. S. Department of Agriculture, Farmers Home Administration:

1. Acknowledge the recommended Milwaukee River watershed plan and utilize the plan as a guide in the administration and granting of loans and aids for water supply and waste disposal plants and facilities within the watershed.

2. Approve only those grant applications for the construction of water supply and waste treatment facilities that are located and designed in accordance with the land use and water pollution abatement elements of the Milwaukee River watershed plan.

U. S. Department of Agriculture, Soil Conservation Service: It is recommended that the U. S. Department of Agriculture, Soil Conservation Service:

1. Acknowledge the recommended Milwaukee River watershed plan and utilize the plan as a guide in the administration and granting of federal aids for resource conservation and development and for construction of multi-purpose watershed projects within the Region and in the provision of technical assistance for land and water conservation.

U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service: It is recommended that the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service:

1. Acknowledge the recommended Milwaukee River watershed plan and utilize the plan in the administration of its agricultural conservation programs.

U. S. Department of the Army, Corps of Engineers: It is recommended that the U. S. Department of the Army, Corps of Engineers:

1. Acknowledge the recommended Milwaukee River watershed plan and terminate or complete its suspended flood control study of the Milwaukee River watershed, giving due consideration and weight to the plan recommendations.

(This page intentionally left blank)

Chapter X

SUMMARY AND CONCLUSIONS

INTRODUCTION

This report is the second in a series of two volumes which together present the major findings and recommendations of the Southeastern Wisconsin Regional Planning Commission Milwaukee River watershed planning program. The first volume, published in December 1970, set forth the basic principles and concepts underlying the study and presented in summary form the basic facts pertinent to the preparation of the comprehensive plan for the physical development of the Milwaukee River watershed, with particular emphasis upon the existing state of the land and water resources of the basin and the developmental and environmental problems associated with these resources. The first volume also contained forecasts of anticipated future growth and change within the watershed and an analysis of water law as such law relates to watershed plan preparation and implementation, with particular emphasis upon the legal aspects of flood control and pollution abatement.

This, the second and final volume of the series, sets forth watershed development objectives, principles, and standards; presents alternative plan elements for land use and water control facility development, including flood control and water pollution abatement facilities, and for natural resource preservation and enhancement within the watershed; and recommends a comprehensive watershed development plan designed to meet watershed development objectives under existing and probable future conditions. It presents estimates of the costs of implementing the recommended plan over a 20-year plan implementation period and recommends means for plan implementation. In addition, this volume provides a comparative analysis of the changes which may be expected to occur within the watershed by 1990 if present development trends are allowed to continue without redirection in the public interest.

WATERSHED DEVELOPMENT OBJECTIVES

The primary objective of the Milwaukee River watershed planning program is to assist the local, state, and federal units and agencies of government in abating the serious water and water-related resource problems existing within the Milwaukee River basin by developing a workable plan to guide the staged development of water control facilities and related resource conservation and management programs for the watershed. The problems to be abated include flood damage, water pollution and conflicting water uses, soil erosion, deteriorating fish and wildlife habitat, and the complex effects of rapidly changing land use. Accordingly, following ascertainment of present and probable future conditions within the watershed,[1] a framework of watershed development objectives with supporting principles and standards was established to guide the design of alternative land use and water control facility plans for the watershed and to provide a basis for the evaluation of the relative merits of these alternative plans. The 10 watershed development and management objectives and supporting principles and standards set forth in this volume relate to land use and water control facility development, water supply, engineering design, and economic feasibility and were formulated within the context of broader regional development objectives. Briefly, this framework of watershed development objectives and standards envisions a future watershed environment which is varied, safe, healthful, efficient, and aesthetically pleasing.

ALTERNATIVE PLANS

In the preparation of the comprehensive plan for the physical development of the Milwaukee River watershed, a concerted effort was made to offer for public evaluation all physically feasible alternative plan elements which might satisfy one or more watershed development objectives. Each alternative plan element was evaluated insofar as possible in terms of engineering, economic, and

---

[1] *The reader may at this point wish to review Chapter XVI, "Summary," of Volume 1 of this report, which summarizes the inventory, analysis, and forecast findings of the study, thereby describing qualitatively and quantitatively the resource related problems of the Milwaukee River watershed requiring attention. The comprehensive watershed development plan recommended in this volume is addressed to the resolution of these problems.*

legal feasibility and with respect to the satisfaction of the watershed development objectives. The alternative plan elements considered can best be visualized in terms of various combinations of land use patterns and water control facilities.

The land use base element of the comprehensive Milwaukee River watershed plan is set within the context of the adopted regional land use plan. This land use base element envisions the modification of land use development trends within the watershed in order to meet stated development objectives and thereby achieve a safer, more healthful, pleasurable, and efficient land use pattern, while meeting the gross land use demands generated by forecast population and employment levels. The land use base element emphasizes the efficient provision of utility services, cohesive urban development on appropriately suitable soils, preservation of prime agricultural lands, preservation of unique resource areas, and protection of floodland areas from further encroachment by urban development.

Under the recommended land use base element, urban development within the watershed would be channeled into areas appropriately located and particularly suitable for such development in three different population density ranges. Prime agricultural areas and primary environmental corridors, the latter encompassing the surface waters and associated undeveloped shorelands and floodlands and the best remaining woodlands, wetlands, wildlife habitat areas, and potential park and related open-space sites, would be preserved and protected from urban development. Existing land uses not developed in conformance with these proposals would be considered nonconforming, and provisions would be made for their eventual discontinuance and removal. The attainment of a sound land use pattern throughout the watershed, particularly within the riverine areas of the watershed, thus comprises the basic and most important recommendation of the comprehensive Milwaukee River watershed plan.

In the adaptation, refinement, and detailing of the regional land use plan in the Milwaukee River watershed study, three alternative natural resource protection plan elements and three alternative outdoor recreation and related open-space plan elements were considered. With respect to resource protection, the three alternatives were:

1. A minimum alternative which would provide basically for the preservation of the remaining undeveloped primary environmental corridors of the watershed by acquisition for public park, parkway, and open-space purposes in those areas of the watershed which are expected to be in urban use by 1990, the plan design year, and through appropriate floodland, shoreland, and conservancy zoning in those areas of the watershed which are expected to remain in rural use through 1990. In addition, this minimum alternative would include public acquisition of selected remaining high-value wetland areas and high-value woodland areas located in primary environmental corridors adjacent to the existing publicly owned and leased woodland, wetland, and wildlife areas. The primary environmental corridor and related woodland and wetland areas to be acquired under this alternative would total about 29,300 acres, or about 29 percent of the primary environmental corridor area within the watershed.

2. An intermediate alternative which would, in addition to the public land acquisition and zoning proposals contained in the first alternative, provide for the preservation through acquisition for public use of all remaining undeveloped primary environmental corridor lands along the main stem of the Milwaukee River from the City of Milwaukee to the Village of Kewaskum in Washington County. The additional environmental corridor area to be acquired under this alternative would total about 3,400 acres, or an additional 3 percent of the primary environmental corridor area within the watershed, over and above the first alternative.

3. An optimum alternative which would, in addition to the proposals contained in the first and second alternatives, provide for the public acquisition of additional selected undeveloped primary environmental corridor areas, particularly high-value lands needed to provide additional protection for certain significant resource values, such as the remaining trout streams in the watershed and areas having future multiple-purpose reservoir potential. The additional

area to be acquired under this alternative would total about 8,900 acres, or an additional 9 percent of the primary environmental corridor area within the watershed, over and above the first and second alternatives.

With respect to park and outdoor recreation, the three alternatives considered were:

1. A minimum alternative designed to provide sufficient public outdoor recreation area within the watershed to meet only the anticipated user demand of the 1990 resident population of the watershed and the Region, as approximated by the adopted regional and watershed land use development standards of 10 acres of local park land per one thousand resident population and four acres of regional park land per one thousand resident population. Included in this alternative was the acquisition and development of one new major regional park site to supplement the five existing regional park sites within the watershed, the expansion of one of the existing regional park sites, and the acquisition and development of additional local park sites for community and neighborhood use. New park area to be acquired under this alternative would total about 2,000 acres, over and above the nearly 3,700 acres of existing regional and local park land in the watershed.

2. An intermediate alternative which would, in addition to the proposals contained in the first alternative, include the acquisition and development of additional outdoor recreation site area needed to meet a portion of the demand for outdoor recreation within the watershed generated by out-of-Region users, the additional area required being selected from the best remaining high-value potential park sites within the watershed. Additional park area to be acquired under this alternative would total about 4,450 acres, over and above the first alternative.

3. An optimum alternative which would, in addition to the proposals contained in the first two alternatives, provide for the preservation of sufficient park land to meet all of the outdoor recreational demand expected to be generated by out-of-Region and out-of-watershed users, as well as by residents of the watershed. Additional park area to be acquired under this alternative would total about 4,400 acres, over and above the first and second alternatives.

In addition to the foregoing natural resource protection and park and outdoor recreation alternative plan elements, several related parkway pleasure drive and scenic drive plan elements were evaluated in the watershed study.

In addition, a second land use base element was prepared based upon a continuation of existing development trends within the watershed in the absence of any effort to regulate such trends on an areawide basis in the public interest. This alternative is not to be construed as a plan but rather as a forecast of one of the many possible end results of unplanned development within the watershed. It was intended to serve not as a recommendation but as a basis for comparison for the evaluation of the potential benefits of the recommended watershed plan.

Coupled with the foregoing land use plan alternatives, a number of water quantity and water quality control facility alternatives were explored. These included the following:

1. For flood control: floodland zoning and the acquisition of floodland areas for public park, parkway, and open-space use; dike and floodwall construction and channel improvements; diversion channel construction; and reservoir construction. Of all of the alternative structural flood control plan elements evaluated in the watershed study, only the Waubeka Reservoir was found to be an economically sound and aesthetically acceptable structural alternative, fully compatible with the watershed development objectives, and then only on a multiple-purpose basis. The Waubeka Reservoir was, however, not included in the recommended plan on the grounds that the flood control benefits constituted a very small proportion of the total benefits to be derived from such a reservoir and would, in and of themselves, not economically justify construction of the reservoir; that there was neither the institutional structures available nor the public support

required to create such an institutional structure for the development of a major reservoir having primarily recreational benefits; that construction of the reservoir, by reducing the frequency and extent of flooding, would alter the natural characteristics of the environmental corridors below the dam, and encourage the development of those corridors for intensive urban use by removing one of the principal constraints on such development and thereby make the preservation of these corridors more difficult; and that it was unwise to include as a major plan element, upon which the nature and effectiveness of other major plan elements depended, a facility the construction of which would be highly improbable in the face of both growing public discontent with reservoir proposals of any kind and the long-standing local public opposition to a reservoir project in the upper Milwaukee River watershed.

2. For stream water pollution abatement in the upper watershed: the provision of advanced waste treatment (85 percent phosphorus removal); the provision of tertiary and advanced waste treatment (80 percent nitrogenous oxygen demand, 95 percent biochemical oxygen demand, and 90 percent phosphorus removal); the provision of secondary waste treatment and disposal of sewage effluent by land irrigation; the provision of advanced waste treatment combined with instream aeration; and the provision of advanced waste treatment combined with low-flow augmentation.

3. For abatement of pollution from combined sewer overflows in the lower watershed: storage of the sewer overflows and slow release for eventual treatment at existing sewage treatment plants; flow-through and in-flow treatment of the sewer overflows; complete separation of the combined sanitary-storm sewer system to eliminate combined sewer overflows; and a combination of the storage and flow-through treatment alternatives.

4. For lake pollution abatement: weed harvesting; algae control; the provision of manure holding tanks and construction of bench terraces or the institution of other appropriate agricultural land management practices to control nutrient contribution from agricultural runoff; installation of sanitary sewerage systems to control nutrient contribution from urban land uses, lake water mixing, bottom draw devices, water replacement, nutrient removal, fish harvesting, dredging, and algae harvesting.

Alternative water supply plans were also considered, including the further development of the deep aquifer supply, the further development of the shallow aquifer supply, and the establishment of a major public water utility in southern Ozaukee and northern Milwaukee Counties utilizing Lake Michigan as a source of water.

RECOMMENDED WATERSHED PLAN

Each of the alternative plan elements considered was evaluated individually and in various compatible combinations and a comprehensive watershed plan synthesized. The resultant comprehensive watershed development plan, which is recommended for adoption as a guide for the physical development of the Milwaukee River watershed, contains the following salient proposals.

Land Use Element

The land use element recommends regulation of land use development over the entire Milwaukee River watershed through local zoning in order to assure the expansion of urban development into those areas of the watershed that can be readily served by centralized public water supply and sanitary sewerage systems and that are covered by soils suitable for urban uses. The remaining prime agricultural areas of the watershed would be protected from destruction through urban encroachment, as would the remaining primary environmental corridors of the watershed. The latter encompass not only the surface water resources and associated undeveloped shorelands and floodlands of the watershed but almost all of the best remaining woodlands, wetlands, wildlife habitat areas, and potential park sites. The environmental corridors would be protected from further urban encroachment and eventual deterioration and destruction by appropriate floodland, shoreland, and conservancy zoning, as well as by selected public acquisition in rural areas of the watershed and by public acquisition for park, parkway, and related open-space purposes in urban areas of the watershed. It should be noted in this respect that the floodland zoning and acquisition recommendations incorporated in the land use element of the plan constitute the basic flood control recommendation of the watershed plan.

In addition to the public acquisition of all remaining undeveloped primary environmental corridors in urban areas of the watershed, the recommended plan provides for the acquisition of all of the remaining undeveloped primary environmental corridor along the main stem of the Milwaukee River from Milwaukee to the Village of Kewaskum in Washington County; the public acquisition of selected remaining high-value wetland areas located in the primary environmental corridors; the public acquisition of selected remaining high-value woodland areas located in the primary environmental corridors and constituting additions to the Kettle Moraine State Forest; and public acquisition of selected additional environmental corridors included in the recommended plan in order to provide additional protection for significant elements of the natural resource base, such as the remaining trout streams in the watershed and areas having future multiple-purpose reservoir potential. In all, the plan recommends public acquisition of about 41,600 acres of primary environmental corridor land which, when added to the 24,300 acres of primary environmental corridor land already in public ownership, would result in a total of about 65,900 acres of public ownership, or about 66 percent of the total primary environmental corridor area within the watershed, being permanently preserved and maintained through public ownership.

The plan also recommends the acquisition of sufficient additional park and outdoor recreation area to meet the anticipated 1990 outdoor recreation demand within the watershed, including the demand generated by out-of-watershed and out-of-Region users, as well as by residents of the watershed. Included in this proposed new recreational land area, totaling approximately 10,900 acres, are about 700 acres for the acquisition and development of one new regional park in the watershed—the Lucas Lake-Paradise Valley regional park—and the expansion of one existing regional park in the watershed—the Hawthorne Hills County Park in Ozaukee County—to provide multiple-use capability. The recommended plan would provide sufficient outdoor recreation area to meet the forecast user demand for the five major outdoor recreation activities requiring additional land and thereby avoid damaging overuse of recreational resources and facilities; the concomitant deleterious effects on the natural resource base; and increasing conflicts between recreation uses and users. Implementation of the resource protection plan element described in the preceding paragraphs would result in the public acquisition of nearly 75 percent of the required outdoor recreation lands.

The plan also recommends the development of a new parkway pleasure drive in the City of Milwaukee from Lincoln Memorial Drive near the McKinley Marina on Lake Michigan to and along the Milwaukee River valley to a junction with the existing Estabrook Park Drive at its intersection with Capitol Drive in the Village of Shorewood, together with the development of a system of primary and secondary Milwaukee River scenic drives, beginning at the northerly terminus of the Milwaukee River Parkway in the City of Glendale and extending throughout the watershed along the major stream courses, with connections to the existing and long-established Kettle Moraine Scenic Drive.

The land use plan element, which includes recommendations for basin-wide land use development, a natural resource protection element, a park and outdoor recreation element, and a parkway and scenic drive element, is graphically summarized on Map 65 set forth in Chapter VII of this volume.

Flood Control Element

The basic flood control plan element recommended for inclusion in the comprehensive Milwaukee River watershed plan is nonstructural, consisting of the land use development proposals contained in the land use element of the watershed plan, particularly as these land use proposals affect the riverine areas of the watershed. Of particular importance in this respect are the land acquisition recommendations made for the preservation of environmental corridor lands within the watershed. No structural water control facilities are recommended for inclusion in the Milwaukee River watershed plan, because all available alternative structural flood control plan elements are either both economically unsound and aesthetically unacceptable or, in the case of the proposed Waubeka Reservoir, were deleted from the recommended plan by the Watershed Committee for the reasons set forth earlier in this chapter.

Certain nonstructural plan elements, however, are recommended for inclusion in the comprehensive watershed plan, including:

1. The institution of appropriate land use controls, including zoning, building, and subdivision control regulations, to prevent the construction of new buildings in floodways located through areas already in, or committed to, urban development and within the 100-year recurrence interval flood hazard lines in all other areas of the watershed. Such zoning would serve to render all existing structures in the urban floodways as nonconforming structures.

2. The gradual, voluntary removal over a long period of time by public purchase of all of the structures rendered nonconforming uses in the urban floodways.

3. The floodproofing of all existing structures located in the floodplains of the watershed that are between the outer limits of the floodways or 10-year recurrence interval flood hazard lines and the outer limits of the 100-year recurrence interval flood hazard lines.

4. The continuation of a long-established stream gaging program.

It is important to note that full implementation of the voluntary floodway removal and floodproofing plan elements noted above would provide an average annual flood-damage alleviation benefit of $129,500, or 86 percent of the total average annual flood damage within the watershed.

Stream Water Pollution Abatement Element

The recommended plan proposes the abatement of stream water pollution problems within the lower Milwaukee River watershed through the following measures:

1. Completion of the long-range relief sewer construction program currently being conducted by the Milwaukee-Metropolitan Sewerage Commissions. Completion of this relief sewer program should eliminate all of the separate sanitary sewer overflows to the streams and watercourses of the lower Milwaukee River watershed.

2. The connection to the Milwaukee metropolitan sewerage system of eight of the 26 industrial waste outfalls which now discharge directly to Lincoln Creek or to the Milwaukee River within Milwaukee County. Of the remaining 18 industrial waste outfalls, 13 discharge only cooling waters to the storm sewer system and would not require treatment, and five are inorganic waste sources which require improved pretreatment before discharge to the storm sewer system.

3. The construction of a combination deep tunnel mined storage/flow-through treatment system to collect, convey, and adequately treat all combined sewer overflows emanating not only in the 5,800-acre combined sewer service area of the Milwaukee River watershed but throughout the 17,200-acre combined sewer service area in Milwaukee County.

The recommended plan proposes the abatement of stream water pollution problems within the upper Milwaukee River watershed through the following measures:

1. The provision of secondary waste treatment and post-chlorination for disinfection at the municipal sewage treatment facilities serving the communities of Adell, Fredonia, and Newburg.

2. The provision of secondary waste treatment, post-chlorination for disinfection, and either streamflow augmentation or discharge of sewage effluent to a seepage pond at a new sewage treatment facility proposed to serve the Village of Cascade and urban development in the nearby Lake Ellen area.

3. The provision of secondary waste treatment, tertiary waste treatment, and post-chlorination for disinfection at the existing sewage treatment facility serving the Village of Random Lake.

4. The provision of secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination for disinfection at the municipal sewage facilities serving the following communities: Campbellsport, Cedarburg-Grafton, Jackson, Kewaskum, and Saukville. Advanced treatment of wastes generated in the Cedarburg-Grafton sewer service areas would be accomplished at a new treatment facility located near the confluence of the

Milwaukee River and Cedar Creek, with secondary waste treatment continuing to be provided at the existing Cedarburg and Grafton sewage treatment plants.

5. The provision of secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), post-chlorination for disinfection, and instream aeration at the West Bend sewage treatment facility. The West Bend facility would be an areawide facility serving not only the West Bend sewer service area but also the sanitary sewer service areas around Big Cedar, Little Cedar, Silver, and Wallace Lakes. Instream aeration would be provided by mechanical aerators located on the Milwaukee River main stem below the West Bend sewage treatment plant and by diffuser aerators located in the Newburg Pond.

6. Connection of the Thiensville sanitary sewer service area to the Milwaukee metropolitan sewerage system through the City of Mequon sewerage system, together with abandonment of the existing Thiensville sewage treatment facility.

7. The connection to municipal sewerage systems of four industrial waste discharges which now discharge directly to the Milwaukee River stream system, together with the provision of adequate treatment facilities at eight industrial plant locations, in order to prevent the discharge of inadequately treated industrial wastes to the stream system.

8. The institution, as appropriate and on a voluntary basis, of agricultural land use management practices to about 65,000 acres of agricultural land in the Milwaukee River watershed located outside the subwatersheds of the major lakes in the watershed.

9. The continued operation of a water quality monitoring program at 12 sampling locations throughout the watershed.

Implementation of the recommended stream and lake water quality management plan element for the entire watershed, including the elimination of separate and combined sewer overflows, would abate all of the major sources of stream pollution existing within the watershed and reduce the municipal waste loadings on the stream system from about 18,000 pounds of BOD and about 720 pounds of phosphorus per average day to about 1,200 pounds and about 130 pounds, 93 percent and 82 percent reductions, respectively. Implementation of these recommendations would provide the stream water quality levels necessary to meet the state-established stream water use objectives and standards, as well as the effluent standards established by the federal Lake Michigan Enforcement Conference. In addition, implementation of these recommendations would serve to restore substantially the quality of the water in the main stem of the Milwaukee River and its major tributaries, thereby facilitating restoration of a game fishery, consisting of facultative species, and the safe use of the stream system for partial-body-contact recreational uses.

Lake Water Pollution Abatement Element

The recommended plan proposes the abatement of lake pollution problems within the watershed through the following measures:

1. The provision of sanitary sewer service at Big Cedar, Ellen, Forest, Green, Kettle Moraine, Little Cedar, Random, Silver, and Wallace Lakes. Such service would be provided at three of the nine lakes—Forest, Green, and Kettle Moraine—through the establishment of new sanitary sewerage systems and treatment facilities providing secondary waste treatment and post-chlorination for disinfection. Sewer service for Big Cedar, Little Cedar, Silver, and Wallace Lakes would be provided through trunk sewer connections to the existing City of West Bend sanitary sewerage system, with secondary waste treatment, advanced waste treatment (90 percent phosphorus removal), and post-chlorination for disinfection provided at the West Bend sewage treatment plant. Sewer service for Ellen Lake would be provided at the proposed Village of Cascade sewage treatment plant. Sewer service for Random Lake would be provided at the existing Village of Random Lake sewage treatment plant.

2. The provision of chemical control of nuisance algal blooms, as necessary, at Big Cedar, Ellen, Forest, Little Cedar, Mauthe, Smith, Twelve, and Wallace Lakes. This

recommendation can serve only to suppress the symptoms of the underlying water quality problem and, as such, should only be considered a temporary measure to be used until more permanent abatement is achieved through the other recommended plan proposals.

3. Machine harvesting of the aquatic weed growths, as necessary, at Auburn, Big Cedar, Crooked, Ellen, Forest, Kettle Moraine, Little Cedar, Long, Lucas, Mauthe, Random, Smith, and Twelve Lakes.

4. A long-term program of the institution of good soil and water conservation practices to control pollution from agricultural runoff through the construction of bench terraces and the institution of other appropriate agricultural land management measures on agricultural lands within the tributary watersheds of Auburn, Big Cedar, Crooked, Ellen, Little Cedar, Long, Lucas, Mauthe, Random, Smith, Twelve, and Wallace Lakes.

The installation of the sanitary sewerage systems is recommended to eliminate the health hazards that may presently exist in the lakes as a result of inadequate or malfunctioning individual on-site soil absorption sewage disposal systems and to reduce the nutrient input to the lakes. Soil and water conservation practices, including the construction of bench terraces, are recommended as the best means of reducing the nutrient input and sediment load from agricultural areas to the major lakes within the watershed. The algae control and weed harvesting operations are recommended to alleviate nuisances caused by excessive aquatic growths present in many of the lakes within the watershed.

Water Supply Element

Lake Michigan and the three ground water aquifers which underlie the Milwaukee River watershed constitute the principal sources of water supply within the watershed and, if properly used and managed, comprise renewable water resources which can serve the watershed for all time to come. The shallow sand and gravel and dolomite aquifers can be developed to meet all foreseeable demand within the upper watershed for domestic and livestock watering purposes, providing that such aquifers are carefully protected from pollution through septic tank sewage disposal systems, dumps, and improperly located and operated sanitary land fills and urban and agricultural runoff. The deep sandstone aquifer provides the most dependable source of large quantities of ground water supply for wells within the watershed, with generally good quality except for high dissolved solids content occurring along the eastern boundary of the watershed. The plan contains recommendations concerning well location and spacing necessary to achieve proper utilization of not only the deep sandstone aquifer but also the shallow sand and gravel and dolomite aquifers. Important to the protection of the ground water aquifers will be the implementation of the recommendations contained in the land use base element of the recommended watershed plan, particularly those relating to the provision of public sanitary sewerage service to urban areas.

In addition to the foregoing management recommendations with respect to the three ground water supply aquifers in the Milwaukee River watershed, the plan recommends the following water supply elements:

1. The creation of a municipal water supply system to serve jointly the Villages of Bayside and River Hills in Milwaukee County and the City of Mequon and the Village of Thiensville in Ozaukee County, which system would utilize Lake Michigan as its source of water supply.

2. The establishment of public water supply systems in the unincorporated Village of Waubeka in Ozaukee County, the Village of Jackson and the unincorporated Village of Newburg in Washington County, and the Village of Cascade in Sheboygan County.

THE UNPLANNED ALTERNATIVE

The recommended comprehensive plan for the Milwaukee River watershed was designed specifically to meet the established watershed development objectives and standards, which include the water use objectives and supporting water quality standards established by the State of Wisconsin for the Milwaukee River and its major tributaries and the sewage effluent and related standards promulgated by the federal Lake Michigan Enforcement Conference. Implementation of the recommended plan can, therefore, be expected to provide a safer, more healthful, and more pleasant, as well as more orderly and efficient, environment within the watershed. Implementation of the recommended watershed plan would assist in the resolution of many of the existing areawide development problems, would avoid the development of new problems, and would do much to protect and enhance the underlying and sustaining natural resource base.

The alternative would be to continue recent development trends within the watershed, utilizing only local development plans and policies to constrain the action of the urban land market in shaping the future development pattern within the watershed. This unplanned alternative would require the least amount of effort on an areawide basis toward regulation of development in the public interest and would require few restraints on the operation of the urban land market in determining the future character, intensity, and spatial distribution in land use development within the watershed. The unplanned alternative, however, could be expected to lead to a continued intensification of existing environmental problems within the watershed, including especially flooding and water pollution, and could be expected to result in the nearly total destruction of the natural resource base and in the production of a land use pattern which would be as disorderly and inefficient as it would be ugly. Under the unplanned alternative, average annual flood costs along the main stem of the Milwaukee River would be expected to increase from $119,000 per year at the present time to $160,000 per year in 1990; and damages from a single 100-year recurrence interval flood could be expected to increase from $1.8 million at the present time to $2.2 million in 1990. The established water use objectives and standards could not be expected to be met for over 64 miles, or about 65 percent, of the main stem of the Milwaukee River nor for significant reaches of the following major tributaries: Lincoln Creek, Silver Creek (Sheboygan County), Adell Tributary, and Cedar Creek. Finally, continued deterioration of the quality of water in the 19 major natural lakes of the watershed could be expected.

The need to protect the floodlands of the perennial stream system, the best remaining woodlands and wetlands, the best remaining wildlife habitat area, and the best remaining agricultural areas would be ignored, as would the value of developing an integrated system of park and open-space areas adequate to meet the forecast recreational demand and centered on the primary environmental corridors of the watershed. Failure to recognize these needs and values has indeed been the case within the watershed in the past, as attested to by the growing developmental and environmental problems and, in particular, by the continued development on the natural floodlands. Continuation of these past practices can only lead to a further deterioration and destruction of the natural resource base of the watershed, increasing costs for governmental facilities and services, and a decline in the overall quality of life within the watershed.

COST ANALYSIS

In order to assist the public officials concerned in evaluating the elements of the recommended Milwaukee River watershed plan, a preliminary capital improvements program was prepared, with the necessary land acquisition and facility construction staged and the attendant costs distributed over a 20-year plan implementation period. The adoption of capital improvement programs for implementation of the watershed plan will require determination by responsible public officials of not only those plan elements which are to be implemented, and the timing of such implementation, but also of the principal beneficiaries and the available means of financing.

The full capital investment cost of implementing the recommended comprehensive watershed plan for the Milwaukee River watershed is estimated at $112.8 million over the 20-year plan implementation period. Of this total cost, $49.9 million, or about 44 percent, is required for implementation of the recommended natural resource base protection, outdoor recreation, and parkway and scenic drive plan elements and would be used primarily for land acquisition; $47.3 million, or about 42 percent, is required for implementation of the recommended stream water quality management plan element; $10.3 million, or about 9 percent, is required for implementation of the recommended lake water quality management plan element; $5.3 million, or about 5 percent, is required for implementation of the recommended water supply plan element; and $31,100, or less than 1 percent, is required for implementation of the recommended water resources monitoring and dam investigation programs. The average annual cost of the total capital investment required for plan implementation would be approximately $5.6 million, or about $9.25 per capita, the per capita cost being based on a watershed population of 611,000 persons equal to the anticipated average resident population of the watershed between the 1967 existing population level of 544,000 persons and the anticipated 1990 population level of 678,000 persons.

It is extremely important to note, in considering the total cost of plan implementation, that, of the total estimated watershed plan implementation cost of $112.8 million, an estimated $57.1 million, or about 50 percent, would be incurred in any case by the federal, state, and local units of government concerned simply to provide the facilities necessary to accommodate the forecast population growth and accompanying urbanization as would be manifested in land development within the watershed, as well as to meet current state standards with respect to surface water pollution abatement. Expenditures of these funds in the absence of the comprehensive watershed plan would not serve to fully meet the watershed development objectives and standards but could, on an overall basis, be expected to lead instead to a further deterioration of the overall quality of the environment within the watershed and the intensification of environmental and developmental problems. Although the primary beneficiaries of the implementation of the recommended comprehensive watershed plan will be the residents of the watershed, certain regional, state, and national benefits would accrue from full plan implementation. In this respect full utilization of all sources of financial assistance at the state and federal levels of government is recommended. Such utilization could serve to reduce the local plan implementation costs for most of the plan elements by approximately 50 percent.

In order to assess the possible impact of implementation of the watershed plan on the public financial resources of the local units of government within the watershed, an analysis was made of the long-term historic public expenditures by the counties, cities, villages, and towns within the watershed for public park and outdoor recreation, sanitary sewerage, and major open channel drainage improvements and facilities. This analysis revealed that the local units of government in the watershed had expended, over the last 11 years, approximately $85.5 million for the construction, operation, and maintenance of public sanitary sewerage facilities, or an average annual expenditure of about $7.8 million. Similarly, approximately $57.8 million was expended by the local units of government for the acquisition, development, maintenance, and operation of park and related open spaces, or an average annual expenditure of $5.3 million. Finally, approximately $8.8 million was expended by the local units of government for the land acquisition, construction, and maintenance required for open channel drainage improvements, amounting to an average annual expenditure of $0.8 million. Based on these past expenditures, three alternative forecasts were prepared to indicate the possible range of future expenditures by local units of government within the watershed for public sanitary sewerage, park and outdoor recreation, and major open channel drainage improvements. When the average of the three alternative forecasts for public sanitary sewerage, park and outdoor recreation, and open channel drainage purposes was compared with the estimated plan implementation costs, it became clear that the cost of implementing the watershed plan is such as to be reasonably attainable through continuing the current level of public expenditures for these purposes. It is also clear that, if the adopted water use objectives and standards are to be met and if the remaining prime elements of the sustaining natural resource base are to be permanently protected and preserved, the level of expenditures needed to implement the watershed plan is necessary and warranted.

IMPLEMENTATION

The legal and governmental framework existing in the Milwaukee River watershed is such that the existing state, areawide, county, and local units of government can readily implement all of the major recommendations contained in the comprehensive Milwaukee River watershed plan. In Chapter IX of this volume, a comprehensive, cooperative, intergovernmental plan implementation program is set forth which indicates the specific actions which will be required of each level, agency, and unit of government operating within the watershed if the recommended watershed plan is to be fully implemented. These levels, agencies, and units of government include, at the local level, the governing bodies of the cities, villages, towns, and counties within the watershed; at the areawide level, the Metropolitan Sewerage District of Milwaukee County; at the state level, the Wisconsin Department of Natural Resources, Wisconsin Department of Local Affairs and Development, Wisconsin Department of Transportation, Wisconsin Division of Health, and the Wisconsin Soil Conservation Board; and at the federal level, the U. S. Department of Housing and Urban Development; the U. S. Department of

Agriculture, Soil Conservation Service, Farmers Home Administration, and Agricultural Stabilization and Conservation Service; the U. S. Environmental Protection Agency, Water Quality Office; and the U. S. Department of the Interior, Bureau of Outdoor Recreation.

Primary emphasis in Milwaukee River watershed plan implementation is based upon actions by the Wisconsin Department of Natural Resources; the City of Milwaukee Sewerage Commission and Metropolitan Sewerage Commission of the County of Milwaukee; the five county boards of the Counties of Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington; and by certain individual municipal units of government. It is recommended that the Wisconsin Department of Natural Resources continue to conduct periodic water pollution surveys and reevaluate, amending as necessary, and enforce pollution control orders in accordance with the Milwaukee River watershed plan recommendations; encourage counties and local units of government within the watershed to follow the plan recommendations relative to floodland and shoreland zoning; expand the boundaries of the Northern Unit of the Kettle Moraine State Forest to include urban environmental corridor and main stem environmental corridor lands located to the north and west of the City of West Bend and in the Tri-Lakes areas of the watershed; develop a new state recreation area at the Lucas Lake-Paradise Valley park site southwest of the City of West Bend in order to provide a third major state recreation area in the Northern Unit of the Kettle Moraine State Forest; acquire selected high-value woodland areas in environmental corridors; acquire selected high-value wetland areas in environmental corridors; approve the creation of a joint municipal water supply system to serve the Villages of River Hills, Bayside, and Thiensville and the City of Mequon and individual water supply systems to serve the Villages of Cascade and Jackson and the unincorporated Villages of Waubeka and Newburg; and approve only such applications for state and federal aid in partial support of the construction and improvement of municipal pollution prevention and abatement facilities that are located and designed in general accordance with the recommended Milwaukee River watershed plan.

It is recommended that the county units of government establish sound floodland zoning provisions; review and amend, as necessary, the recently established shoreland zoning ordinances to ensure that the objectives of the Milwaukee River watershed plan will be served by such ordinances; adopt sanitary codes regulating the installation of septic tank sewage disposal systems; acquire land designated as urban primary environmental corridors, main stem environmental corridors, and selected additional environmental corridors along the major stream courses in the watershed; maintain and expand regional outdoor recreation areas; and acquire additional high-value outdoor recreation sites as additions to the county park systems.

It is further recommended that all cities and villages within the watershed adopt a floodland zoning ordinance consistent with the plan recommendations; that the City of Cedarburg and the Village of Grafton jointly provide advanced waste treatment at a new treatment facility; that the Village of Thiensville contract with the Metropolitan Sewerage District of Milwaukee County to provide for sewage treatment services in order to enable abandonment of the existing Thiensville sewage treatment plant; that the City of West Bend provide advanced waste treatment and instream aeration facilities and provide contractual sewer service to the Tri-Lakes and Wallace Lake sewer service areas; that the Village of Cascade establish a new public sanitary sewerage system and contract to provide sewer service for the Lake Ellen area; that the Villages of Adell, Campbellsport, Fredonia, Jackson, Kewaskum, Random Lake, and Saukville and the Newburg Sanitary District provide for the specified levels of waste treatment at their existing sewage treatment plants; that the City of Milwaukee Sewerage Commission undertake the responsibility of implementation of plan recommendation dealing with the abatement of pollution caused by combined sewer overflows; that the City of Milwaukee Sewerage Commission and the Metropolitan Sewerage Commission of Milwaukee County complete, as rapidly as possible, the trunk and relief sewer construction program in order to abate serious pollution problems caused by separate sanitary sewer overflows in the watershed; that the City of Mequon and the Villages of Bayside, River Hills, and Thiensville establish a joint municipal water utility utilizing Lake Michigan as a source of water supply; and that the Villages of Cascade and Jackson and the unincorporated Villages of Newburg and Waubeka establish municipal water supply systems.

Finally, the plan recommends that should the county and local units of government which are charged with the responsibility for implementation of the natural resource protection, park and outdoor recreation, and water pollution abatement plan elements evidence a lack of interest in pursuing vigorously the required plan implementation actions, the Milwaukee River Watershed Committee consider recommending revising, and the Regional Planning Commission consider revising, the plan implementation recommendations so as to include pursuit of the creation of a comprehensive river basin district that could be given the authority under state legislation to fully implement, in particular, the natural resource protection, park and outdoor recreation, and water pollution abatement plan elements, as well as the flood control plan elements.

The foregoing enumeration of certain recommended plan implementation activities for summary purposes does not mean that the other plan implementation actions recommended in Chapter IX of this volume and not repeated here may be neglected. In the final analysis, the implementation of the recommended Milwaukee River watershed plan must proceed in a comprehensive, fully coordinated fashion, with the assistance and cooperation of all affected levels, units, and agencies of government within the watershed.

CONCLUSION

Although the cost of adopting and implementing the recommended comprehensive watershed plan for the Milwaukee River basin may appear high, the cost of not doing so is even higher, not only as measured in monetary terms but also as measured in terms of an irreversible deterioration of the natural resource base and a decline in the overall quality of the environment and, hence, the overall quality of life within the watershed. The failure to act upon the plan recommendations in a timely manner will inevitably commit local units of government within the watershed to the unnecessary expenditure of large amounts of public funds for future corrective measures. If the existing trend in urbanization continues within the watershed, those elements of the recommended plan requiring public acquisition of land should be substantially implemented within the first 10 years of the plan design period or the opportunity to acquire these important lands may be lost for all time. If the floodlands of the perennial stream system are not protected from further incompatible development, as recommended in the plan, urban flood damages will continue to mount. If the pollution abatement recommendations contained in the plan are not implemented, surface water quality may be expected to continue to deteriorate rapidly within the watershed; and its full potential for utilization will never be realized. If the park and related open-space acquisition and development recommendations contained in the plan are not implemented, the growing demand for recreational facilities may be expected to press so heavily upon the recreational resources of the watershed as to cause the serious decline in their quality.

Time is of the essence, for, if the recommended plan is not implemented, urban development within the watershed may be expected to continue to place intensive demands upon the limited resource base, which resource base must serve not only the watershed but the entire Southeastern Wisconsin Region and surrounding counties. The inevitable result will be the further intensification of existing developmental and environmental problems and the creation of new problems which will be extremely expensive to solve if, indeed, solutions will be at all possible.

APPENDICES

(This page intentionally left blank)

Appendix A

TECHNICAL ADVISORY COMMITTEE ON NATURAL RESOURCES AND ENVIRONMENTAL DESIGN

Cyril Kabat . . . . Chairman	Assistant Director, Bureau of Research, Wisconsin Department of Natural Resources
Kurt W. Bauer . . . . Secretary	Executive Director, SEWRPC
Richard W. Akeley	State Conservationist, U. S. Soil Conservation Service
William E. Frantz	Public Hearing Engineer, Division of Highways, Wisconsin Department of Transportation
George F. Hanson	State Geologist and Director, University of Wisconsin Extension Division-Geological and Natural History Survey
Charles L. R. Holt, Jr.. . .	District Chief, Water Resources Division, U. S. Geological Survey
Al J. Karetski	Director, Bureau of Local and Regional Planning, Wisconsin Department of Local Affairs and Development
Robert J. Mikula	County Landscape Architect, Milwaukee County Park Commission
Donald W. Niendorf.	Conservation Education Specialist, Soil Conservation Board of The University of Wisconsin
C. R. Ownbey	Chief, Planning Branch, Great Lakes Region, U. S. Environmental Protection Agency
William Sayles	Director, Bureau of Water and Shoreland Management, Division of Environmental Protection, Wisconsin Department of Natural Resources
Walter J. Tarmann	Executive Director, Waukesha County Park and Planning Commission
Harold W. Weber.	Division Engineer, Sewer Construction and Maintenance, Sewerage Commission of the City of Milwaukee
George B. Wesler	Chief, Planning and Reports Branch, U. S. Army Corps of Engineers
Donald G. Wieland	Division Engineer, Sewer Design, Sewerage Commission of the City of Milwaukee
Harvey E. Wirth	State Sanitary Engineer, Division of Health, Wisconsin Department of Health and Social Services
Theodore F. Wisniewski . .	Assistant to the Administrator, Division of Environmental Protection, Wisconsin Department of Natural Resources
Kenneth B. Young	Associate Chief, Water Resources Division, U. S. Geological Survey

(This page intentionally left blank)

Appendix B

MILWAUKEE RIVER WATERSHED COMMITTEE

Richard W. Cutler . . . . . Chairman	Attorney, Brady, Tyrrell, Cotter & Cutler, Milwaukee; Member, Village of Fox Point Plan Commission; Commissioner, SEWRPC
Kurt W. Bauer . . . . Secretary	Executive Director, SEWRPC
Vinton W. Bacon	Professor, College of Applied Science and Engineering, University of Wisconsin-Milwaukee
Ray F. Blank	Ozaukee County Board Supervisor
Clarence E. Boyke	Fond du Lac County Board Supervisor
Delbert J. Cook	Chairman, Cedar Creek Restoration Council
Arthur G. Degnitz	Washington County Board Supervisor
Nick R. Didier	Realtor, Port Washington
Herbert A. Goetsch.	Commissioner of Public Works, City of Milwaukee
Howard W. Gregg	General Manager, Milwaukee County Park Commission
LeRoy W. Grossman	Director Emeritus, Capitol Marine Bank; Member, Milwaukee River Flood Control Board
Gilbert J. Howard	Fond du Lac County Board Supervisor
John J. Juntenen	County Planner, Sheboygan County
John T. Justen	President, Pfister & Vogel Tanning Company, Milwaukee
J. Bryan Keating	District Conservationist, U. S. Soil Conservation Service, Fond du Lac County
John L. Kratz	Citizen Member, Washington County
Thomas A. Kroehn	District Director, Southeast District, Wisconsin Department of Natural Resources
Ray D. Leary	Chief Engineer and General Manager, Milwaukee-Metropolitan Sewerage Commissions
Dean Livingston	District Conservationist, U. S. Soil Conservation Service, Sheboygan County
Reuben T. Lueloff	President, Village of River Hills
Dr. Darrell M. Martin . . .	Resident Manager, St. Regis Paper Company, Milwaukee
Carl Otte	Sheboygan County Board Supervisor
George Watts	President, George Watts & Sons, Milwaukee
Donald W. Webster	Consulting Civil Engineer, Milwaukee

(This page intentionally left blank)

Appendix C

RAINFALL AND RUNOFF DATA FOR STORM WATER DRAINAGE AND FLOOD CONTROL FACILITY DESIGN

Figure C - 1

POINT RAINFALL

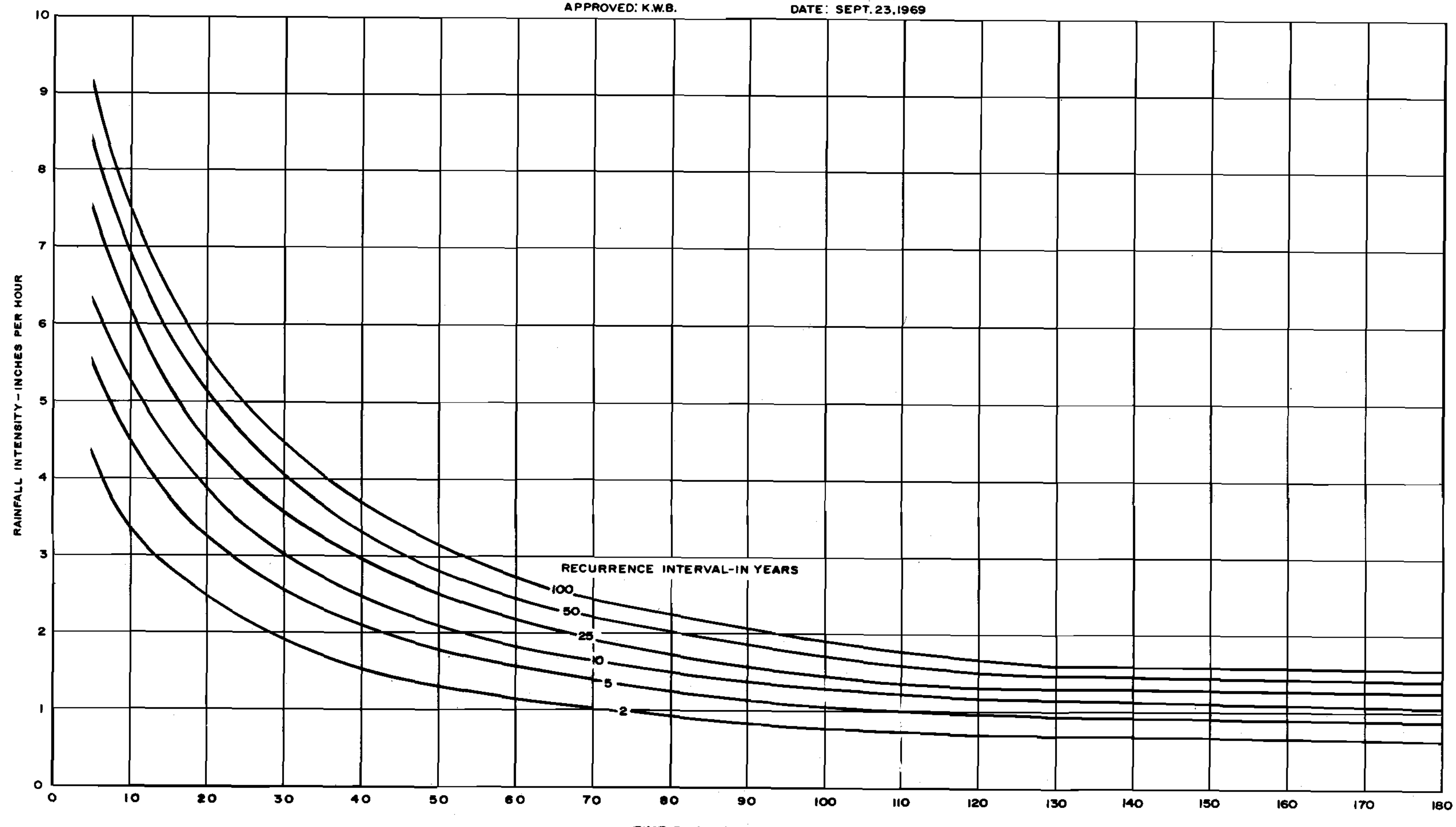
INTENSITY - DURATION - FREQUENCY

FOR DURATIONS OF 0 TO 180 MINUTES

MILWAUKEE, WISCONSIN

PREPARED BY
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
WAUKESHA, WISCONSIN
FROM
NATIONAL WEATHER SERVICE RECORDS
FOR
PERIOD FROM 1903 THROUGH 1966

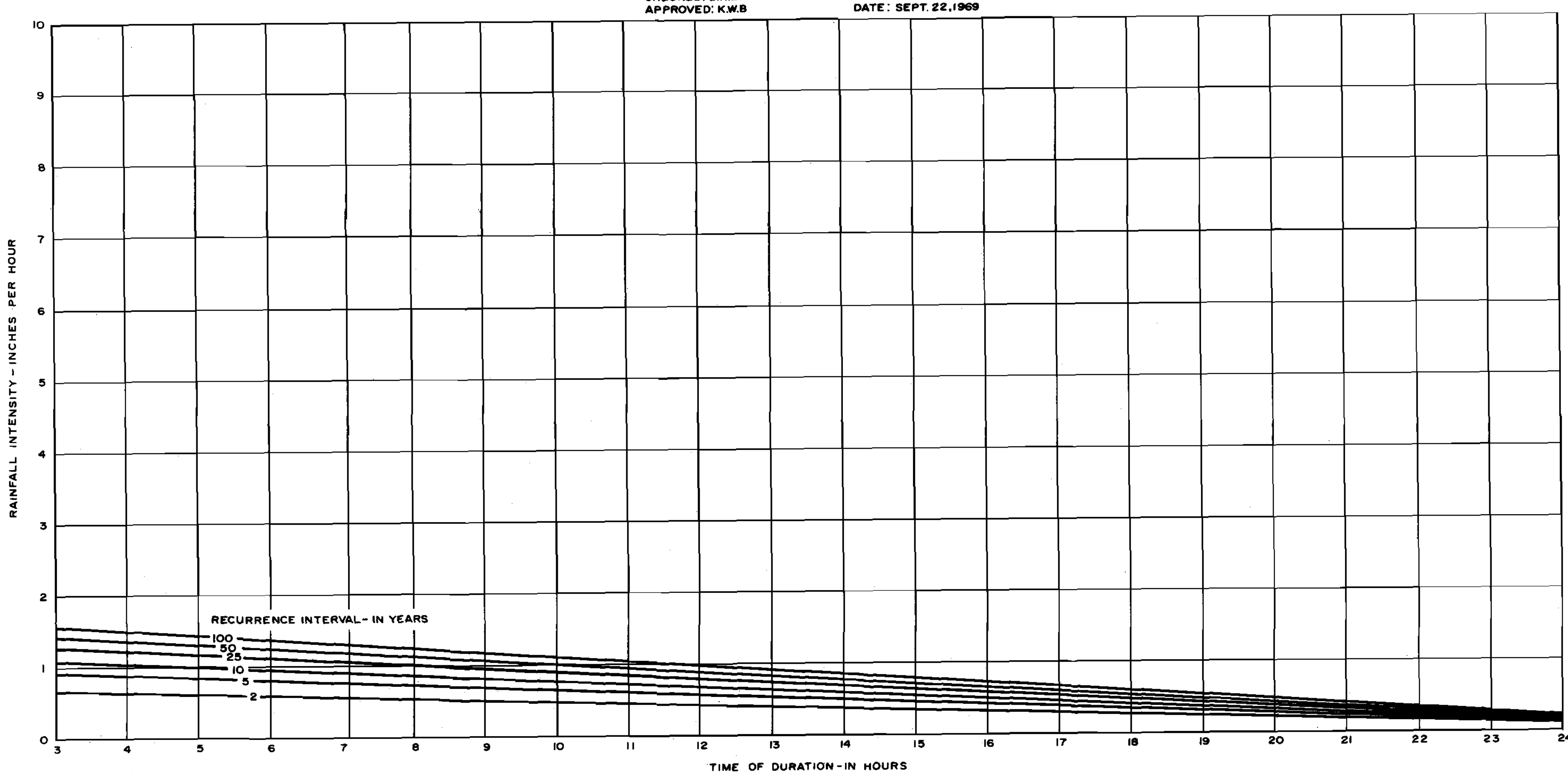
DRAWN: R.L.R. DATE: JUNE 23, 1969
CHECKED: D.R.B. DATE: SEPT. 23, 1969
APPROVED: K.W.B. DATE: SEPT. 23, 1969



Source: *SEWRPC.*

Figure C-2
POINT RAINFALL
INTENSITY – DURATION – FREQUENCY
FOR DURATIONS OF 3 TO 24 HOURS
MILWAUKEE, WISCONSIN
PREPARED BY
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
WAUKESHA, WISCONSIN
FROM
NATIONAL WEATHER SERVICE RECORDS
FOR
PERIOD FROM 1903 THROUGH 1966

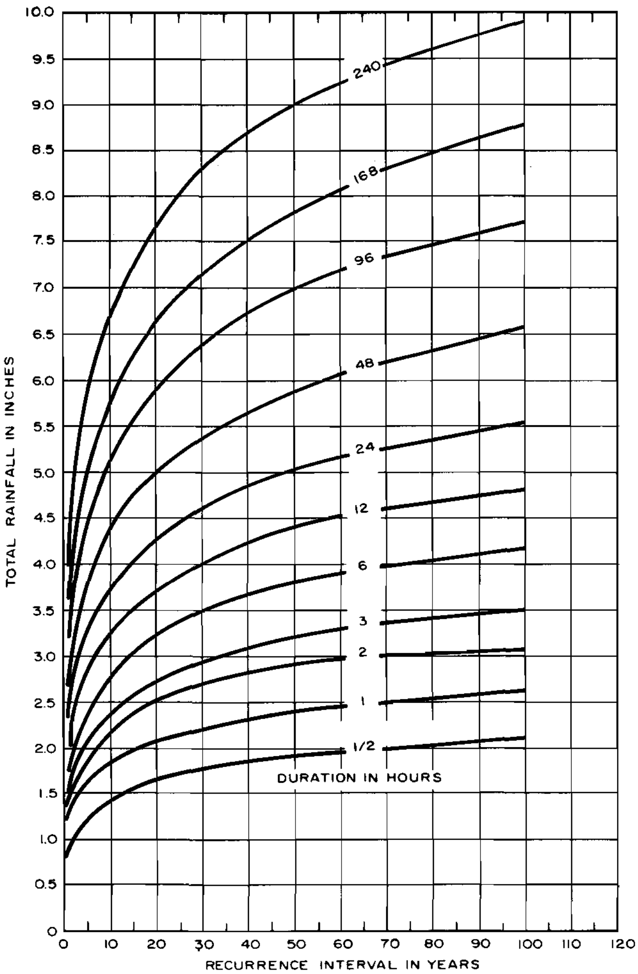
DRAWN: R.L.R DATE: JUNE 22, 1969
CHECKED: D.R.B. DATE: SEPT. 22, 1969
APPROVED: K.W.B DATE: SEPT. 22, 1969



Source: *SEWRPC.*

Figure C-3

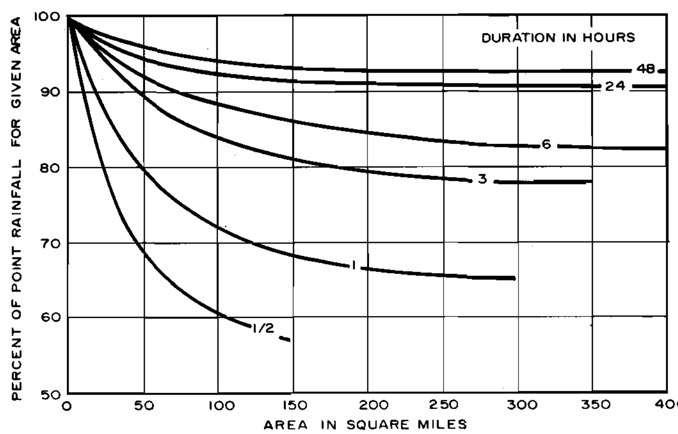
POINT RAINFALL DEPTH-DURATION-FREQUENCY RELATIONSHIPS IN THE REGION AND THE MILWAUKEE RIVER WATERSHED



Source: National Weather Service and SEWRPC.

Figure C-4

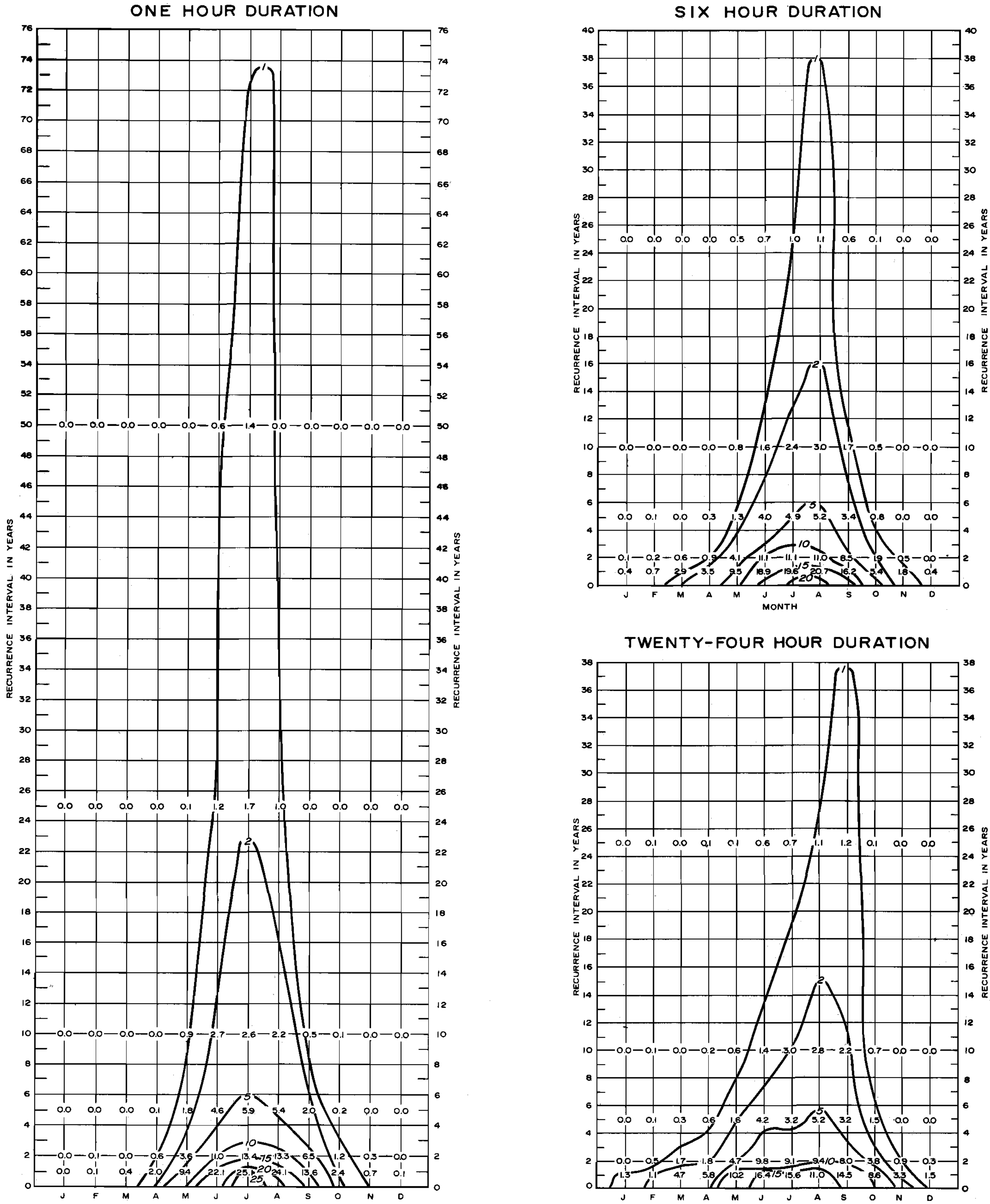
RAINFALL DEPTH-DURATION-AREA RELATIONSHIPS IN THE REGION AND THE MILWAUKEE RIVER WATERSHED



Source: National Weather Service and SEWRPC.

Figure C-5

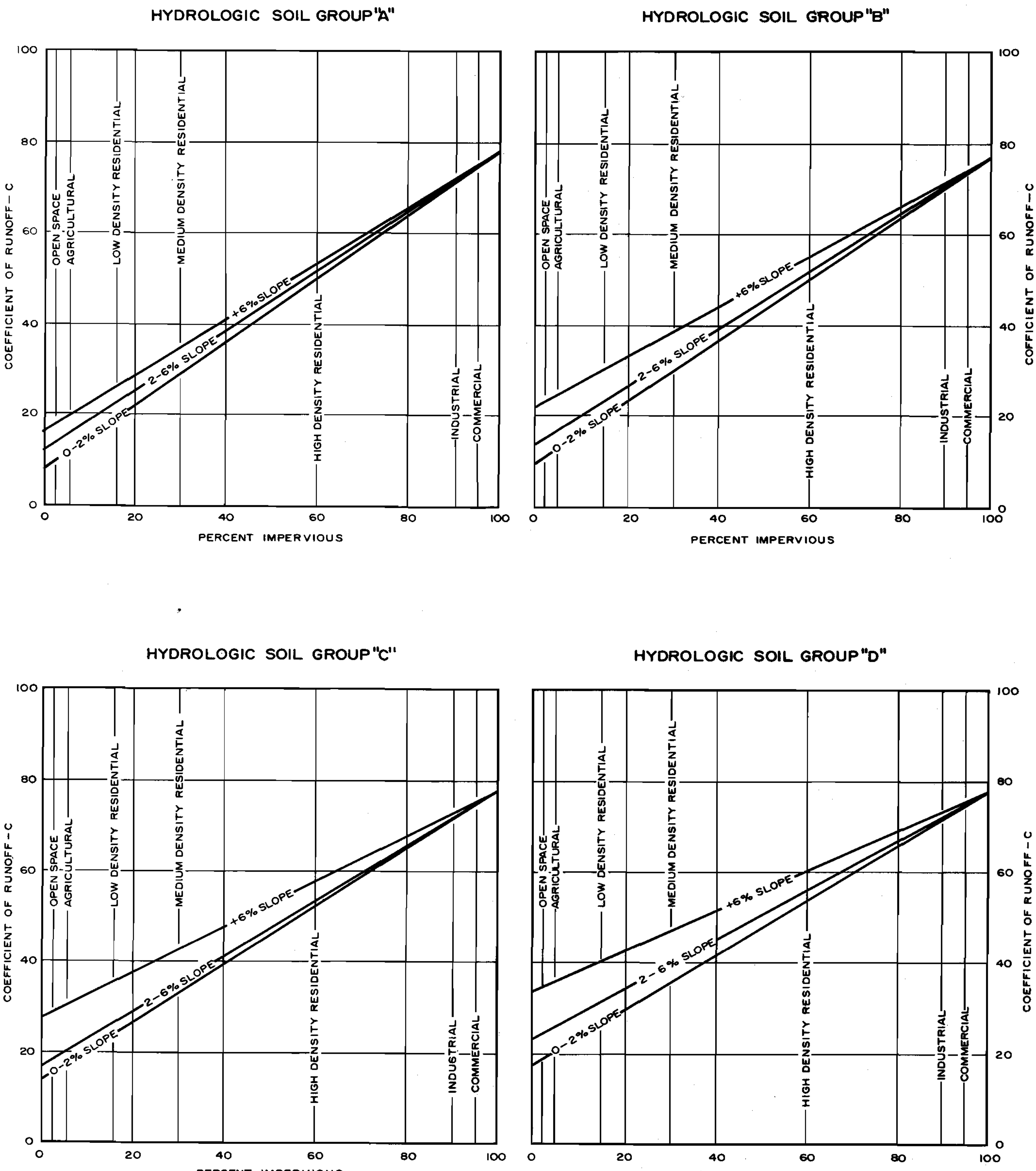
SEASONAL VARIATION OF RAINFALL EVENT DEPTH IN THE REGION AND THE MILWAUKEE RIVER WATERSHED



CURVE NUMBERS INDICATE THE PROBABILITY IN PERCENT OF OBTAINING A RAINFALL EVENT IN ANY MONTH OF A PARTICULAR YEAR WITH A DEPTH EQUAL TO OR GREATER THAN THE RAINFALL DEPTH CORRESPONDING TO A GIVEN RECURRENCE INTERVAL AS SHOWN IN FIGURE C-3.

Source: National Weather Service and SEWRPC.

Figure C-6
COEFFICIENT OF RUNOFF CURVES FOR HYDROLOGIC SOIL GROUPS



Source: SEWRPC.

Table C-1

WEIGHTED RUNOFF COEFFICIENTS FOR USE IN THE RATIONAL FORMULA

LAND USE	PERCENT IMPERVIOUS AREA	HYDROLOGIC SOIL GROUP											
		A			B			C			D		
		SLOPE RANGE (PERCENT)			SLOPE RANGE (PERCENT)			SLOPE RANGE (PERCENT)			SLOPE RANGE (PERCENT)		
		0 - 2	2 - 6	6 & OVER	0 - 2	2 - 6	6 & OVER	0 - 2	2 - 6	6 & OVER	0 - 2	2 - 6	6 & OVER
INDUSTRIAL.......	90	0.67 0.85	0.68 0.85	0.68 0.86	0.68 0.85	0.68 0.86	0.69 0.86	0.68 0.86	0.69 0.86	0.69 0.87	0.69 0.86	0.69 0.86	0.70 0.88
COMMERCIAL.......	95	0.71 0.88	0.71 0.89	0.72 0.89	0.71 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.90	0.72 0.89	0.72 0.89	0.72 0.90
HIGH-DENSITY RESIDENTIAL......	60	0.47 0.58	0.49 0.60	0.50 0.61	0.48 0.59	0.50 0.61	0.52 0.64	0.49 0.60	0.51 0.62	0.54 0.66	0.51 0.62	0.53 0.64	0.56 0.69
MEDIUM-DENSITY RESIDENTIAL......	30	0.25 0.33	0.28 0.37	0.31 0.40	0.27 0.35	0.30 0.39	0.35 0.44	0.30 0.38	0.33 0.42	0.38 0.49	0.33 0.41	0.36 0.45	0.42 0.54
LOW-DENSITY RESIDENTIAL......	15	0.14 0.22	0.19 0.26	0.22 0.29	0.17 0.24	0.21 0.28	0.26 0.34	0.20 0.28	0.25 0.32	0.31 0.40	0.24 0.31	0.28 0.35	0.35 0.46
AGRICULTURE......	5	0.08 0.14	0.13 0.18	0.16 0.22	0.11 0.16	0.15 0.21	0.21 0.28	0.14 0.20	0.19 0.25	0.26 0.34	0.18 0.24	0.23 0.29	0.31 0.41
OPEN SPACE.......	2	0.05 0.11	0.10 0.16	0.14 0.20	0.08 0.14	0.13 0.19	0.19 0.26	0.12 0.18	0.17 0.23	0.24 0.32	0.16 0.22	0.21 0.27	0.28 0.39
FREEWAYS AND EXPRESSWAYS......	70	0.57 0.70	0.59 0.71	0.60 0.72	0.58 0.71	0.60 0.72	0.61 0.74	0.59 0.72	0.61 0.73	0.63 0.76	0.60 0.73	0.62 0.75	0.64 0.78

SOURCE- SEWRPC.

Appendix D

ECONOMIC ANALYSES OF RECREATIONAL DEVELOPMENT AND THE VALUE OF LAND ENHANCEMENT AT THREE PROPOSED RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED

OBJECTIVE

The objective of this appendix is to present the results of a study of the potential demand for recreation at three proposed reservoirs in the Milwaukee River watershed, including a description of the technique used to estimate the potential demand for lake-oriented recreational uses and of the method used to analyze the economic feasibility of recreational development to meet such potential demand.

OVERVIEW

Reservoirs impounded behind dams are among the alternative plan elements that were considered in the development of a comprehensive plan for the development of the land and water resources of the Milwaukee River watershed. Three potential single reservoirs—Waubeka, Newburg, and Horns Corners—along with a fourth impoundment alternative, consisting of the Newburg and Horns Corners Reservoirs, hydraulically connected via the Saukville depression, were selected for detailed technical and economic analysis. Each of these sites has the potential to function as a multi-purpose facility serving recreational, flood control, low-flow augmentation, and water supply needs. This appendix deals with the costs and benefits that would accrue from recreational development undertaken as a part of the reservoir development and an evaluation of the enhancement of land values that could take place after a dam and reservoir were built.

Based upon analyses made by the Wisconsin Department of Natural Resources,[1] the need for water-based recreation facilities in the Milwaukee area and surrounding counties is almost unlimited; and, therefore, it is possible to consider recreational development at any of the proposed reservoir sites. The analyses presented in this appendix demonstrate that, after a reservoir is constructed, the benefits from development of recreation facilities will generally be more than twice the costs of their development and operation.

The initial three sections of this appendix deal with recreation analyses. The expected annual visitation to recreation sites is the basis for development of costs of recreation facilities and recreation-user benefits. The demand curve method of analysis, which is determined on a supply-and-demand market basis, is used for evaluation of specific sites.

The potential for enhancement of basic land values for residential and commercial development is described and quantified in the fourth section of the appendix, and the economic impact of the project on the nearby region is described in the last section. The concepts of economic analyses which served as a guide in this study are presented in Chapter II, Volume 2, of this report.

It is estimated that initial (1970) use of recreation facilities at the Newburg or Waubeka Reservoirs could be expected to total 1,560,000 visitations[2] yearly and that recreational use could be expected to increase to 2,354,000 annual visitations by 1990 and to nearly 4 million visitations within a period of 50 years. Visitations to the Horns Corners Reservoir could be expected to rise from an initial rate of 2,340,000 to 3,480,000 in 1990 and to more than 5 million in 50 years. The difference in visitation rates to the potential reservoir recreation developments is due to the relative proximity of the sites to Milwaukee, with the Horns Corners location being situated closer to that population center and with no consideration being given to the varying quality of the potential recreational experience provided by the three reservoirs. Recreation facilities required to support the initial levels of use were estimated to cost $4,745,300 for Waubeka; $4,615,000 for Newburg; and $6,160,000 for the Horns Corners development. Annual net benefits from recreation use were estimated to total $1,600,000 and $2,470,000, respectively, for the initial and 1990 use levels at Waubeka and Newburg. Annual net benefits for a Horns Corners development were estimated as $2,420,000 and $3,280,000, respectively, for initial and 1990 use levels. The present worth of these recreation costs and benefits for a project with a 50-year life, assuming replacement and addition of facilities at 20 and 40 years, and with a discount rate of 6 percent are shown in Table D-6 of this appendix.

It should be emphasized that recreational benefits are only one type of benefit analyzed for the reservoir alternatives which were considered in the course of the watershed study. Complete economic analyses, including costs and benefits for the entire multiple-purpose development of a dam, reservoir, and recreation facilities, are presented in Chapter IV, Volume 2, of this report.

RECREATIONAL NEED, DEMAND, AND BENEFITS

Two methods currently being used to make recreation user-benefit evaluations are the "aggregate approach" and "the demand curve method." The demand curve method was selected for the analyses of the specific potential projects in the Milwaukee River watershed and is described in this appendix. The aggregate approach is described very briefly below as it was used by the State of Wisconsin to prepare a state-wide recreational plan for 1968.[3]

The Aggregate Approach

The need for, or surplus of, new recreation facilities is estimated in the aggregate approach as the difference between the existing or forecast areawide recreation participation, the existing participation being indicated by an inventory, and the recreation opportunities afforded by existing recreation facilities, as indicated by an inventory. It is shown in the 1968 Wisconsin Department of Natural Resources report that the greatest need for recreation facilities in Wisconsin exists in the southeastern region, which includes the seven counties of the SEWRPC area plus Columbia, Dane, Dodge, Jefferson, and Rock Counties, and in the east central region, which includes the 10 counties located immediately to the north along Lake Michigan. The Milwaukee River watershed lies in these two regions; and the prime potential reservoir sites lie on, or in close proximity to, the east-west boundary between the two regions. The projected recreation needs for the year 2000 are shown in Table D-1.

[1] *Wisconsin Department of Natural Resources, Wisconsin's Outdoor Recreation Plan, 1968.*

[2] *A recreation visitation is defined as the use, by one individual, of a public recreation facility for any part of a day. Visitations may be subdivided into either a camper visitation category, reserved for users that spend the night at a recreation facility, or a day-user visitation category. Recreation visitation may also be subdivided as to season, giving rise to summer visitation, which refers to park users between and including Memorial Day and Labor Day, and winter visitation, which pertains to the remainder of the year.*

[3] *Ibid., Footnote 1.*

Table D-1

SELECTED RECREATIONAL NEEDS IN SOUTHEASTERN AND EAST CENTRAL WISCONSIN FOR THE YEAR 2000[a]

RECREATION ACTIVITY	PROJECTED DEFICIT[b]		
	SOUTHEASTERN WISCONSIN	EAST CENTRAL WISCONSIN	TOTAL[c]
CAMPING (DEVELOPED SITES).....	17,695	4,130	21,825
SWIMMING BEACH (ACRES)................	1,506	513	2,019
BOATING (USERS)................	303,400	32,300	335,700
PICNICKING (TABLES)...............	16,000	3,668	19,668

[a] FOR THE PURPOSES OF THIS TABLE, SOUTHEASTERN WISCONSIN IS DEFINED AS THE SEVEN-COUNTY AREA SERVED BY SEWRPC PLUS DODGE, JEFFERSON, ROCK, DANE AND COLUMBIA COUNTIES. EAST CENTRAL WISCONSIN LIES ALONG LAKE MICHIGAN IMMEDIATELY TO THE NORTH AND CONSISTS OF SHEBOYGAN, FOND DU LAC, GREEN LAKE, WINNEBAGO, CALUMET, MANITOWOC, KEWAUNEE, BROWN, OUTAGAMIE AND DOOR COUNTIES. THE PROPOSED RESERVOIR SITES ARE LOCATED ON OR IN CLOSE PROXIMITY TO THE EAST-WEST BOUNDARY BETWEEN THESE TWO REGIONS AND THEREFORE, BY VIRTUE OF THEIR LOCATION, WOULD HAVE THE POTENTIAL TO SATISFY SOME OF THE INDICATED RECREATIONAL NEEDS.

[b] DEFICIT IS DEFINED AS THE DIFFERENCE BETWEEN THE PROBABLE 1972 SUPPLY AND THE EXPECTED REQUIREMENTS FOR THE YEAR 2000.

[c] AS INDICATED IN TABLE D-5 OF THIS APPENDIX, THE INITIAL RECREATIONAL DEVELOPMENT PROPOSED FOR WAUBEKA RESERVOIR WOULD INCLUDE 740 CAMP SITES, 19 ACRES OF DRY SWIMMING BEACH, AND 1,200 PICNIC TABLES.

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

Areawide statistics, as used in the aggregate approach, can provide a valuable frame of reference for policy-making decisions. They are, however, of limited use for comparing specific alternative projects or especially for considering alternative, competitive uses of the same water, such as lowering a reservoir pool level for low-flow augmentation use as opposed to maintaining the pool level for recreation use.

The Demand Curve Method

Demand curve analyses were used to prepare the recreation user-benefit estimates presented in this appendix for the specific reservoir-related projects considered. This method of analysis is based upon a measure of the willingness of the consumer to pay for a quantity of recreation, given the recreation supply conditions that exist in the area under study. A brief description of the method is presented in this appendix, while a more detailed description may be found in the text: Economics of Outdoor Recreation, Marion Clawson and Jack L. Knetsch, The Johns Hopkins Press, 1966.

The demand curve indicates the amount of resources that people are willing to invest in the recreation sector of the economy. The investment is determined on a supply-and-demand market basis in the same manner as the amounts of resources devoted to food, clothing, and automobiles are determined. The demand curve for recreation at a particular site expresses the quantity of recreation which consumers are willing to purchase at varying prices per unit of recreation service, indicating that at lower prices people are willing to purchase more services, while at higher prices people are willing to purchase less services.

The demand curve for a potential site can be used to forecast the number of recreationists who would use the site, and it may also be used to calculate the monetary value of annual user benefits which can be attributed to the site. This latter step requires the development of a relationship between travel distance to reach the site and the cost of travel. Using appropriate monetary values for the cost of vehicle operation and for the value of travel time and discomfort, it is possible to equate distance to the site with travel costs.

The procedure by which the demand curve method was used in the economic analysis of the multiple-purpose reservoir sites in the Milwaukee River watershed may be divided into five steps:

1. Collection of pertinent data from existing recreation sites in order to develop user-origin curves for those sites.

2. Selection of a curve applicable to the site being studied, considering the relative size and quality of the site, accessibility, nearness to population centers, and the existence of other nearby sites.

3. Calculation of the total annual visitation to the site being studied from the user-origin curves and the population distribution.

4. Conversion of user-origin curves to site demand curves by use of appropriate values for vehicle operational expenses and travel distance. Site visitation is calculated for various levels of simulated prices.

5. Computation of total monetary benefits which are equivalent to the area under the demand curve.

Development of User-Origin Curves for Existing Sites: The SEWRPC staff undertook surveys of recreation activity at Terry Andrae and Mauthe Lake State Parks and the Root River Parkway, all within, or in close proximity to, the Region, in the summer of 1968; and these data are available from the Commission files in a readily usable form. In addition, during the same summer, the Wisconsin Department of Natural Resources conducted a user survey of 31 state parks within the state; and these data were used in the development of user-origin curves.

Approximately 0.5 percent of all summer visitors at the recreation sites were interviewed, usually on three separate days at each park site. Information collected included: 1) whether the visitor was from in-state or out-of-state; 2) whether his visit was primarily for day-use or camping; and 3) how far he had traveled from his last overnight stop. In addition to computer print-outs of the survey data, the Wisconsin Department of Natural Resources prepared a listing of visitors by distance from the parks. This information was used to prepare the per capita user-origin curves.

The total summer visitation to the parks was known from traffic counter readings, while the number of camping visitors was obtained from campground registrations. The difference between total visitations and camper visitations was assumed to be day user visitations. The traffic counter method of measuring visitation may lead to overestimates of visitation, depending on where the counter is located, how often it is read, and the traffic patterns of the park users. Camper registration is considered to be accurate. Any error in the traffic counts thus would be reflected in the day-use figures. There was no direct means of estimating the degree of error in the data; and, therefore, the derived per capita user-origin curves were checked against curves from similar parks elsewhere in the United States. Since they were in close agreement, any data error was assumed to be small.

Total summer visitation from concentric zones around the park was calculated by multiplying the ratio of surveyed visitors from the zone to the total summer visitors surveyed times the total annual visitation. It was assumed that the road mileage reported in the survey could be used to approximate the airline distance from home to the park and that the sample survey was a good cross section of the total visitation. Both of the foregoing assumptions are valid because the traffic patterns are fairly direct, and any error would fall within the width of the concentric zones. In an attempt to assure that the survey was representative for the entire summer season, surveys were conducted on both weekdays and weekends throughout the summer season. Each park was surveyed for at least three days, with greater emphasis being placed in the surveys at the major park sites.

The 1968 population within each zone was estimated using the following information sources:

1. Population Note No. 7, Department of Rural Sociology, University of Wisconsin, for the State of Wisconsin outside the SEWRPC area;

2. SEWRPC population estimates by civil division for the SEWRPC area; and

3. Population estimates prepared by the Northeastern Illinois Planning Commission (NIPC) and 1960 census data for the State of Illinois.

Except for the SEWRPC area, these data were available by county. Since the zones were narrower than the counties, the percentage of the county population in the zone was estimated on the basis of relative land areas and population concentrations by civil divisions.

Per capita summer visitation was calculated by dividing visitation to parks from the zone by total population in the zone. A summary of the results of these computations for Devils Lake State Park is presented in Table D-2. These computations were carried out for Devils Lake and High Cliff State Parks, since they are similar to the potential sites in the Milwaukee River watershed, in that they have the following characteristics:

1. Large water surface area.

2. Large, diversified parks offering a full range of recreational opportunities.

3. Attractive to people from urban centers for both day-use and weekend activities.

Table D-2

PER CAPITA VISITATION TO DEVILS LAKE STATE PARK BY CONCENTRIC ORIGIN ZONES DAY USERS--SUMMER 1968

CONCENTRIC ORIGIN ZONE (INNER AND OUTER RADIUS MEASURED FROM PARK IN MILES)	SUMMER VISITATION FROM EACH ZONE[a]	1968 POPULATION OF EACH ZONE[b]	SUMMER PER CAPITA VISITATION BY ZONE
0-10	95,000	13,400	7.09
10-20	58,000	65,400	0.89
20-30	32,000	164,200	0.19
30-40	42,000	154,200	0.27
40-50	285,000	122,300	2.33
50-60	10,600	159,400	0.07
60-70	21,100	264,000	0.08
70-80	26,400	315,000	0.084
80-90	42,000	766,100	0.055
90-100	63,300	1,161,300	0.054
100-120	78,880	553,800	0.143
120-140	10,560	1,506,300	0.007
140-180	306,000	5,378,000	0.057

[a]BASED ON REPRESENTATIVE USER SURVEYS FOR THE PARK AND TOTAL TRAFFIC COUNTS OBTAINED DURING THE SUMMER OF 1968.

[b]POPULATION ESTIMATES WERE OBTAINED FROM THE DEPARTMENT OF RURAL SOCIOLOGY AT THE UNIVERSITY OF WISCONSIN, SEWRPC, THE NORTHEASTERN ILLINOIS PLANNING COMMISSION, AND 1960 U. S. CENSUS DATA.

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

For comparison with the curves derived for the two Wisconsin parks, per capita user-origin curves were available for the 3,400 acre Cagles Mill-Mansfield Reservoir development in central Indiana and the larger Allegheny and Kerr Reservoir facilities located in Pennsylvania and on the Virginia-North Carolina border, respectively.

These three supplemental curves and the Devils Lake and High Cliff curves are shown in Figure D-1. The Devils Lake curve is particularly irregular because there is an exceptionally high attendance from Madison relative to its population and its distance from the park. It is considered significant that all the curves have the same general shape, fall within a relatively close range, and that the differences and irregularities may be attributed to population concentrations in the vicinity of the various parks, giving rise to above-average per capita visitations.

Selection of a User-Origin Curve Representative of the Potential Sites: The group of curves in Figure D-1 are bounded on the upper side by the curve for the Kerr Reservoir recreation development and on the lower side by the High Cliff State Park curve. The visitation intensity diminishes from those sites which offer the most in terms of overall size, water surface, variety of facilities, and quality to those which are more limited. The potential sites in the Milwaukee River watershed would be larger and provide a greater variety of facilities than Devils Lake but a lesser variety than the Kerr Reservoir. People from the Chicago area seem to have a greater propensity to travel long distances to recreate than people from less congested urban areas. Therefore, the visitation rate from beyond 70 miles may be expected to remain higher for a Milwaukee River site than, for example, the Kerr Reservoir.

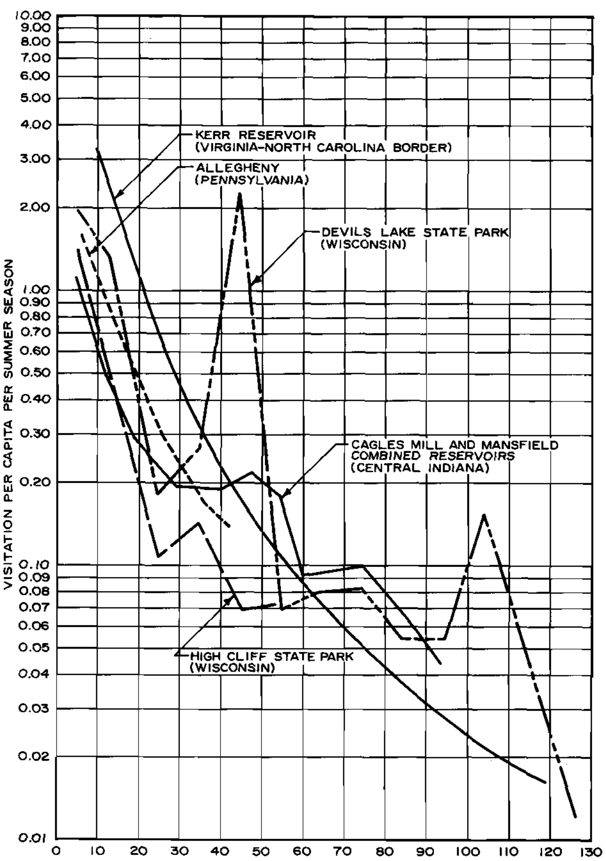
The curve shown in Figure D-2, which follows the general shape of the user-origin curves for the existing recreation developments, was selected as being most appropriate for the Waubeka, Newburg, and Horns Corners reservoir sites. It includes a relatively high visitation rate from as far away as the Chicago area.

Determination of the Total Summer Recreation Visitation for the Potential Sites: Summer visitation to the proposed sites is computed by applying the summer per capita visitation rate to the population distribution around the site. Population data were obtained from the same sources as were used to establish the user-origin curves for existing sites. The same population distribution was assumed for the Waubeka and Newburg sites because these two reservoirs are located close to each other. A separate population distribution was calculated for the Horns Corners site because it is approximately 15 miles closer to Milwaukee and could be expected to attract people from Milwaukee at a slightly higher rate.

It is generally agreed that attendance at recreation facilities may be expected to increase as population, leisure time, disposable income, and the quality of transportation service increase. A projection of the increase in total regional attendance would be of little consequence with a small site, as "present attendance" would occupy to capacity the facilities which could be made available. The sites considered, however, are very large; and land around the reservoir could be reserved for future development. For the purposes of this study, which was to evaluate—not design—alternate recreation developments, the minimum expected increase in attendance, based on forecast population growth only, was assumed.

Figure D-1

SUMMER USER-ORIGIN CURVES FOR EXISTING RECREATION DEVELOPMENTS SIMILAR TO PROPOSED RECREATION DEVELOPMENTS AT THE POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED

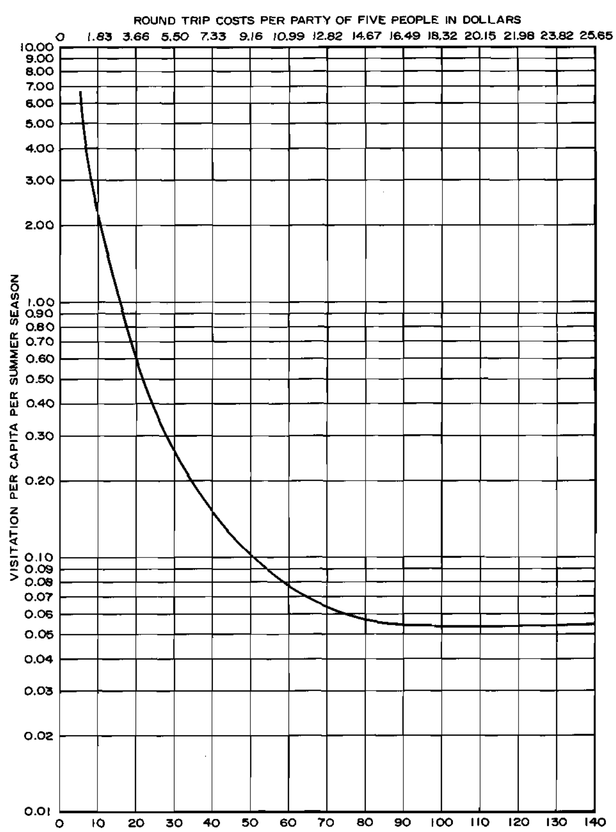


NOTE: *THE VISITATION VALUES ON THIS GRAPH ARE FOR DAY USERS AND EXCLUDE CAMPERS WHICH HAVE A SUMMER VISITATION EQUAL TO TEN PERCENT OF THE DAY USERS.*

Source: Harza Engineering Company.

Figure D-2

SUMMER USER-ORIGIN CURVE DEVELOPED FOR POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED



NOTE: ROUND TRIP COSTS PER PARTY OF FIVE PEOPLE IN ONE VEHICLE ARE COMPUTED ON THE BASIS OF $0.0916 PER VEHICLE MILE WHICH IS THE SUM OF A VEHICLE OPERATING COST OF $0.0516 PER VEHICLE MILE AND A TRAVEL TIME COST OF $0.04 PER VEHICLE MILE. THE VISITATION VALUES ON THIS GRAPH ARE FOR DAY USERS AND EXCLUDE CAMPERS WHICH HAVE A SUMMER VISITATION EQUAL TO TEN PERCENT OF THE DAY USERS.

Source: Harza Engineering Company.

Summer visitation to the potential Waubeka, Newburg, and Horns Corners recreational developments was computed for the 1970 population and the 1990 population using the representative user-origin curve shown in Figure D-2; and the trend indicated by the visitations for these two years was extrapolated on a linear basis to the year 2020 to permit evaluation of the economics of the project for a 50-year life. Projected summer visitations for the three potential reservoirs, exclusive of campers, are shown in Figure D-3. The uncertainty associated with extrapolation of the summer visitation from 1990 to 2020 is not significant, since any differences between the assumed rate and the actual rate for this extrapolated period is greatly reduced in its impact on the economic analysis because benefits and costs are discounted to present worth at 6 percent interest. The effect of discounting places less value on future occurrences. For example, at an interest rate of 6 percent, a benefit or cost accruing five years after the project is initiated has a present worth of about 75 percent, whereas a benefit or cost accruing 20 years later has a present worth of 31 percent; and the fiftieth year accrual has a present worth of only 5 percent.

Recreation development in the Milwaukee River watershed may be expected to attract the majority of the users from three population zones: the nearby area, the Milwaukee metropolitan area, and the Chicago metropolitan area. The distribution of the origin of summer users, exclusive of campers from these areas, as derived from estimated 1970 population distributions and the user-origin curve of Figure D-2, is shown in Table D-3.

Development of a Demand Curve for the Potential Sites: The abscissa of a user-origin curve is converted from miles to dollars by use of an appropriate cost per mile factor. The miles traveled to visit a site are converted into monetary units by evaluation of two components of travel costs:

1. Variable costs of operating an automobile for the round-trip mileage involved in visiting a site.

2. Costs of travel time and discomfort to the automobile passengers.

The vehicle operating cost used in this study was $0.0516 per vehicle-mile, as recommended by the American Association of State Highway Officials for road-user benefit studies. The approximate cost for time of travel is more difficult to establish. The problem is one of determining what the typical party of four to five people would be willing to pay, in addition to the vehicle operating cost, to forego having to spend time and undergo travel discomfort and driver strain in going to and from the site.

The American Association of State Highway Officials uses a cost of time of $0.86 per person-hour for road-user benefit studies. The value of time per vehicle-hour at this rate would be about $3.90 for an average party size of 4.5 persons. However, the AASHO rate is based upon intercity travel studies wherein recreation was not necessarily the trip purpose. Willingness to pay for reduced travel time may be considerably different when the trip purpose is related to work rather than when it is related solely to recreation.

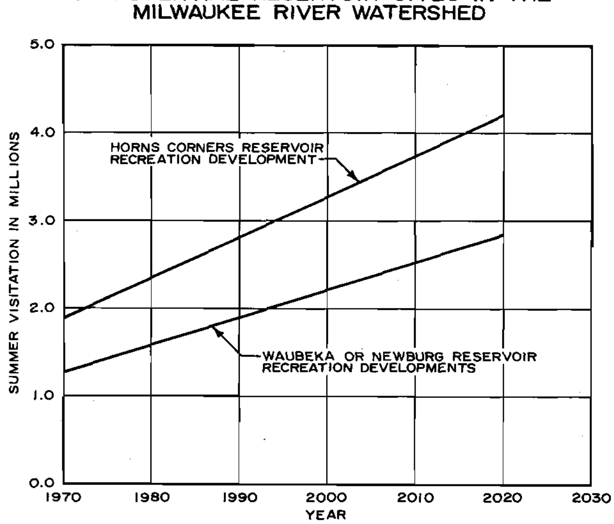
A consideration in evaluating the costs of travel time and discomfort is that many visitors put a positive value on the trip. A sizable proportion of park visitors consider the trip to be an enjoyable, integral part of the recreation experience, with sightseeing along the travel route being an especially valued activity. Such visitors would not consider travel time as a cost incurred as a result of utilizing a recreation facility. On the other hand, some families may prefer instead to travel directly and as quickly as possible to a specific area so that nearly all of their leisure time can be spent at the recreational area. This may imply a perception of a relatively higher cost of travel time for families and groups in transit to and from recreation developments. For the analyses described in this appendix, a time of travel cost of $2.00 per vehicle-hour was used. The $2.00 rate is the same as that used in the Meramac Basin study conducted by Washington University of St. Louis.[4] In the Meramac study, $1.50 was considered a reasonable time of travel cost for the driver; $0.50 was added for one passenger; and all other passengers were considered to incur a zero time of travel cost.

A value of $2.00 per hour per party of five at an average speed of 50 miles per hour is equivalent to a cost of $0.04 per mile. The total travel cost per mile is, therefore, the sum of the vehicle operation cost of $0.0516 per vehicle-mile and the time of travel cost of $0.04 per vehicle-mile, or $0.0916 per vehicle-mile. The upper scale on the abscissa of Figure D-2 is based on this cost, and the visitation rate at which people will come to a site for various incurred costs may be read directly from Figure D-2. For example, a group of five people who incur a total cost of $1.50 may be expected to visit the park 3.40 times per year, since the per capita visitation corresponding to a round-trip cost of $1.50 is 3.40. If the cost is increased by $0.75 per party, to $2.25, the people in that party may be expected to make only 2.00 visits per year. An entire range of hypothetical incremental user costs and resulting summer visitations can thus be simulated, and the results may be expressed as a demand schedule or demand curve. Figure D-4 shows the demand curve constructed for the Waubeka or Newburg sites for the 1970 and 1990 population distributions.

[4]*The Meramac Basin, Water and Economic Development*, Washington University, St. Louis, Missouri, 1961.

Figure D-3

PROJECTED SUMMER RECREATION VISITATION TO POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED



NOTE: PROJECTED SUMMER RECREATION VISITATIONS ARE BASED ON THE USER-ORIGIN CURVE APPLICABLE TO THE THREE RESERVOIR RECREATION DEVELOPMENTS AND ESTIMATED 1970 AND 1990 POPULATION DISTRIBUTIONS FOR THE AREA THAT WOULD BE SERVED BY THE FACILITIES. THE VISITATION VALUES ON THIS GRAPH ARE FOR DAY USERS AND EXCLUDE CAMPERS WHICH HAVE A SUMMER VISITATION EQUAL TO TEN PERCENT OF THE DAY USERS.

Source: Harza Engineering Company.

Table D-3

PROJECTED SUMMER 1970 VISITATION TO THE POTENTIAL RESERVOIR RECREATION DEVELOPMENTS IN THE MILWAUKEE RIVER WATERSHED BY PRINCIPAL ORIGIN ZONES[a]

WAUBEKA OR NEWBURG RECREATION DEVELOPMENTS			
ORIGIN ZONE		SUMMER VISITATION	
NAME	DISTANCE RANGE (IN MILES)	NUMBER	PERCENT
WAUBEKA-NEWBURG AREA	0-10	216,000	17
MILWAUKEE METROPOLITAN AREA	20-40	423,000	34
CHICAGO METROPOLITAN AREA	100-130	325,000	26
OTHER	--	289,000	23
TOTAL SUMMER VISITATION AT THE WAUBEKA OR NEWBURG RECREATION DEVELOPMENTS		1,253,000	100

HORNS CORNERS RECREATION DEVELOPMENT			
ORIGIN ZONE		SUMMER VISITATION	
NAME	DISTANCE RANGE (IN MILES)	NUMBER	PERCENT
HORNS CORNERS AREA	0-10	482,000	26
MILWAUKEE METROPOLITAN AREA	10-30	795,000	42
CHICAGO METROPOLITAN AREA	90-120	325,000	17
OTHER	--	282,000	15
TOTAL SUMMER VISITATION AT THE HORNS CORNERS RECREATION DEVELOPMENT		1,884,000	100

[a]PROJECTED SUMMER VISITATION VALUES WERE DERIVED FROM THE USER-ORIGIN CURVE APPLICABLE TO THE THREE POTENTIAL RESERVOIR SITES AND THE ESTIMATED 1970 POPULATION DISTRIBUTION FOR THE AREA THAT WOULD BE SERVED BY THEM. THE VISITATION VALUES IN THIS TABLE ARE FOR DAY USERS AND EXCLUDE CAMPERS WHICH HAVE A SUMMER VISITATION EQUAL TO TEN PERCENT OF THE DAY USERS.

SOURCE- HARZA ENGINEERING COMPANY.

Computation of Total Annual User Benefits for the Potential Sites: The demand curve was then used to estimate the net annual summer day-user recreation benefit that would accrue from a recreation facility. If a hypothetical fee of $1.20 per person or $6.00 per party of five was charged, the summer visitation, as indicated in Figure D-4, would be 300,000 for the 1970 population distribution rather than the 1,253,400 visitations with no fee; and the total revenue would be $360,000. However, the value or recreation benefit to the visitors is greater than this because some of those who came at a charge of $1.20 per person would have come if the charge had been $2.40 per person; that is, 170,000 of the 300,000 people. The revenue collected with a $1.20 entrance fee would be only $360,000, whereas the value to the 300,000 visitors involved would be much greater. In fact, it is equal to the total area under the demand curve lying to the left of the indicated rate of visitation. With no entrance fee, the total summer visitation benefit at Waubeka in 1970, as determined from the total area beneath the demand curve, would be $1,290,000.

The computations for visitation and user benefits are based on summer day-users. The relatively small number of people who use water-based recreation facilities in the cold season between Labor Day and Memorial Day and the campers are added to the summer day-user figures in order to arrive at annual totals. The 1968 annual attendance figures for Devils Lake and High Cliff for both day-users and campers equal about 113 percent of summer visitation. Therefore, summer visitation and benefits were increased by 13 percent.

The camper user-origin data for Devils Lake and High Cliff was very erratic, indicating that campers are not as sensitive to distance as are day-users. Since campers represent only about 10 percent of total day-users, it was recognized that any discrepancy introduced would be small if the day-user visitation and user benefits were increased by 10 percent to include campers. A summary of 1970 and 1990 visitation and user benefits to the reservoir developments is presented in Table D-4.

DESIGN CRITERIA AND FACILITY COSTS

It was assumed that swimming, boating, picnicking, and camping facilities will be provided for the number of visitations estimated. These activities are either directly dependent on water or are considerably enhanced by its presence and are also the major cost items in a recreation development.

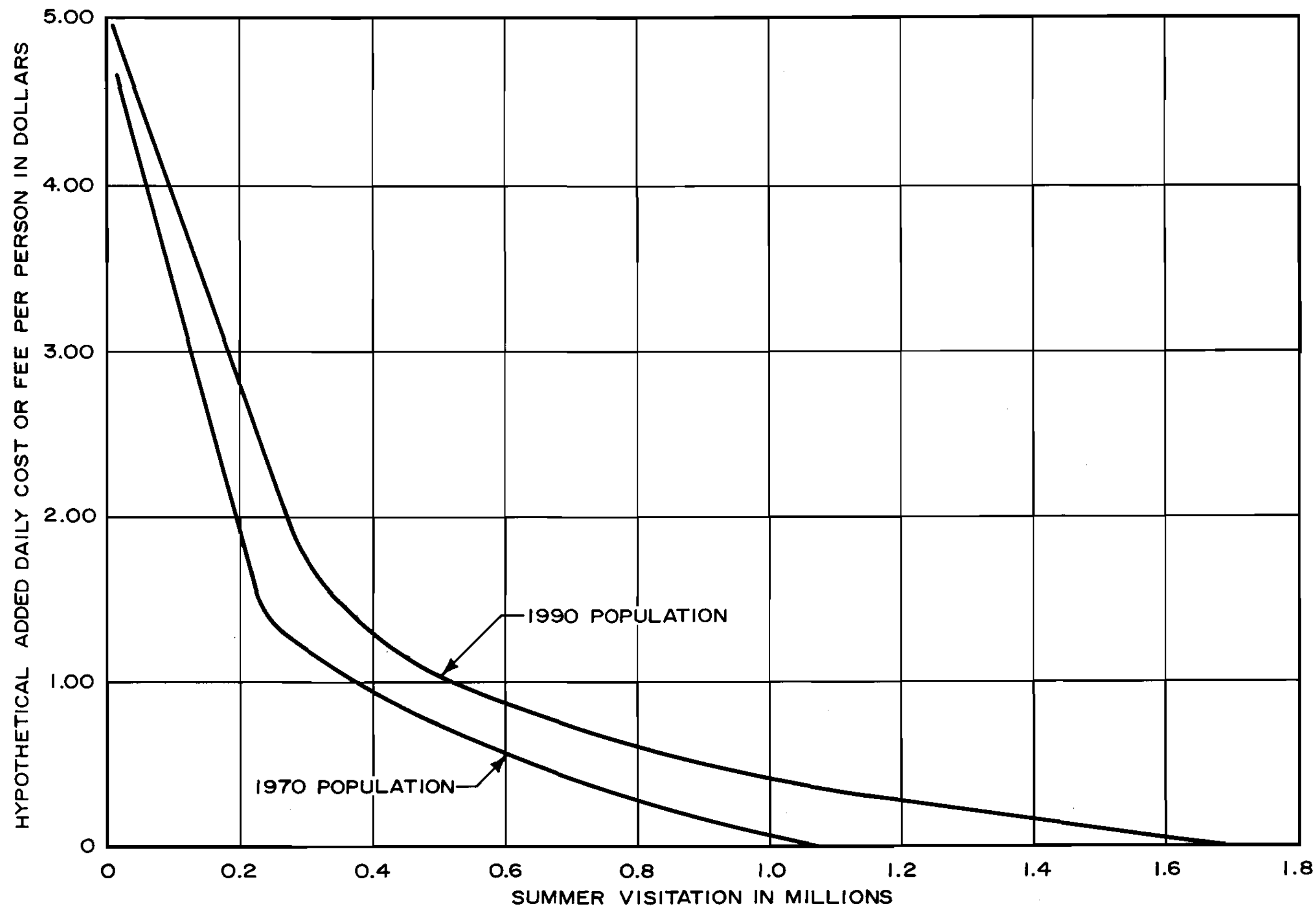
Number and Size of Facilities

Facilities were designed for the attendance which could be expected on the peak day of an average summer week without a national holiday. The design load was computed by the following formula:

Design Load = (Summer Day-User Visitation ÷ 14)x(0.25 ÷ 1.5)
with 14 = to the number of weeks during the summer season;
0.25 = the proportion of the average weekly attendance which may be expected to occur on the peak day; and
1.50 = to the turnover factor.

Figure D-4

SUMMER DEMAND CURVES FOR POTENTIAL WAUBEKA OR NEWBURG RESERVOIR RECREATIONAL DEVELOPMENTS IN THE MILWAUKEE RIVER WATERSHED



NOTE: THESE RELATIONSHIPS ARE BASED ON ESTIMATED 1970 AND 1990 POPULATION DISTRIBUTIONS FOR THE AREA THAT WOULD BE SERVED BY THESE FACILITIES AND THE APPLICABLE USER-ORIGIN CURVE WHICH INCORPORATES A USER COST OF $0.0916 PER VEHICLE MILE FOR A PARTY OF FIVE PEOPLE. THE VISITATION VALUES ON THIS GRAPH ARE FOR DAY USERS AND EXCLUDE CAMPERS WHICH HAVE A SUMMER VISITATION EQUAL TO TEN PERCENT OF THE DAY USERS.

Source: Harza Engineering Company.

Table D-4

VISITATION AND CORRESPONDING BENEFITS FOR POTENTIAL RESERVOIR RECREATION DEVELOPMENTS IN THE MILWAUKEE RIVER WATERSHED 1970 AND 1990

TYPE OF VISIT	SUMMER VISITATION	SUMMER BENEFIT	ANNUAL VISITATION	ANNUAL BENEFIT
WAUBEKA OR NEWBURG RECREATION DEVELOPMENTS				
1970				
DAY-USER	1,253,400	$1,289,500	1,418,000	$1,456,000
CAMPERS	125,300	129,000	141,800	145,600
TOTAL	1,378,700	$1,418,500	1,559,800	$1,601,600
1990				
DAY-USER	1,892,700	$1,985,500	2,140,000	$2,242,000
CAMPERS	189,300	198,600	214,000	224,200
TOTAL	2,081,000	$2,184,100	2,354,000	$2,466,200
HORNS CORNERS RECREATION DEVELOPMENT				
1970				
DAY-USER	1,883,700	$1,949,500	2,125,000	$2,200,000
CAMPERS	188,300	195,000	213,000	220,000
TOTAL	2,072,000	$2,144,500	2,338,000	$2,420,000
1990				
DAY-USER	2,796,900	$2,634,500	3,160,000	$2,980,000
CAMPERS	279,700	263,500	316,000	298,000
TOTAL	3,076,600	$2,898,000	3,476,000	$3,278,000

SOURCE- HARZA ENGINEERING COMPANY.

The design load is the number of people which may be expected to use the site at the same time on the peak day of the average week. The load estimated for Waubeka, based on the 1970 summer day-user visitation of 1,253,400, was 14,900 day-users. Based on studies reported by the Bureau of Outdoor Recreation, it was estimated that at any one time 55 percent of the visitors, at design load, will be swimming; 40 percent, picnicking; and 15 percent, boating. This distribution of uses considers the fact that some visitors will use space at more than one facility during the day.

The 1968 Wisconsin park-user survey indicated an average of five occupants per vehicle. Estimates of the facilities to be provided for users participating in each activity were made using the standards of the Wisconsin Department of Natural Resources, as set forth in Wisconsin's Outdoor Recreation Plan, Wisconsin Department of Natural Resources, 1969, supplemented with additional guidelines provided by that agency and the Harza Engineering Company. Sufficient land was provided to accommodate the facilities and to permit reservation of space for active play areas and nature trails.

Cost of Facilities and Land

Unit costs of developing selected recreation facilities were obtained from unpublished data of the Wisconsin Department of Natural Resources (see Table D-5). Land for the recreation areas was estimated to cost $400 per acre, a value representing the average cost for better lands, exclusive of structures, in the areas of the reservoirs, since it was assumed that most of the recreation areas would be sited on the better lands. Twenty percent was added to the calculated direct costs for contingencies, and an additional 12 percent was added to the estimated costs for the design and supervision of development of the recreation areas.

Estimated costs for developing recreation facilities at Waubeka are shown in Table D-5, based on the 1970 visitation. The costs would be greater for the increasing visitations after 1970, with the exception of fish stocking costs, in that the proposed stocking program summarized in the table was assumed to be repeated at 20-year intervals, with no increase in the number of fish fry and fingerlings added to the reservoir. The Newburg and Horns Corners reservoir sites do not have the potential for a self-sustaining fishery because of their shallow depths and resultant threat of winterkill; and, therefore, the recreation cost and benefit analyses of these two potential impoundments exclude fishery development. The recreation facility cost estimate for the potential Newburg Reservoir is equal to that for the Waubeka Reservoir minus the $96,000 fish stocking cost and attendant 20 percent for contingencies and 12 percent for engineering, for a total initial facility cost of $4,615,000. The initial cost of recreation facilities at the Horns Corners site is estimated at $6,160,000 and is based on the initial cost at the Newburg development, increased approximately in proportion to the larger Horns Corners visitation.

RECREATION BENEFIT-COST ANALYSIS

A summary of visitation-user benefits, costs, and benefit-cost ratios for the Waubeka, Newburg, and Horns Corners sites, with and without land enhancement benefits, is presented in Table D-6 on a present worth basis and indicates that the benefits may be expected to be generally at least twice the costs for these recreation facilities. These costs and benefits include neither the cost of the dam and reservoir, nor the benefits from flood control, low-flow augmentation, and water supply.

The evaluation was performed for a 50-year period at an interest rate of 6 percent. Expenditures include initial investments for land and recreation facilities, replacement cost at 20-year intervals,[5] and operation and maintenance costs. Operation and maintenance costs vary considerably, depending on the quality of the maintenance, the character of the facilities, and especially on the bookkeeping methods used to report costs. Twenty cents per visitor-day was used in this study, and this cost amounts to $312,000 per year at Waubeka for the total 1970 visitation.

For the purposes of discounting benefits and costs, it was assumed that a reservoir at any of the three sites could be completed and ready for initial recreational use in 1975. Furthermore, it was assumed that attendance would increase over a five-year period so that full initial design visitation would occur by 1980. During the five-year period, user benefits would increase linearly; and the facilities would be provided at the same rate. In 1995, when initial facilities would be replaced, sufficient facilities would be provided to accommodate the projected attendance for the year 2000. Annual benefits and operation and maintenance costs were discounted for a 50-year life by decades, with values for each decade being equal to the annual benefits and operation and maintenance costs at the midpoint of the decade.

The Waubeka Reservoir fish stocking economic analysis was an exception to this procedure, in that fish stocking costs and fishing benefits were not increased in proportion to anticipated increasing visitations but, instead, were assumed to be maintained at a uniform level. The stocking program would, therefore, be repeated at a cost of $96,000 every 20 years, those costs having a present worth of $135,000 for a 50-year project life and a 6 percent interest rate. Fishery benefits were estimated to be a uniform $850,500 annually, corresponding to a present worth of $13,405,500. Benefits accruing to fishing were determined by assuming that 9,450 acres of the 10,400 acre normal water surface area would be utilized for sport fishing, with the volume of water below each acre of reservoir surface having a stable annual carrying capacity of 600 pounds of fish. It was further assumed that, during an average year, 20 percent of the fish, or 120 pounds per acre, would be harvested at a value to the sportsman of $0.75 per pound. The harvest percentage and the per pound value were conservatively established at low levels so as to compensate for the possibility that some annual fishing benefit may be included in the annual recreation benefit determined from the demand curve analysis.

LAND VALUE ENHANCEMENT

Evaluation of the economic worth of a reservoir project must account not only for benefits from recreation users but also for benefits resulting from increases in the value of private lands surrounding the reservoir. Many people have a preference for land on or near a lakeshore and are willing to pay additional sums of money to satisfy this preference. The increase in the value of land due to the proximity to a water area should be added to the benefits of the project.

The problem is one of determining how the value of land is influenced by location relative to water areas, population centers, alternative lake opportunities, road access, and distance of the tract from the reservoir. It is necessary to exercise a considerable degree of caution in making analyses of land enhancement benefits. The land enhancement benefit should only include the "value added" to the land that is attributable to the proximity of water and should exclude increased value due to property improvements, utilities, and access. To date, few

[5] *The Wisconsin Department of Natural Resources uses a 20-year life for roads, parking areas, sanitation and water supply facilities, and camping facilities in parks.*

Table D-5

INITIAL RECREATION FACILITY REQUIREMENTS AND COSTS FOR THE WAUBEKA RESERVOIR IN THE MILWAUKEE RIVER WATERSHED

ITEM	SOURCE OF DESIGN CRITERION	DESIGN CRITERION[a]	QUANTITY (EACH)	UNIT COST[b] ($)	TOTAL COST ($)
PICNICKING[c]					
TABLES	I	5 PICNICKERS PER TABLE	1,200	70	83,600
GRILLS	II	1 GRILL FOR 2 TABLES	600	50	30,000
TRASH CANS	II	1 CAN FOR 2 TABLES	600	25	15,000
SHELTERS (INDIVIDUAL TABLE)	IV	1 SHELTER FOR 4 TABLES	300	175	52,500
SWIMMING[d]					
DRY BEACH	I	200 FT^2 PER SWIMMER	820,000 FT^2	0.25/FT^2	205,000
UNDERWATER BEACH	II	100 FT^2 PER SWIMMER	411,000 FT^2	0.10/FT^2	41,100
LIFEGUARD STANDS	IV	1 STAND FOR 500 FT. OF BEACH	4	200	800
DIVING FLOATS AND BOARDS	IV	1 UNIT FOR 750 FT. OF BEACH	2	1,400	2,800
BATHHOUSE	IV	1 BATHHOUSE FOR 750 FT. OF BEACH	2	36,000	72,000
BOATING[e]					
RAMPS	IV	4 PEOPLE PER BOAT AND 40 LAUNCHINGS PER RAMP PER DAY	14	1,500	21,000
DOCKS	IV	1 DOCK PER RAMP	14	1,500	21,000
FISH STOCKING					
WALLEYE FRY	III	NA	10,000,000	0.35/1,000	3,500
NORTHERN PIKE FRY	III	NA	10,000,000	2.00/1,000	20,000
WALLEYE FINGERLINGS	III	NA	50,000	50.00/1,000	2,500
NORTHERN PIKE FINGERLINGS	III	NA	50,000	1,300.00/1,000	65,000
LARGEMOUTH BLACK BASS	III	NA	20,000	250.00/1,000	5,000
PARKING					
DAY-USE (SWIMMING, PICNICKING SPACES)	IV	85 PERCENT OF DESIGN LOAD ASSUMING 4 PEOPLE PER CAR AND 200 FT^2 OF ASPHALT PER SPACE.	3,180	100	318,000
DAY USE (BOATING SPACES)	IV	15 PERCENT OF DESIGN LOAD ASSUMING 4 PEOPLE PER CAR AND 400 FT^2 OF ASPHALT FOR CAR AND TRAILER SPACE.	560	150	84,000
SANITATION					
PICNIC GROUND COMFORT STATIONS	IV	100 PEOPLE PER 8 TOILET UNIT	8 UNITS	11,200	106,400
		150 PEOPLE PER DRINKING FOUNTAIN	40 DRINKING FOUNTAINS	150	
		150 PEOPLE PER SINK.	40 SINKS	260	
BOAT LAUNCHING PIT TOILETS	IV	1 TOILET PER RAMP	14	2,200	30,800
CAMPGROUND COMFORT STATIONS	IV	1 TOILET PER 20 PEOPLE	148 TOILETS	1,500	318,500
		1 SINK PER TOILET	148 SINKS	260	
		1 SHOWER PER 20 PEOPLE	148 SHOWERS	785/PAIR	
WATER SUPPLY					
SUPPLY	IV	1 CENTRAL WELL AND STORAGE TANK	--	--	30,000
DISTRIBUTION	IV	50,000 LINEAL FEET OF PIPE	--	--	175,000
ROADS					
ACCESS ROADS	IV	DOUBLE LANE ASPHALT PROVIDING ACCESS TO CAMPGROUND, BEACH, PICNIC AREA, AND BOAT LAUNCHING FACILITIES	18,480 FT.	6.00/FT.	110,900
CAMPING[f]					
SITES	IV	4 CAMPERS PER SITE	740	800	590,000
LAND					
INTENSIVE USE AREAS	IV	8 PICNIC TABLES PER ACRE	150	400	135,500
		DRY BEACH (SEE ABOVE)	19		
		PARKING SPACE (SEE ABOVE)	20		
		5 CAMP SITES PER ACRE	150		
BUFFER ZONE AND NATURAL STATE AREAS	IV	--	1,661	400	664,500
MISCELLANEOUS					
TRAILS	IV	1 MILE PER 5,000 PEOPLE	3 MI.	450 PER MI.	1,400
SIGNS	IV	ENTRANCE SIGN AND 40 DIRECTIONAL SIGNS	--	--	3,000
SUBTOTAL					3,620,800
		CONTINGENCIES	20%		725,000
		ENGINEERING	9%		399,500
TOTAL					4,745,300[g]

[a]THE FOLLOWING SOURCES OF RECREATION FACILITY DESIGN CRITERIA WERE USED IN ESTABLISHING THE FACILITIES SET FORTH IN THIS TABLE. SOURCES II, III, AND IV WERE USED ONLY WHEN WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS WERE NOT AVAILABLE OR APPLICABLE.

SOURCE I- WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS AS SET FORTH IN WISCONSIN'S OUTDOOR RECREATION PLAN, WISCONSIN DEPARTMENT OF NATURAL RESOURCES, 1968.

SOURCE II- "RATIOS AND DISTANCES BETWEEN PEOPLE, LAND AND FACILITIES ON RECREATION AREAS," DEPARTMENT OF NATURAL RESOURCES, MADISON, WISCONSIN (UNDATED).

SOURCE III- RECOMMENDED FISH STOCKING QUANTITIES WERE PROVIDED DIRECTLY TO SEWRPC BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES STAFF.

SOURCE IV- HARZA ENGINEERING COMPANY.

[b]UNIT COSTS, WITH THE EXCEPTION OF LAND COSTS, WERE OBTAINED FROM UNPUBLISHED DATA PROVIDED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

[c]DESIGN ASSUMES 5,970 PEOPLE USING PICNICKING FACILITIES.

[d]DESIGN ASSUMES 8,200 PEOPLE USING THE SWIMMING FACILITIES WITH 4,100 PEOPLE ON THE BEACH AND 4,100 IN THE WATER.

[e]DESIGN ASSUMES 2,240 PEOPLE USING BOATING FACILITIES.

[f]DESIGN ASSUMES 2,960 PEOPLE USING CAMPING FACILITIES.

[g]THE COMPARABLE TOTAL INITIAL RECREATION FACILITY COST ESTIMATES FOR THE POTENTIAL NEWBURG AND HORNS CORNERS RESERVOIR DEVELOPMENTS, BOTH OF WHICH EXCLUDE A FISHERY DEVELOPMENT BECAUSE OF INADEQUATE DEPTH TO PREVENT WINTERKILL, ARE $4,615,000 AND $6,160,000, RESPECTIVELY.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

exhaustive studies have been made which correlate values with the foregoing factors. Experience at various lakes and reservoirs around the United States provides an indication of the prices which lakeside lots may command.

Land Value Enhancement at Reservoirs Outside Wisconsin

Studies of the Tennessee Valley Authority system[6] indicate that the difference in values of property on the lakefront and at distances of one mile or more from the lake amount to several hundred dollars per acre.

[6]J. L. Knetsch, "Influence of Reservoir Projects on Land Values," Journal of Farm Economics, February 1964, pp. 231-243.

A well-documented example of price increases following the announcement of a reservoir is exhibited in a study prepared for the Pearl River Valley Water Supply District,[7] an agency of the State of Mississippi. Detailed analysis was made of approximately 300 sales involving some 25,000 acres of land adjacent to, and extending as far as two miles from, a 30,000 acre reservoir near Jackson, Mississippi. To establish a normal trend of land prices which could not be attributed to the bene-

[7]H. S. Green and E. Thomas, "Recreation in Combination with Water Supply," American Society of Civil Engineers National Meeting on Environmental Engineering, Chattanooga, Tennessee, May 13-17, 1968.

Table D-6

PRESENT WORTH OF RECREATION AND LAND ENHANCEMENT BENEFITS AND OF RECREATION COST FOR THREE POTENTIAL RESERVOIR DEVELOPMENTS IN THE MILWAUKEE RIVER WATERSHED[a]

POTENTIAL RESERVOIR	BENEFITS		COSTS		BENEFIT/COST RATIO[b]	
	RECREATION	LAND ENHANCEMENT	CAPITAL	OPERATION AND MAINTENANCE	WITHOUT LAND ENHANCEMENT	WITH LAND ENHANCEMENT
WAUBEKA[c]	$50,362,500	$1,615,000	$ 8,655,000	$ 7,870,000	3.05	3.15
NEWBURG[c]	36,957,000	526,000	8,485,000	7,870,000	2.25	2.30
HORNS CORNERS[c]	46,467,000	765,000	11,910,000	10,200,000	2.10	2.13

[a]COSTS ARE FOR RECREATION FEATURES ONLY AND DO NOT INCLUDE COSTS FOR DAMS AND LANDS SUBMERGED BY RESERVOIRS. BENEFITS ARE FOR RECREATION AND LAND ENHANCEMENT ONLY, AND DO NOT INCLUDE OTHER POTENTIAL BENEFITS FROM FLOOD CONTROL, WATER SUPPLY AND LOW FLOW AUGMENTATION. THE ECONOMIC ANALYSES UTILIZE A 6 PERCENT INTEREST RATE, STAGED DEVELOPMENT, AND A 50 YEAR PROJECT LIFE. LAND ENHANCEMENT BENEFITS ACCRUE TO A RESIDENTIAL COMMUNITY THAT IS DEVELOPED OVER A 20 YEAR PERIOD.

[b]A SIMILAR BENEFIT TO COST RATIO DOES NOT ASSURE THAT THE QUALITY OF THE RECREATIONAL EXPERIENCE WOULD BE EQUAL. ONE SITE MAY BE MORE DESIRABLE THAN ANOTHER DUE TO RELATIVE SIZE OR POTENTIAL AESTHETIC FACTORS.

[c]WAUBEKA BENEFITS AND COSTS INCLUDE A PROPOSED FISHERY DEVELOPMENT. SIMILAR DEVELOPMENTS ARE PRECLUDED AT THE NEWBURG AND HORNS CORNERS SITES BECAUSE OF THEIR SMALL DEPTHS.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

fits from the project, a control area at some distance from the project was selected for comparison. The results of the study clearly indicated that there was a sharp increase in sale price per acre after the reservoir location was announced in 1955. The median price for land near the reservoir by May 1963 was almost $600 per acre, while land in the control area was selling for about $180 per acre. Thus, in an area extending two miles from the reservoir shoreline, the enhancement in land values averaged about $400 per acre. It should be noted that the ultimate increase was somewhat greater than this, since the study by the Water Supply District was discontinued before the reservoir had been completely filled.

Land Value Enhancement at Reservoirs in Wisconsin

Elizabeth David and William Lord, in their study[8] of land values around artificial lakes in Wisconsin, concluded that this land is more valuable than land distant from a reservoir and that the value of riparian land has increased in value at a faster rate than nonriparian land. For purposes of their study, escalation in land value was examined at Lake Sherwood, Wisconsin, to determine land value increases around a reservoir. Lake Sherwood, in the Wisconsin Dells area, is a privately developed project in which three dams impound 500 acres of water surface.

Land for the development of the dam, reservoir, and surrounding shoreline was purchased at a cost not exceeding $200 per acre and in some areas of the project, for as little as $50 per acre. Land surrounding the lake was developed to conform to planning standards similar to those established by the SEWRPC (see Table D-7). Development of the shoreline included 400 lakeside lots and a second tier of 400 lots directly behind the lakeside lots and separated by an access road. The lots measured approximately 50 feet along the shoreline and were 200 feet deep, having, therefore, an average size of about one-quarter acre. Each sold for an average price of $5,000. On a per acre basis, the land value was approximately $20,000. The only improvement of the lots was an access road around the perimeter of the lake.

Land Value Enhancement at the Potential Reservoir Sites

In order to determine the amount of land value enhancement which could be expected from the construction of a multi-purpose reservoir, a 251 acre model land development accommodating approximately 1,200 year-round residents was designed by the SEWRPC staff for a site including approximately 8,000 feet of shoreline. The detailed design of the development provided for 348 recreation-residential sites, complete with public sewer and water service, surface streets, and public recreation facilities. The model development is illustrated on Map D-1, and a summary of the salient features of the resultant design is set forth in Table D-8.

A detailed enumeration of the costs of the model recreation-residential development is presented in Table D-9. The overall cost of development of the model was estimated to be about $1,700,000, including costs of land; sanitary sewers; water mains; sewage treatment plant; water supply; street construction; beach development; and other costs associated with design, development, and sales, such as planning and engineering costs, advertising costs, and sales commissions.

[8]*Elizabeth L. David and William B. Lord, Determinants of Property Value on Artificial Lakes (unpublished and undated), University of Wisconsin.*

Table D-7

WISCONSIN RESERVOIR SHORELINE DEVELOPMENT GUIDE APPLICABLE TO THE MILWAUKEE RIVER WATERSHED

SHORELINE USE	PERCENT OF TOTAL SHORELINE
NATURAL STATE PREFERABLY INCLUDING SHORELINE ADJACENT TO MARSHY OR SHALLOW WATER AREAS.	25 (MINIMUM)
PUBLIC BEACH, PICNIC GROUNDS, AND BOATING ACCESS	10 (MINIMUM)
INTENSIVE COMMERCIAL DEVELOPMENT INCLUDING RESORTS AND HOTELS	15 (MAXIMUM)
PRIVATE DEVELOPMENT SUCH AS RESIDENCES, CAMPS, PICNIC GROUNDS, AND FARMLANDS	50 (MAXIMUM)

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND SEWRPC.

Since the market values of the lots within the model development would vary in relation to their proximity to the reservoir shoreline, 10 different sales prices were used for lots in the model development to coincide with the walking distances from the lot to some type of shoreline access, including direct access for shore lots, private beach access for other lots, and public beach access. The total estimated gross market value for the model development was calculated to be $2,481,000. A detailed breakdown of the unit value distribution for the 348 lots in the model development is shown in Table D-10.

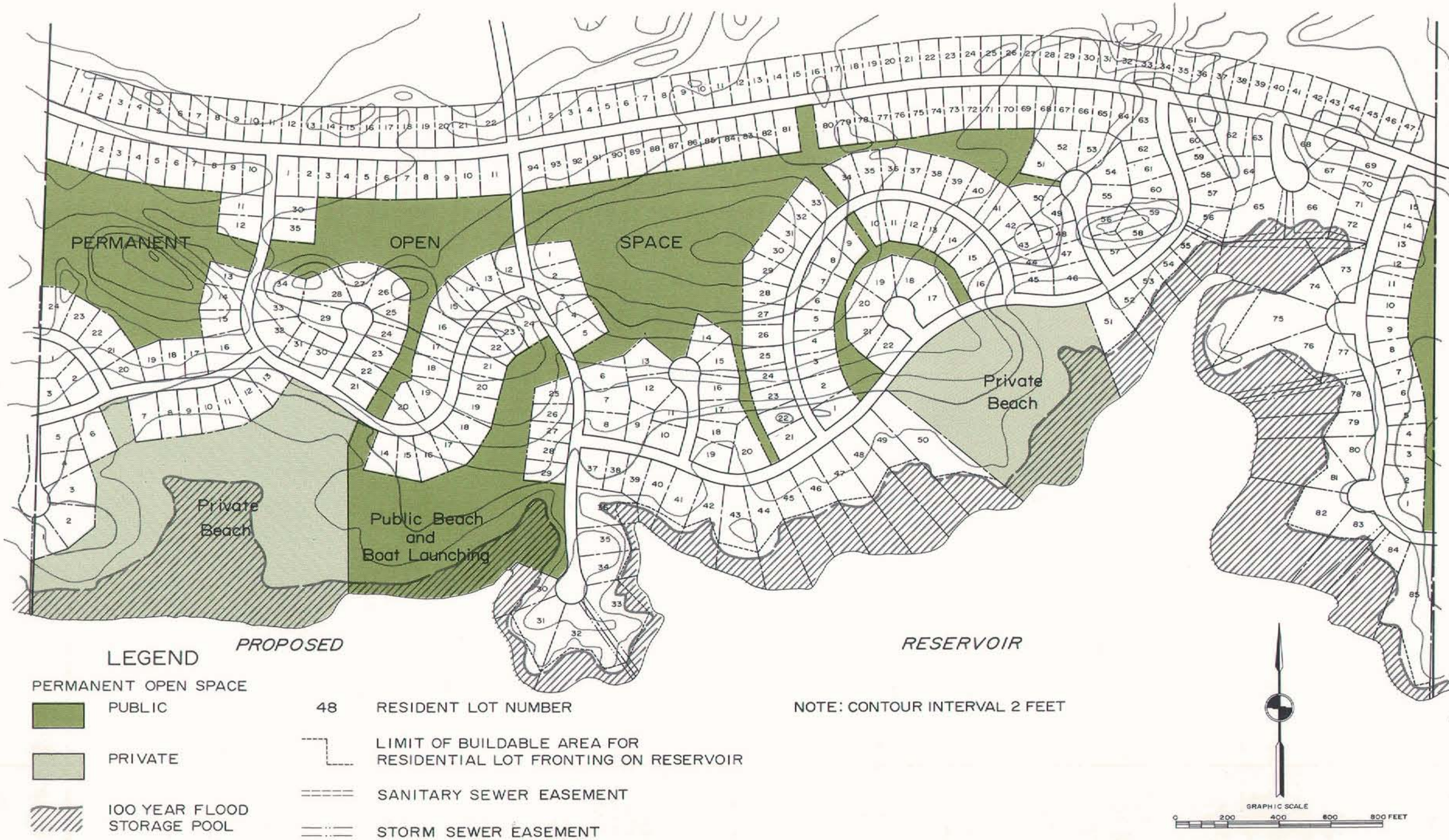
The valuation of land enhancement benefits for the total reservoir was then computed on the assumption that 45 percent of the total shoreline of the Waubeka, Newburg, and Horns Corners reservoir sites would be developed in a manner similar to the model development and would include, as in the model design, public beach, picnic grounds, and boating access. It was further assumed that the costs of development, as well as the estimated market value of the completed developments around these three reservoirs, would be directly proportional to the ratio of developable shoreline to the 1.5 miles of shoreline in the model development. The size and principal economic features of the recreation-residential communities for the Waubeka, Newburg, and Horns Corners potential reservoir sites are summarized in Table D-11.

The private recreation-residential development around each of the three reservoir sites was analyzed for both long-term and short-term development periods. In the short-term development, it was assumed that a large corporation would acquire all of the lands and install the necessary utilities, roadways, and recreation facilities over a five-year period. It was assumed that land sales and development would begin immediately, and all the parcels would be sold and all the outlays expended by the end of the five-year period. The following rate of expenditure was assumed for the cost over the five-year period: one-fourth of the cost would be expended in the first year and one-fourth of the cost expended in the third, fourth, and fifth years, respectively. It was assumed that one-fourth of the lots would be sold by the end of the second year, with the remaining lots to be sold uniformly during the third, fourth, and fifth years.

In the long-term analysis, it was assumed that the total development would take place over a 20-year period. It was assumed that one-fourth of the costs would be expended in the first, fifth, tenth, and fifteenth years. It was also assumed that one-fourth of the lots would be sold in the fifth, tenth, fifteenth, and twentieth years. The overall assumption

Map D-1

MODEL RECREATION – RESIDENTIAL COMMUNITY ADAPTABLE TO POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED



This 251-acre year-round model recreation-residential community adapted to 1.5 miles of typical reservoir shoreline was designed to accommodate approximately 1,200 people on 348 single-family homesites. The costs and benefits attendant to the development of this community were carefully analyzed and then extrapolated to assess the implications of similar, but larger, developments over 3,770 acres of land around the Waubeka Reservoir; 1,255 acres around the Newburg Reservoir; and 1,757 acres around the Horns Corners Reservoir with the conclusion that, for any of the three potential reservoirs, such communities could be supported by the available land and water resource base and would be economically viable.

Source: SEWRPC.

Table D-8

MODEL RECREATION-RESIDENTIAL SHORELINE DEVELOPMENT ADAPTABLE TO POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED[a]

DISTRIBUTION OF LAND USE WITHIN THE MODEL DEVELOPMENT		
LAND USE CATEGORY	ACRES	PERCENT OF TOTAL
PRIVATE RECREATION-RESIDENTIAL SITES[b] (NUMBER- 348)	157.5	62.8
PRIVATE BEACH LOTS	26.8	10.7
PUBLIC BEACH & BOAT LAUNCHING AREA	9.9	3.9
PERMANENT PUBLIC AND PRIVATE OPEN SPACE	30.2	12.0
PUBLIC ROADWAYS	26.6	10.6
TOTALS	251.0	100.0

UTILITY REQUIREMENTS WITHIN THE MODEL DEVELOPMENT	
ITEM	LINEAL FEET
PUBLIC STREET	22,940
SANITARY SEWER--MAIN	6,040
SANITARY SEWER--LATERAL	20,960
WATER MAIN	23,000

[a]SUBSEQUENT ECONOMIC ANALYSES ASSUME THAT 45 PERCENT OF THE PERIPHERY OF THE WAUBEKA, NEWBURG, OR HORNS CORNERS POTENTIAL RESERVOIR SITES WOULD CONSIST OF PRIVATE RECREATION-RESIDENTIAL DEVELOPMENT WITH LAND USES APPORTIONED ACCORDING TO THIS TYPICAL DEVELOPMENT.

[b]SUPPLEMENTAL DATA FOR PRIVATE RECREATION-RESIDENTIAL SITES-

AVERAGE GROSS PRIVATE RECREATION-RESIDENTIAL SITE AREA 31,400 SQ FT
AVERAGE NET PRIVATE RECREATION-RESIDENTIAL SITE AREA 19,750 SQ FT
MINIMUM NET PRIVATE RECREATION-RESIDENTIAL SITE AREA 10,000 SQ FT

SOURCE- SEWRPC.

Table D-9

DEVELOPMENT COSTS FOR THE MODEL RECREATION-RESIDENTIAL DEVELOPMENT PROPOSED FOR POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED

ITEM	REQUIREMENTS	UNIT COST	TOTAL COST
LAND	251 ACRES	$800.00[a]	$ 201,000
STREET GRADING AND SURFACING	22,940 LINEAL FEET	$ 15.00	344,000
SANITARY SEWER--MAIN	6,040 LINEAL FEET	$ 22.75	137,000
SANITARY SEWER--LATERAL	20,960 LINEAL FEET	$ 10.00	209,600
WATER MAIN	23,000 LINEAL FEET	$ 10.00	230,000
WATER SUPPLY AND TREATMENT FACILITIES	--	--	150,000
SEWAGE TREATMENT FACILITIES	--	--	100,000
SITE GRADING AND SURFACE DRAINAGE	--	--	18,000
BEACH AND PRIVATE RECREATION FACILITIES	--	--	50,000
SUBTOTAL (CAPITAL COSTS, UTILITIES, AND OTHER IMPROVEMENTS)			$1,439,600
ENGINEERING AND PLANNING SERVICES	--	--	$ 81,000
SALES COMMISSIONS	--	--	125,000
ADVERTISING	--	--	50,000
SUBTOTAL (SERVICES)			$ 256,000
TOTAL COST OF MODEL DEVELOPMENT			$1,695,600

[a]A LAND ACQUISITION COST OF $800 PER ACRE, COMPARED TO THE CURRENT ESTIMATED AVERAGE MARKET VALUE OF $400 PER ACRE FOR AGRICULTURAL LAND, WAS USED PRIMARILY TO REFLECT THE ACQUISITION COSTS OF RESIDENCES AND OTHER STRUCTURES.

SOURCE- SEWRPC.

used in the long-term development analysis was that only one-fourth of the developable land would be developed at one time. It was assumed that it would take five years to sell all the lots within this first stage of development. At this rate the total development would be staged in five-year development increments over the total 20-year development period. The assumed dispersements and sales and attendant present worth values are indicated in Table D-12 for both the short-term and long-term development periods at the Waubeka Reservoir.

Approximately 120,000 feet of shoreline would be available on the proposed Waubeka Reservoir for private development; and, with development similar to that of the model, the total area for development would approximate 3,770 acres. Using the more conservative long-term development period, the present worth of land value enhancement for this land, calculated as the present worth of anticipated sales minus the present worth of scheduled costs, is $1,615,000, which is equivalent to $430 per acre. The value of the land for agricultural use, exclusive of structures, is about $400 per acre, and with the structures, approximately $800 per acre. At Newburg, using the same procedure, the present worth of land value enhancement around the reservoir was calculated to be $526,000, or $430 per acre; and at Horns Corners, the present worth of land value enhancement around the reservoir was calculated to be $765,000, or $430 per acre.

These estimated values are considered to be the minimum probable increase in land value as a result of the reservoir projects. All the reservoir sites studied are within commuting distance of the Milwaukee urbanized area and, therefore, would be subject to urban development pressures. It is probable that, with the passage of time and increased development, worth of the lakeshore property would increase substantially over that estimated in this study.

In addition, a search of recent advertisements in Milwaukee newspapers showed that vacant lakefront property within the Milwaukee River watershed ranged in value from $2,500 to $30,000 per acre, depending upon location and improvements to the land parcels. This compares to the range of market values used in the cost analysis of $9,800 per acre to $33,000 per acre for fully improved residential sites.

In summary, land enhancement benefits could definitely be expected to accrue to any of the three potential reservoir sites, in that the presence of an impoundment would increase the value of land developed as a recreation-residential community about $400 per acre above its current

Table D-10

MARKET VALUE OF LOTS IN THE MODEL RECREATION-RESIDENTIAL DEVELOPMENT ADAPTABLE TO POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED[a]

TYPE OF RESIDENTIAL-RECREATIONAL SITE	NUMBER OF LOTS	MARKET VALUE PER LOT	TOTAL MARKET VALUE
SHORE LOTS	34	$15,000	$ 510,000
DIRECT ACCESS PRIVATE BEACH LOTS	12	12,000	144,000
DIRECT ACCESS PUBLIC BEACH LOTS	16	10,000	160,000
LOTS LOCATED WITHIN 250 FEET WALKING DISTANCE OF PRIVATE BEACH LOTS	40	9,000	360,000
LOTS LOCATED WITHIN 250 FEET WALKING DISTANCE OF PUBLIC BEACH LOT	8	8,000	64,000
LOTS LOCATED WITHIN 500 FEET WALKING DISTANCE OF PRIVATE BEACH LOTS	45	7,000	315,000
LOTS LOCATED WITHIN 500 FEET WALKING DISTANCE OF PUBLIC BEACH LOTS	5	6,000	30,000
LOTS LOCATED WITHIN 1,000 FEET WALKING DISTANCE OF PRIVATE BEACH LOT	48	5,500	264,000
LOTS LOCATED WITHIN 1,000 FEET WALKING DISTANCE OF PUBLIC BEACH LOTS	8	5,000	40,000
LOTS LOCATED MORE THAN 1,000 FEET FROM A PUBLIC OR PRIVATE BEACH LOT	132	4,500	594,000
TOTAL	348	--	$2,481,000

[a]THE DISTRIBUTION OF THE LOT TYPES AND THEIR MARKET VALUES CORRESPOND TO A MODEL RECREATION-RESIDENTIAL DEVELOPMENT HAVING A TOTAL AREA OF 251 ACRES.

SOURCE- SEWRPC.

Table D-11

SUMMARY OF RECREATION-RESIDENTIAL COMMUNITY DEVELOPMENT ON THE PERIPHERY OF POTENTIAL RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED

POTENTIAL RESERVOIR	TOTAL RESERVOIR SHORELINE (MILES)	SHORELINE WITH COMMUNITY DEVELOPMENT[a] (MILES)	RATIO OF SIZE OF COMMUNITY DEVELOPMENT TO SIZE OF MODEL DEVELOPMENT[b]	TOTAL NUMBER OF ACRES	APPROXIMATE PERMANENT POPULATION	TOTAL NUMBER OF LOTS	TOTAL EXPENDITURES DURING DEVELOPMENT	TOTAL SALES DURING DEVELOPMENT	PRESENT WORTH LAND VALUE ENHANCEMENT- 5 YEAR DEVELOPMENT PERIOD AT 6 PERCENT INTEREST[c]	PRESENT WORTH LAND VALUE ENHANCEMENT- 20 YEAR DEVELOPMENT PERIOD AT 6 PERCENT INTEREST[c]
WAUBEKA	50	22	15	3770	18,000	5220	$25,500,000	$37,200,000	$7,995,000	$1,615,000
NEWBURG	17	8	5	1255	6,000	1740	8,475,000	12,400,000	2,672,000	526,000
HORNS CORNERS	23	10	7	1757	8,500	2435	11,860,000	17,360,000	3,760,000	765,000

[a]APPROXIMATELY 45 PERCENT OF THE TOTAL RESERVOIR SHORELINE WOULD BE DEVELOPED AS A RECREATION-RESIDENTIAL COMMUNITY.

[b]THIS RATIO IS BASED ON THE 1.5 MILES OF SHORELINE REQUIRED BY THE MODEL 251 ACRE RECREATION-RESIDENTIAL COMMUNITY.

[c]REFER TO TABLE D-12 FOR DERIVATION OF THE PRESENT WORTH OF LAND VALUE ENHANCEMENT FOR SHORT TERM AND LONG TERM DEVELOPMENT PERIODS.

SOURCE- SEWRPC.

Table D-12

DISBURSEMENTS AND SALES OVER 5-YEAR AND 20-YEAR DEVELOPMENT PERIODS FOR RECREATION-RESIDENTIAL COMMUNITY AT WAUBEKA RESERVOIR

5-YEAR DEVELOPMENT PERIOD						20-YEAR DEVELOPMENT PERIOD					
COSTS			SALES			COSTS			SALES		
TIME IN YEARS FROM BEGINNING OF DEVELOPMENT	INCREMENTAL COST INCURRED AT INDICATED TIME	PRESENT WORTH OF INCREMENTAL COSTS AT 6 PERCENT INTEREST	TIME IN YEARS FROM BEGINNING OF DEVELOPMENT	INCREMENTAL SALES AT INDICATED TIME	PRESENT WORTH OF INCREMENTAL SALES AT 6 PERCENT INTEREST	TIME IN YEARS FROM BEGINNING OF DEVELOPMENT	INCREMENTAL COST INCURRED AT INDICATED TIME	PRESENT WORTH OF INCREMENTAL COSTS AT 6 PERCENT INTEREST	TIME IN YEARS FROM BEGINNING OF DEVELOPMENT	INCREMENTAL SALES AT INDICATED TIME	PRESENT WORTH OF INCREMENTAL SALES AT 6 PERCENT INTEREST
0	$ 6,375,000	$ 6,375,000	2	$ 9,300,000	$ 8,280,000	0	$ 6,375,000	$ 6,375,000	5	$ 9,300,000	$ 6,970,000
2	6,375,000	5,670,000	3	9,300,000	7,800,000	5	6,375,000	4,760,000	10	9,300,000	5,200,000
3	6,375,000	5,330,000	4	9,300,000	7,370,000	10	6,375,000	3,550,000	15	9,300,000	3,880,000
4	6,375,000	5,030,000	5	9,300,000	6,950,000	15	6,375,000	2,650,000	20	9,300,000	2,900,000
TOTAL	$25,500,000	$22,405,000[a]	--	$37,200,000	$30,400,000[a]	TOTAL	$25,500,000	$17,335,000[b]	--	$37,200,000	$18,950,000[b]

[a]THE PRESENT WORTH OF LAND VALUE ENHANCEMENT AT WAUBEKA RESERVOIR FOR THE SHORT TERM 5 YEAR DEVELOPMENT PERIOD IS EQUAL TO THE PRESENT WORTH OF THE SHORT TERM SALES MINUS THE PRESENT WORTH OF THE SHORT TERM COSTS OR $7,995,000 WHICH IS EQUIVALENT TO $2,150 PER ACRE OF COMMUNITY DEVELOPMENT.

[b]THE PRESENT WORTH OF LAND VALUE ENHANCEMENT AT WAUBEKA RESERVOIR FOR THE LONG TERM 20 YEAR DEVELOPMENT PERIOD IS EQUAL TO THE PRESENT WORTH OF THE LONG TERM SALES MINUS THE PRESENT WORTH OF THE LONG TERM COSTS OR $1,615,000 WHICH IS EQUIVALENT TO $430 PER ACRE OF COMMUNITY DEVELOPMENT.

SOURCE- SEWRPC.

estimated value, with structures of $800 per acre. However, as indicated in Table D-6, these land enhancement benefits are small relative to the public recreation benefits that would accrue from any of the reservoir developments.

LOCAL ECONOMIC IMPACT

Introduction

The traveling and recreation-bound public exerts considerable influence on the economic base and structure of many areas and communities. Some areas depend almost entirely upon tourism during certain periods of the year for their annual cash inflow. From the viewpoint of the local economy, the economic impact of recreational development, therefore, is very real. An attempt is made in this section to quantify this impact where possible, and where this is not possible, to describe economic impact qualitatively.

In general, recreation areas influence nearby communities in the following ways:

1. Increase in land values.
2. Stimulation from project construction.
3. Development of new homesites and possible development of new industries.
4. Stimulation of retail trade.
5. Improvement in quality and variety of local services offered in nearby towns.

The potential increase in land values was dealt with in the preceding section of this appendix. Benefits from enhanced land values are considered primary benefits and are credited directly to the economic worth of the project. The influence of the other factors of economic impact accrues to the local economy and is considered in the following paragraphs.

Immediate Stimulation from Project Construction

One of the most obvious factors stimulating the local economy will be the activities associated with the initial construction of the dam and recreational facilities. Construction projects of the magnitude envisioned will have a short-term effect brought about by the requirements of the construction force for goods and services and the local employment provided during the construction period. This phase usually lasts from three to five years. It may be followed by a slump in local economic activity, depending upon how quickly stimulation from recreational activity begins.

Development of Residential Areas and Industry

Reservoir developments have a pronounced effect on local real estate values. The demand for property on or in the proximity to almost any body of water seems to be virtually insatiable in present-day society; and, no doubt, will continue at a high level. Construction of cottages and summer homes for vacationing will occur, followed by more substantial construction for permanent residency. Local and regional commerce is stimulated, and additional employment is created by building construction and supply of materials and services to the building industry. A lakeside environment for a home or cottage during active working years or retirement is apparently desired by many Americans. The construction of multiple-purpose reservoirs will afford many people in the Region with the opportunity of satisfying this desire.

The growth of recreational opportunity is one of the factors necessary to attract industry, although it is not a sufficient factor by itself. Other factors, such as the growth of nearby markets; the availability of raw materials and labor; and the suitability of transportation facilities, utilities, and social and civic amenities, are important as well. Given the other important elements, the availability of ample water recreation facilities may be the deciding reason for an industry to choose a location in the Milwaukee River basin.

Stimulation of Retail Trade

As already noted, visitors to recreation areas may be generally classified in two categories. The local, or day-outing, group travels to an activity area and returns home at the end of the day. The vacationist or long-distance traveler may come from another state and often will remain at the site for a period of several days. Their needs are different, and the business of providing goods and services required by each will generate different patterns of expenditure. Therefore, the nature of a proposed recreation development and the type of attractions to be provided could influence greatly the nature and extent of the economic impact in the area.

The problem of quantifying the increase in economic activity in a community or region as a result of a recreation development is a complex one. Calculations of the magnitude of the expenditures made by park users are necessarily inexact, due to variations in such factors as travel distance, preference of activity, and tastes and desires of the participants for goods and services they purchase.

Estimates can be made, however, which indicate "order of magnitude" expenditures that may be expected; and, by comparison, the relative importance of alternative proposed developments can be judged. From the estimates of expenditures, approximations of the increase in income in the local community may be calculated.

Table D-13 shows the typical expenditures by visitors to Wisconsin State Parks, as determined in surveys by the Wisconsin Department of Natural Resources in 1968. The sample included all expenditures made within a 20-mile radius of the park.

An expenditure of $2.25 per visitor-day was considered to compare favorably with expenditures at the Kettle Moraine Northern Unit and was used in the calculation of expenditures expected to occur at the proposed Milwaukee River watershed reservoir sites. Marion Clawson estimated

Table D-13

DAILY EXPENDITURES PER VISITOR TO WISCONSIN STATE PARKS[a]

STATE PARK	EXPENDITURES IN DOLLARS PER VISITOR				
	LODGING	EAT AND DRINK	CAR	OTHER	TOTAL
DEVILS LAKE	0.63	1.31	0.48	0.42	2.85
HIGH CLIFF	0.28	0.72	0.23	0.16	1.40
BIG FOOT BEACH	0.24	0.81	0.16	0.19	1.55
KETTLE MORAINE NORTHERN UNIT (INCLUDES MAUTHE LAKE)	0.38	1.24	0.66	0.33	2.23
PENINSULA	0.69	1.27	0.15	0.42	2.98
TERRE ANDRAE	0.22	0.75	0.21	0.22	1.40
ALL WISCONSIN PARKS (AVERAGE)	0.35	0.96	0.29	0.28	1.69

[a]EXPENDITURES WITHIN A 20 MILE RADIUS OF THE PARK AS DETERMINED BY 1968 USER SURVEYS.

SOURCE- WISCONSIN DEPARTMENT OF NATURAL RESOURCES.

expenditures in or near state parks to be $1.68 per visitor-day in a 1960 study made for the Outdoor Recreation Resources Review Commission (ORRRC).[9] At an annual increase of 5 percent per year over a 10-year period, this amount would grow to $2.26 per visitor-day at today's prices. It is emphasized, however, that assignment of this value is an uncertain undertaking, considering the adequacy of data available, the advancing costs of goods and services, and the increase of disposable family income.

Part of the initial local expenditures by recreationists is respent outside the local community to pay for goods imported to the community. The remainder is spent in the local areas. and a part of these expenditures are then immediately removed from the local economy. The remainder is used to purchase goods and services within the community. This process continues until the effect of the initial expenditure becomes insignificant. The process of an expenditure working its way through the economy is termed the multiplier effect. The amount of the expenditure which remains in the community after each round accrues as an addition to local income. About 70 cents of every dollar spent on recreation in the community may be expected to remain in the area as additions to local income. The number of annual visitor-days at each potential site for 1980, total local expenditures, and increases in local income based upon the above assumptions are given in Table D-14. Annual expenditures at the proposed sites may be expected to range from $4,460,000 at Waubeka and Newburg to over $6,530,000 at Horns Corners. The increases in local income at 70 percent range from $3,120,000 to $4,570,000 for these sites.

Local Services

With the completion of a recreation reservoir, local government units frequently find themselves faced with the problem of upgrading public services and improving roads, schools, and sewer and water systems. In the long run, additional revenues from higher property values are usually forthcoming to meet these demands. However, in the short run, local government may be hard pressed to meet the need for improved services.

[9]See ORRRC Report No. 24, Economic Studies of Outdoor Recreation, Outdoor Recreation Resources Review Commission, 1962.

Table D-14

ESTIMATED LOCAL EXPENDITURES BY RECREATION VISITORS TO RESERVOIR SITES IN THE MILWAUKEE RIVER WATERSHED AND ATTENDANT INCREASE IN LOCAL INCOME

POTENTIAL RESERVOIR	ANNUAL VISITOR DAYS[a]	ANNUAL LOCAL EXPENDITURES[b]	ANNUAL LOCAL INCOME[c]
WAUBEKA	1,980,000	$4,460,000	$3,120,000
HORNS CORNERS	2,900,000	6,530,000	4,570,000
NEWBURG	1,980,000	4,460,000	3,120,000

[a]1980 ANNUAL VISITATION AS INTERPOLATED FROM TABLE D-4.

[b]BASED ON A VISITOR-DAY EXPENDITURE OF $2.25 WITHIN AN APPROXIMATELY 20 MILE RADIUS OF THE RESERVOIR RECREATION FACILITIES.

[c]THIS ASSUMES THAT AN EQUIVALENT OF 70 PERCENT OF THE ORIGINAL VISITOR EXPENDITURES REMAIN IN THE LOCAL AREA AS ADDITIONS TO THE ECONOMY.

SOURCE- HARZA ENGINEERING COMPANY.

The purchase of lands for the construction of the dam and reservoir causes an immediate reduction in the property tax base. The length of time that it takes local government to recoup lost revenue depends upon the extent and rapidity of recreation-related construction and how quickly property values in the lake vicinity are reassessed.

A study of the effect on local land values of the construction of Lake Cumberland in Kentucky was completed in 1967. The study demonstrated that, in the long run, counties wherein the reservoir is located more than recover the initial tax loss. The impact, however, causes short-run difficulties in administration of local finance.

With the upgrading of local services, the quality of life in the community improves for all residents—older inhabitants of the area, as well as newer residents attracted by the facility. The extent and quality of the improvements ultimately depends upon the reaction of established leaders to the demand for new services. If leaders in a community see the opportunity as one of responding to the needs of an economy serving water recreation, development may be swift and economic progress may be pronounced.

Appendix E

APPLICATION OF THE NEW TOWN CONCEPT TO THE PROPOSED WAUBEKA RESERVOIR SITE IN THE MILWAUKEE RIVER WATERSHED

INTRODUCTION

The purpose of this appendix is to present in summary form the results of a special analysis conducted by the Commission staff under the Milwaukee River watershed study of the potential application of "new town" concepts to the comprehensive development of the multiple-purpose Waubeka Reservoir and its environs. It was recognized that the Waubeka Reservoir, should it be included in the recommended comprehensive plan for the Milwaukee River watershed, could—because of the recreational opportunities and other amenities it would provide—become a focal point for the development of a new town in the Southeastern Wisconsin Region. It is important to note that the analysis conducted under the watershed study was limited to land use planning considerations and did not include studies of other considerations, such as market feasibility or impact upon existing and planned urban development elsewhere in the Region.

OVERVIEW OF THE NEW TOWN CONCEPT

The term "new town" has been used by land use planners to describe the development of new communities, ranging in size from small cities down to large land subdivision plats, usually on an undeveloped site in an essentially rural setting and basically separated from, and independent of, the public utility and community facility base, as well as of the economic base, of any existing central city. The meaning of the term has not changed significantly in contemporary use, even though the term new town has more recently also been used, or misused, to describe major new urban developments located within an existing urbanized area and completely dependent on an existing central city for the provision of day-to-day facilities and services, as well as for the provision of the economic base necessary to sustain the new urban development. Such development could be better described as a large-scale extension or expansion of the existing urbanized area. An example of such development would be the North Ridge Lakes project within the City of Milwaukee. For the purposes of this appendix, the term "new town" will be defined as a concentration of urban development, physically separated from, and essentially independent of, the existing central cities in the Region.

Historically, whole new settlements, or urban communities, were developed—many in accordance with documented plans—at points of transhipment or break in bulk on major trade routes or at other places where urban activities were required to serve commercial needs, beginning with locations on water bodies, waterways, and major trails, with later locations on major railroad routes, and still more recently, on major highway routes. New towns have also been developed at places near sources of raw material or power and at places having a favorable climate and other amenities for the purposes of serving health, religious, educational, governmental, and, more recently, retirement functions.

Some European countries, notably Great Britain, have prepared extensive plans and have developed new communities for the purpose of dispersing population from the major central cities to outlying areas. It is this latter concept of planned urban dispersal which, in light of intensive urban growth in and around central cities, has led in the past few years in the United States to proposals for the development of new urban centers or new towns either wholly or partially separated from the older central cities and their contiguous urbanized areas. The objective is the creation of a high quality urban environment within a natural setting, and attainment of this goal is thought to be possible by constructing an entirely new urban plant in accordance with a meticulously developed comprehensive plan. Quality features associated with such proposed new towns generally include the presence of lakes and waterways, the provision of a framework of natural open areas and corridors to give form and shape to the urban development; a variety of housing types and densities, each oriented and architecturally designed so as to complement adjacent types and densities, as well as the surrounding natural features; the presence of adequate cultural facilities and water- and land-oriented recreation areas; the proper provision of commercial and professional services; and, for many residents, the provision of varied employment opportunities. Proponents of the new town concept believe that the quality of community life is enhanced by attracting, as permanent residents, people that represent a broad cross section of society, as measured by cultural background, education levels, income, age distribution, and interests. As previously indicated, the new town is an attempt to create a complete heterogeneous community with minimal dependence on surrounding urban centers and, therefore, contrasts sharply with the typical suburban subdivision type of development which is generally homogeneous in the characteristics of its population and which emphasizes residential land uses, thereby serving only as an extension of the existing population center to which it is attached.

Existing or proposed new towns throughout the United States have projected populations in the range of 50,000 to 200,000 people, and about half of these developments are located in California. New towns in this country are usually financed by large private organizations, such as petroleum and insurance corporations, although the Federal Government, through the U. S. Department of Housing and Urban Development, provides loans and grants (Title VII of the Housing and Urban Development Act of 1970) for planning and development of new communities. New town developers actively seek compatible commercial and industrial activity within the confines of the project, as well as the establishment of major education complexes and government office centers, all of which provide local employment opportunities. Irvine Ranch, a California new town, for example, is being developed in conjunction with a branch of the state university; and Reston, Virginia, was selected as the site of a federal office complex initially employing more than 3,000 people. Most new towns in the United States have not, however, been able to attract employment opportunities for residents to the degree envisioned in the original concept. One possible reason for this is that the new towns are typically located in proximity to existing large urban areas and on or near good transportation routes, especially freeways, thus providing easy access to employment opportunities throughout the nearby larger urban areas and reducing the need to provide major employment centers within the confines of the new towns.

THE REGIONAL LAND USE PLAN AND THE NEW TOWN CONCEPT

The new town concept was explored in the formulation of the regional land use plan alternatives as the satellite city land use plan alternative.[1] In the exploration of this alternative for regional development, it was determined that such new communities, if they were to be located within the seven-county Southeastern Wisconsin Region, could best be developed upon a base of existing urban development and the attendant municipal facilities and services provided by certain small cities and villages located within still largely rural areas of the Region. Accordingly, the satellite city land use plan alternative proposed accelerating urban growth and development in the Cities of Port Washington in Ozaukee County, West Bend in Washington County, Oconomowoc in Waukesha County, Whitewater in Walworth County, and Burlington in Racine County, while simultaneously decelerating urban growth and development in other parts of the Region—specifically, the Kenosha, Milwaukee, and Racine metropolitan areas. Such decentralization would require stimulus and action from higher levels of government to bring about the far-reaching reversal of existing growth and development trends involved.

The rank-based expected value method of alternative plan evaluation utilized in the regional land use planning effort indicated that, of the four alternative regional growth and development patterns explored, the satellite city alternative, if the probability of implementation were neglected in the evaluation, would have better achieved the regional land use development objectives than any of the other alternative plans considered. If the probability of implementation was considered, however, the controlled existing trend alternative land use plan better met the development objectives. This conclusion, based upon a purely technical evaluation, was reinforced by the results of the public hearings held on the alternative regional land use plans. The hearings indicated that the satellite city plan alternative was rejected by citizens and elected officials as the recommended land use plan for the Region basically because of the practical political problems involved in implementation. Consequently, the concept of accelerating urban development in communities outside the major metropolitan areas within the Region, while judged sound from a purely theoretical point of view, was rejected as impractical, at least over the planning period to 1990.

ADAPTATION OF THE NEW TOWN CONCEPT TO THE WAUBEKA POTENTIAL MULTI-PURPOSE RESERVOIR IN THE MILWAUKEE RIVER WATERSHED

A major work effort undertaken as part of the Milwaukee River watershed study included the evaluation of three major multi-purpose reservoirs proposed to be located on the main stem of the Milwaukee River upstream from the unincorporated community of Newburg in eastern

[1] *See SEWRPC Planning Report No. 7, Volume 2, Forecasts and Alternative Plans--1990, June 1966.*

Washington County; on Cedar Creek upstream from the unincorporated community of Horns Corners in the Town of Cedarburg in Ozaukee County; and on the main stem and the North Branch of the Milwaukee River upstream from the unincorporated community of Waubeka in the Town of Fredonia in Ozaukee County. Of these three multi-purpose reservoir sites, the so-called Waubeka Reservoir, the largest of the three, was determined to provide the most benefits for the primary purpose of flood control, as well as for year-round outdoor recreation and low-flow augmentation purposes. The benefits and costs of this alternative reservoir proposal are discussed in Chapter IV of this volume.

In reviewing the potential for the development of such a large body of water (10,400 acres at conservation pool elevation) within 35 miles of the Milwaukee urbanized area, it became apparent that the resource value created by such action could have significant effects on land development in the Southeastern Wisconsin Region. It also became apparent that, in light of the development opportunities provided by this significant change in the natural landscape, the potential for planned land use development around the shoreline of the reservoir and in the proximity thereto should be explored. Accordingly, three alternatives for planned land use development around the Waubeka Reservoir were explored, after having rejected as potentially detrimental to the created water resource, a minimum alternative of acquiring only the lands proposed to be devoted to the dam site and water impoundment and allowing the private land market to constitute the primary determinant of the land use pattern around the reservoir (see Table E-1).

All three of the planned land use alternatives considered embrace the concept of acquisition of all lands within a specifically defined project boundary by a single public, semipublic, or private agency which could direct their integrated development in accordance with a sound, long-range plan. The lands within the project boundaries would total 24,100 acres and would include not only the entire proposed reservoir site, totaling approximately 10,400 acres, but an additional 13,700 acres adjacent to the reservoir which are proposed to be protected in a natural state, developed for intensive recreation use, or developed for urban purposes under the auspices of the public, semipublic, or private agency assuming responsibility for the development (see Map E-1). The three alternative land use development schemes considered by the Commission staff, therefore, differed only in the amount and spatial distribution of the proposed urban development.

The first alternative explored envisioned new town development in only the Fredonia-Waubeka area of the watershed and proposed a total development in this area of nearly 4,000 acres, having a projected population of about 29,000 persons. This alternative assumed that all new urban development would be concentrated in the area considered and that no significant urban development would occur around the unincorporated communities of Batavia, Boltonville, and Newburg, as a result of the development of the reservoir. The cost to acquire and develop the urban area designated in Alternative No. 1 was estimated at $34.1 million.

The second alternative explored envisioned, in addition to the new town development in the Fredonia-Waubeka area proposed under Alternative No. 1, additional urban development in the Batavia, Boltonville, and Newburg areas totaling approximately 1,000 acres. The total urban development in the environs of the reservoir under this alternative would thus approximate 5,000 acres and have a total projected population of about 36,500 persons, with an estimated total land acquisition and development cost of $42.3 million.

The third alternative explored is shown on Map E-1 and envisioned new town development in the Fredonia-Waubeka area of approximately 5,700 acres and additional urban development in the Batavia, Boltonville, and Newburg areas, totaling approximately 1,800 acres. The total urban development would thus approximate 7,500 acres (see Table E-2). Under the proposed development scheme, the total population in the four development areas would approximate 58,000 persons. New urban development would be primarily concentrated in a new town consisting of 10 planned development districts or neighborhood units located in the Fredonia-Waubeka area, encompassing, in addition to Waubeka, the two existing unincorporated communities of Fillmore and Kohler. Of the approximately 5,700 acres of urban development in this new town, approximately 3,100 acres would be developed for residential use. It is expected that this residential land would accommodate approximately 13,600 dwelling units and a total population of about 45,000, based on proposed development at medium population densities.

Due to the close proximity of the new town development to existing major employment centers in the Milwaukee, West Bend, and Port Washington areas, the new town development would not be a wholly self-contained community in the sense that employment opportunities for all of the people who would live in the new town would be generated within the new

Table E-1

ALTERNATIVE 'NEW TOWN' DEVELOPMENT PROPOSALS IN THE WAUBEKA RESERVOIR SITE AREA

ALTERNATIVE	URBAN DEVELOPMENT UNIT	URBAN DEVELOPMENT UNIT AREA (ACRES)			TOTAL PROJECTED POPULATION[b]	TOTAL DWELLING UNITS[c]	COSTS		
		EXISTING[a]	PROPOSED	TOTAL			ACQUISITION[d]	DEVELOPMENT[e]	TOTAL
1	FREDONIA[f]-WAUBEKA[g]	220	3,730	3,950	29,300	8,880	$ 2,984,000	$31,080,000	$34,064,000
2	FREDONIA-WAUBEKA	220	3,730	3,950	29,300	8,880	$ 2,984,000	$31,080,000	$34,064,000
	BATAVIA[g]	99	251	350	2,100	640	200,800	2,240,000	2,440,800
	BOLTONVILLE[g]	83	267	350	2,400	730	213,600	2,555,000	2,768,600
	NEWBURG[g]	66	285	350	2,600	790	228,000	2,765,000	2,993,000
	TOTAL	468	4,533	5,000	36,400	11,040	$ 3,626,400	$38,640,000	$42,266,400
3	FREDONIA-WAUBEKA	220	5,500	5,720	44,800	13,580	$ 4,400,000	$47,530,000	$51,930,000
	BATAVIA	99	470	569	3,900	1,180	376,000	4,130,000	4,506,000
	BOLTONVILLE	83	649	732	5,500	1,670	519,200	5,845,000	6,364,200
	NEWBURG	66	390	456	3,500	1,060	312,000	3,710,000	4,022,000
	TOTAL	468	7,009	7,477	57,700	17,490	$ 5,607,200	$61,215,000	$66,822,200

[a] AS DETERMINED IN THE SEWRPC 1967 LAND USE INVENTORY.

[b] INCLUDES EXISTING 1967 POPULATION (ROUNDED TO NEAREST 100).

[c] BASED ON 3.3 PERSONS/DWELLING UNIT (ROUNDED TO NEAREST 10).

[d] BASED ON $800/ACRE OF PROPOSED URBAN DEVELOPMENT LAND (INCLUDING ANY EXISTING STRUCTURES).

[e] LAND DEVELOPMENT COST ESTIMATED AT $3,500/DWELLING UNIT, INCLUDING STREETS, PUBLIC UTILITIES, AND COMMUNITY FACILITIES AND PLANNING, ENGINEERING, AND PROMOTIONAL COSTS.

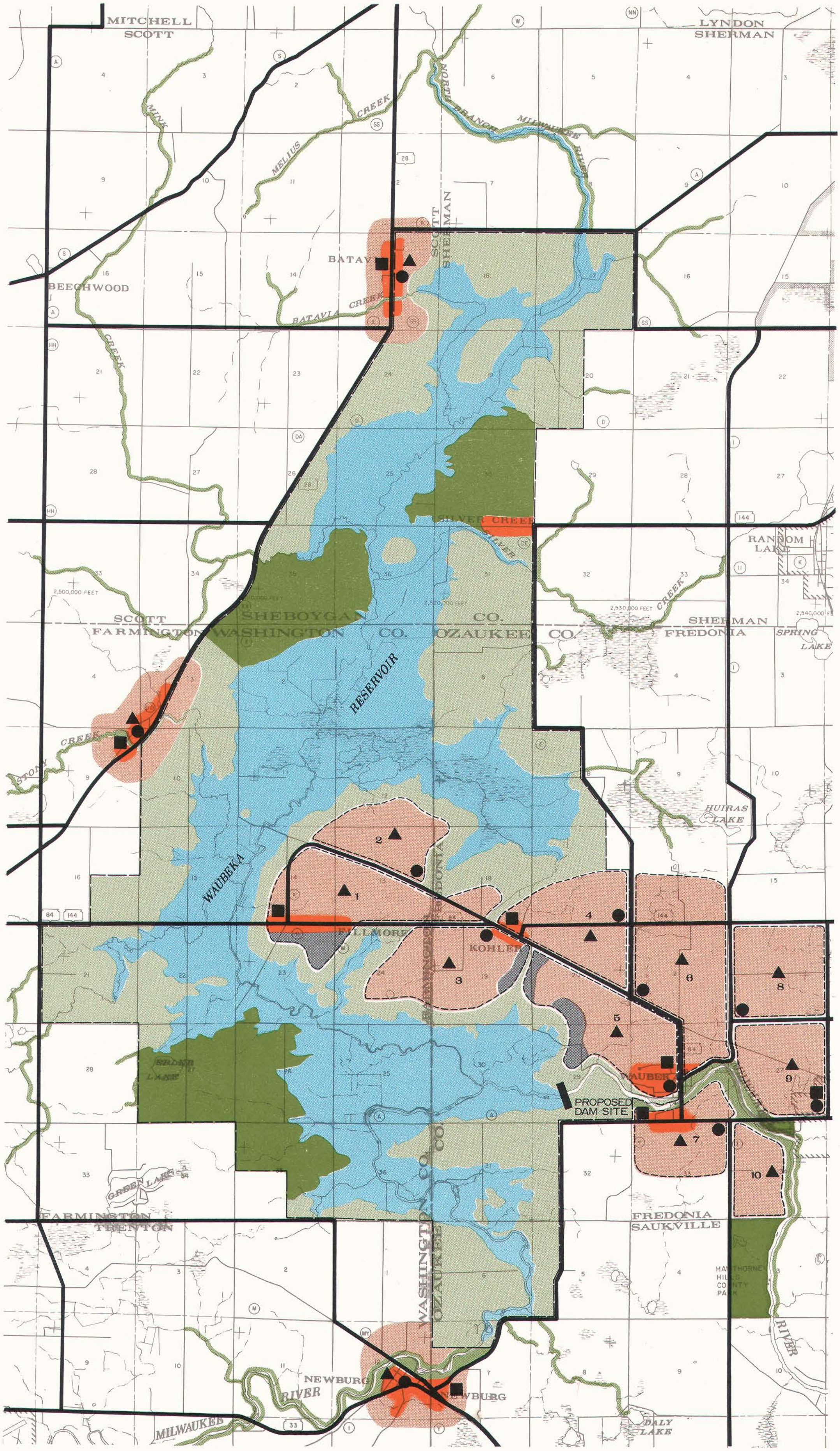
[f] VILLAGE OF FREDONIA.

[g] UNINCORPORATED PLACES.

SOURCE- SEWRPC.

Map E-1

POTENTIAL NEW TOWN DEVELOPMENT AT THE WAUBEKA RESERVOIR IN THE MILWAUKEE RIVER WATERSHED



Source: SEWRPC.

Table E-2

PROPOSED 'NEW TOWN' DEVELOPMENT AND OTHER URBAN DEVELOPMENT IN THE WAUBEKA RESERVOIR SITE AREA

DEVELOPMENT UNITS	TOTAL DEVELOPMENT AREA (ACRES)	EXISTING URBAN DEVELOPMENT (ACRES)	GROSS DEVELOPABLE LAND (ACRES)	NET DEVELOPABLE LAND[a] (ACRES)	PROPOSED NEW LAND USE DEVELOPMENT -(NET ACRES)[c]					ESTIMATED EXISTING 1967 POPULATION	PROPOSED NEW DEVELOPMENT[b] POPULATION	TOTAL POPULATION	TOTAL DWELLING UNITS
					RESIDENTIAL	RETAIL AND SERVICE	INDUSTRIAL	GOVERNMENT AND INSTITUTIONAL	TRANSPORTATION AND COMMUNICATION				
BATAVIA[d]	568.7	99.0	469.7	446.2	263.2	29.0	11.2	31.2	111.6	155	3,800	3,900	1,180
BOLTONVILLE[d]	731.7	83.2	648.5	616.1	363.6	40.0	15.4	43.1	154.0	305	5,200	5,500	1,670
NEWBURG[d]	456.2	65.9	390.3	370.8	218.8	24.1	9.2	26.0	92.7	378	3,100	3,500	1,060
NEW NEIGHBORHOOD													
NO. 1	766.2	48.8	717.4	681.5	402.1	44.3	17.0	47.7	170.4	22	5,800	5,800	1,760
NO. 2	424.7	--	424.7	403.5	238.1	26.2	10.1	28.2	100.9	--	3,400	3,400	1,030
NO. 3	674.4	17.2	657.2	624.3	368.3	40.6	15.6	43.7	156.1	42	5,300	5,300	1,610
NO. 4	430.5	15.8	414.7	394.0	232.5	25.6	9.8	27.6	98.5	25	3,300	3,400	1,030
NO. 5	701.6	78.9	622.7	591.6	349.0	38.4	14.8	41.5	147.9	208	5,000	5,200	1,580
NO. 6	918.3	4.3	914.0	868.2	512.2	56.4	21.7	60.8	217.1	86	7,300	7,400	2,240
NO. 7	426.2	34.4	391.8	372.2	219.6	24.2	9.4	26.0	93.0	56	3,100	3,200	970
NO. 8	552.4	--	552.4	524.8	309.6	34.3	13.1	36.7	131.1	--	4,400	4,400	1,330
NO. 9	549.0	20.6	528.4	497.0	293.3	32.3	12.4	34.8	124.2	90	4,400	4,500	1,360
NO. 10	276.9	--	276.9	263.1	155.2	17.1	6.6	18.4	65.8	--	2,200	2,200	670
NEW NEIGHBORHOOD SUBTOTAL	5,720.2	220.0	5,500.2	5,220.2	3,079.9	339.4	130.5	365.4	1,305.0	529	44,200	44,800	13,580
WAUBEKA SITE TOTALS	7,476.8	468.1	7,008.7	6,653.3	3,925.5	432.5	166.3	465.7	1,663.3	1,367	56,300	57,700	17,490

[a]NET DEVELOPABLE LAND EQUALS GROSS DEVELOPABLE LAND MINUS THAT AREA COVERED BY SOILS POORLY SUITED FOR URBAN DEVELOPMENT EVEN WITH THE PROVISION OF PUBLIC UTILITIES.

[b]AT MEDIUM-DENSITY DEVELOPMENT (SEE TABLE A-1, APPENDIX A, PAGE 217, OF SEWRPC PLANNING REPORT NO. 7, VOLUME 2, FORECASTS AND ALTERNATIVE PLANS--1990, JUNE 1966).

[c]INCLUDES ONLY THOSE LANDS DEVOTED TO LAND USE CATEGORY SHOWN. RECREATION SITES WOULD BE AVAILABLE ON OTHER LANDS RESERVED FOR PARK AND OPEN SPACE USES ADJACENT TO THE RESERVOIR.

[d]EXISTING UNINCORPORATED PLACE.

SOURCE- SEWRPC.

town. The largest proportion of employment opportunities within the new town would be created by proposed retail and service land uses, with emphasis on recreation-related retail and service establishments. Proposed local industrial development could provide some additional employment opportunities; however, as already noted, the major industrial employment centers would be located outside the new town in other areas of the Region, readily accessible by high-speed, all-weather highway transportation facilities. Like other new towns in the United States, then, the Waubeka new town would not be totally independent of nearby metropolitan areas.

The presence of the reservoir, with a vast potential for recreation use and development, could also be expected to stimulate urban development in the unincorporated communities of Batavia, Boltonville, and Newburg, which lie adjacent to the proposed reservoir and are served by major state trunk highways which afford a high level of accessibility between these three unincorporated places and larger communities in the Region. It is expected that each of these communities would ultimately encompass a population of from 3,500 to 4,000 people, with attendant industrial, retail, governmental and institutional, and transportation uses added, as required, to serve the new urban development (see Table E-2).

Development within the reservoir project boundaries, as shown on Map E-1, would be related to the primary objective of preserving the natural resource amenities created by the reservoir. Under this alternative the entire approximately 50-mile shoreline of the reservoir is proposed to remain in public ownership or control. Three multiple-use regional parks, encompassing a total area of 2,100 acres, would be developed within the project boundary (24,100 acres) as state recreation facilities. Those other lands within the project boundary not devoted to urban use, including active recreational use (3,280 acres) or water storage area (10,400 acres), would be preserved for general open space or passive recreational pursuits. It is assumed that the agency which undertakes the acquisition and development of the reservoir would also assume the leading role in the development of the lands around the reservoir, including land planning, development, and disposal. Such development will also involve local, county, state, and federal units and agencies of government, as well as the private sector of the economy.

The development of a large fresh-water reservoir in close proximity to major urban population concentrations, which presently generate a greater demand for recreation development than can be readily met within the Southeastern Wisconsin Region, may be expected to bring about significant changes in land development in this Region. The possibilities for creating a high-quality environment for urban life, while at the same time maintaining and, indeed, enhancing, the natural environment, are great. The introduction of the reservoir and adjacent urban recreation-related development in the now basically rural areas of Ozaukee, Sheboygan, and Washington Counties would also require a reevaluation of the provision of major public services, as well as community regulations in this area, including, but not limited to, the following: 1) the level of waste treatment provided by the Fredonia and Newburg sewage treatment plants; 2) the construction of municipal waste treatment facilities in the Batavia and Boltonville areas; 3) the additional improvement of existing major standard arterial street and highway facilities in order to meet increased traffic demand generated by the new development; and 4) the strengthening of local ordinances dealing with the regulation of urban development in order to ensure the development of those areas outside the project. It would also require a major reevaluation of the adopted regional land use plan because of the redistribution of urban development and population which would be entailed by the development of a new town in conjunction with the Waubeka Reservoir.

INTRODUCTION TO APPENDICES F, G, AND H

A comprehensive watershed plan setting forth the general location and characteristics of areas subject to flooding and of proposed water control facilities is necessary as a statement of how best to achieve agreed-upon, long-range watershed development objectives. Such a plan is, however, quite ineffective as a sound basis for plan implementation through the advanced reservation and acquisition of land required for recommended facility construction, the exercise of local land use controls, and the extension of technical assistance and advice from the Regional Planning Commission to the concerned state and local units and agencies of government with respect to the specific relationships of plan recommendations to day-to-day community development decisions. It was, therefore, pointed out in the original Milwaukee River Watershed Planning Program Prospectus that the more precise and definitive data required for the advanced reservation of land, the exercise of land use controls, and the proper extension of technical assistance would be provided as an integral part of the comprehensive watershed planning effort for certain reaches of the riverine areas of the watershed.

In the case of areas subject to inundation, such data would include large-scale maps showing the precise and accurate location of the 10- and 100-year recurrence interval flood hazard lines. Consequently, precise planning base maps were prepared under the Milwaukee River study for 21.75 square miles of riverine area. These maps consist of 1" = 200' scale, four-foot-two-foot contour interval topographic maps, prepared to National Map Accuracy Standards and are based upon a monumented control survey network which accurately relates the U. S. Public Land Survey System to the State Plane Coordinate System. This control survey network permits the accurate correlation of topographic and cadastral (property boundary line) data and, most importantly, permits the accurate reproduction in the field of lines shown on the maps—whether these lines represent the limits of flood hazard areas or the limits of sites required for water control facility construction. These maps were prepared for those riverine areas of the watershed expected to experience relatively rapid urbanization within the next decade, as well as for those areas of the watershed in which floodland structure removal was being recommended (see Index Map H-1). The maps show the location of the 10- and 100-year recurrence interval flood hazard lines as these lines would be effected upon the landscape under the land use and water control facility development recommended in the watershed plan.

The precise planning base maps were prepared to meet the specifications recommended for official mapping in SEWRPC Planning Guide No. 2, Official Mapping Guide, and thereby provide a sound basis for the preparation of detailed local development plans and plan implementation devices, with particular emphasis upon sound floodland and shoreland zoning. A sample large-scale precise planning base map is shown on Map H-2. Copies of the precise planning base maps may be obtained from the Southeastern Wisconsin Regional Planning Commission, together with attendant horizontal and vertical control survey data. The Cities of Mequon and West Bend and the Villages of Brown Deer, Germantown, and River Hills within the Milwaukee River watershed have also prepared similar precise planning base maps to Commission recommended standards for certain riverine areas of the watershed (see Index Map H-1). Copies of these maps may be obtained directly from the indicated municipalities.

In order to provide a sound basis for the preparation of detailed local development plans and plan implementation devices, including the enactment of floodland and shoreland zoning ordinances in those areas of the watershed not covered by the precise planning base maps, high water and streambed profiles were prepared as part of the Milwaukee River watershed study for 216 miles of major stream channel. These profiles are reproduced in Appendix F and indicate the high water surface elevations which may be expected under the land use and water control plan for the 10- and 100-year recurrence interval floods, together with pertinent bridge, culvert, and water control facility locations and elevations and stream bed profiles. Opposite each profile in Appendix F is reproduced a small-scale topographic map of the channel reach covered. These topographic maps were compiled at scales of 1" = 2000' and 1" = 5208', with 10- and 20-foot contour intervals, respectively, and are published at a scale of 1" = 2640' (1" = 0.5 miles), and show the location and extent of the lands anticipated to be flooded by the 10- and 100-year recurrence interval flood events, as determined from the high water surface profiles. In order to more readily permit the high water surface profiles and attendant hydrologic and hydraulic engineering data to be used to refine the location of the flood hazard lines through local field surveys, second order bench marks referred to Mean Sea Level Datum (1929 Adjustment) were set by the Commission as a part of the watershed study effort on or near all bridges, culverts, and dams on the major stream channel network.

It is important to note that the high water surface profiles and flood hazard maps prepared under the Milwaukee River watershed study are applicable to flood events which would occur under existing conditions of land use and water control facility development within the watershed, as well as flood events which may be expected to occur under future conditions of land use and water control facility development within the watershed, as recommended in the comprehensive watershed plan.

Accompanying the high water surface profiles are tables setting forth selected hydraulic engineering information for each of 205 bridges and culverts[1] within the watershed (see Appendix G). These data include the structure identification; construction date, if known; recommended flood event design frequency; instantaneous peak discharge for the 10-, 50-, and 100-year recurrence interval flood events; corresponding elevations of the upstream high water surface; head loss; and water depth at flood stage at low point in bridge approach road, as well as water depth at flood stage on the road at the centerline of the structure.

[1] *Table 34, page 135, of Volume 1 of this report, indicates that in 1967 there were a total of 189 bridges and culverts crossing the Milwaukee River and its major tributaries upstream from the North Avenue Dam. An additional 16 bridges are located downstream from the dam and have been included in the hydraulic analysis summary tables in Appendix G, resulting in a total of 205 bridges and culverts.*

Appendix F

HIGH WATER AND STREAM BED PROFILES AND TOPOGRAPHIC MAPS SHOWING AREAS SUBJECT TO FLOODING FOR THE MILWAUKEE RIVER AND SELECTED MAJOR TRIBUTARIES

Map F-1

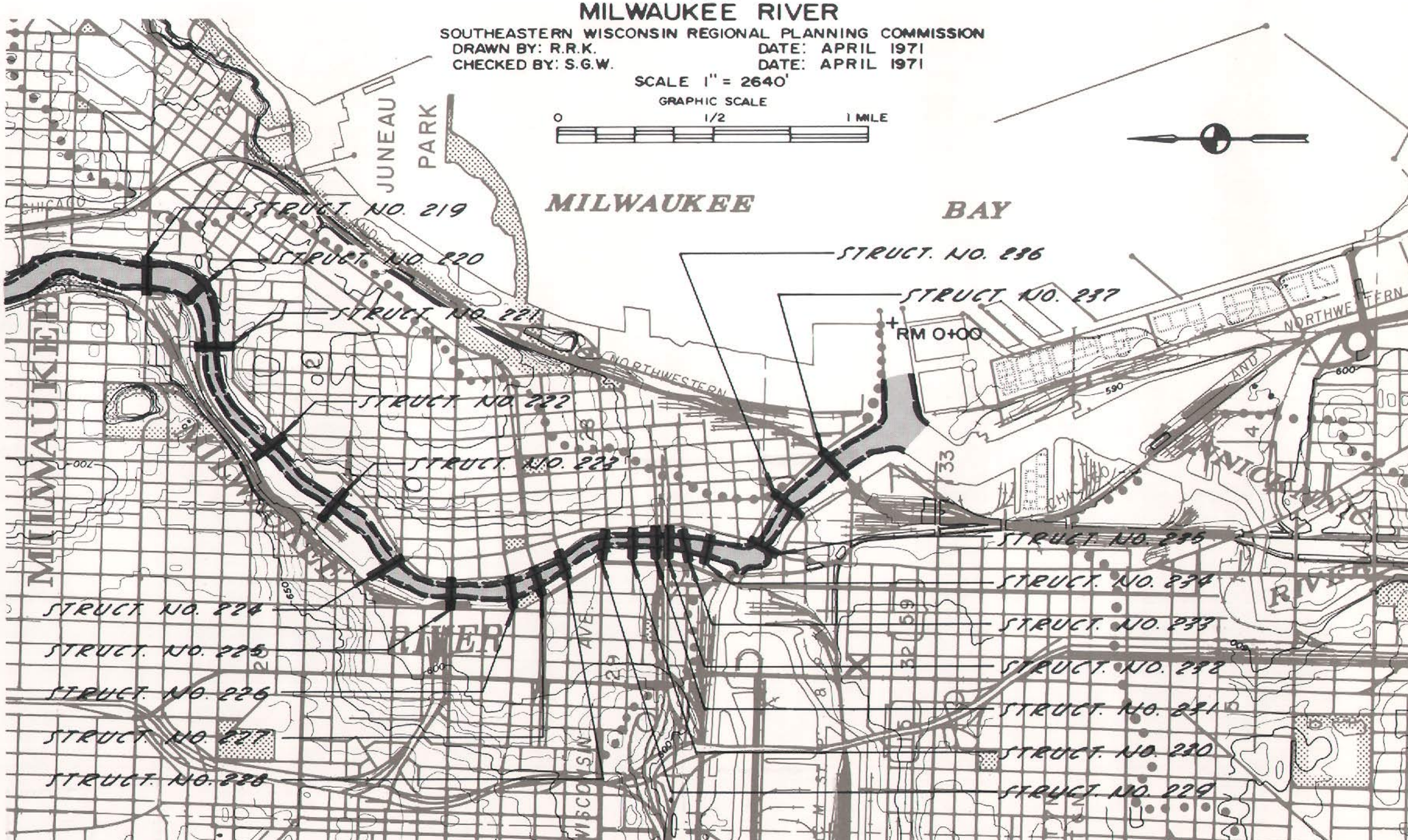
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

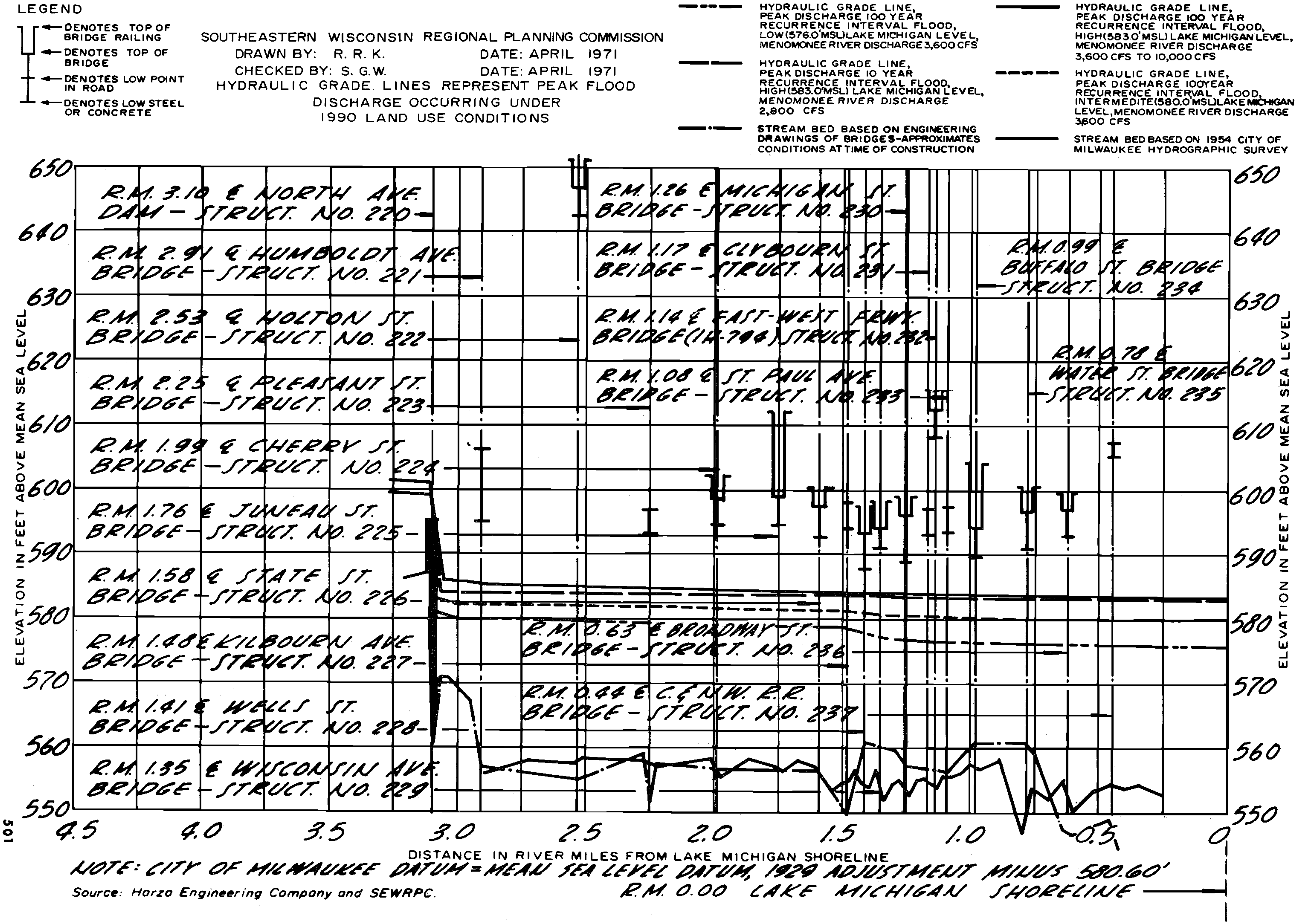
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER



Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

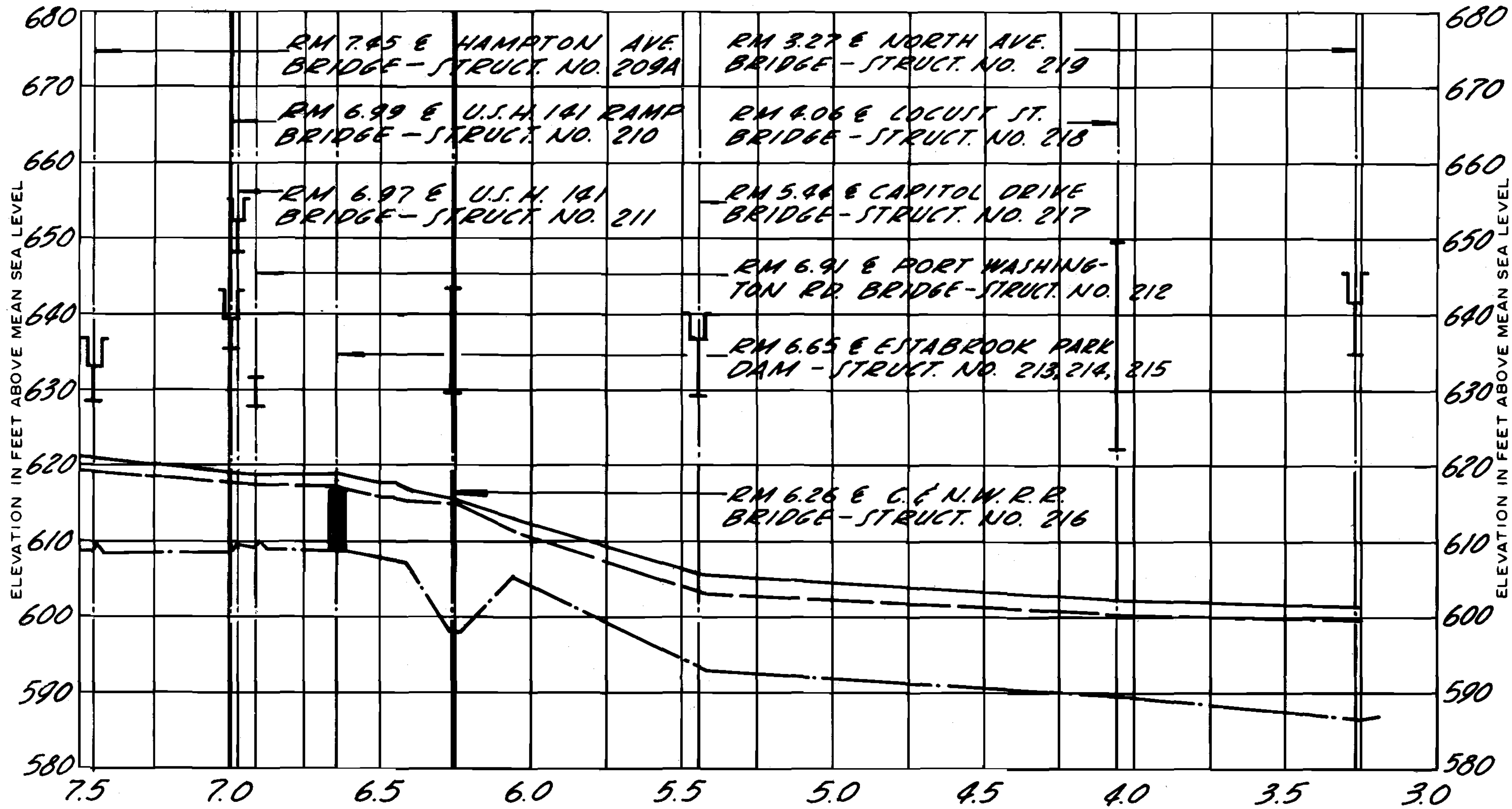
CHECKED BY: S. G. W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



NOTE: CITY OF MILWAUKEE DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 580.60'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

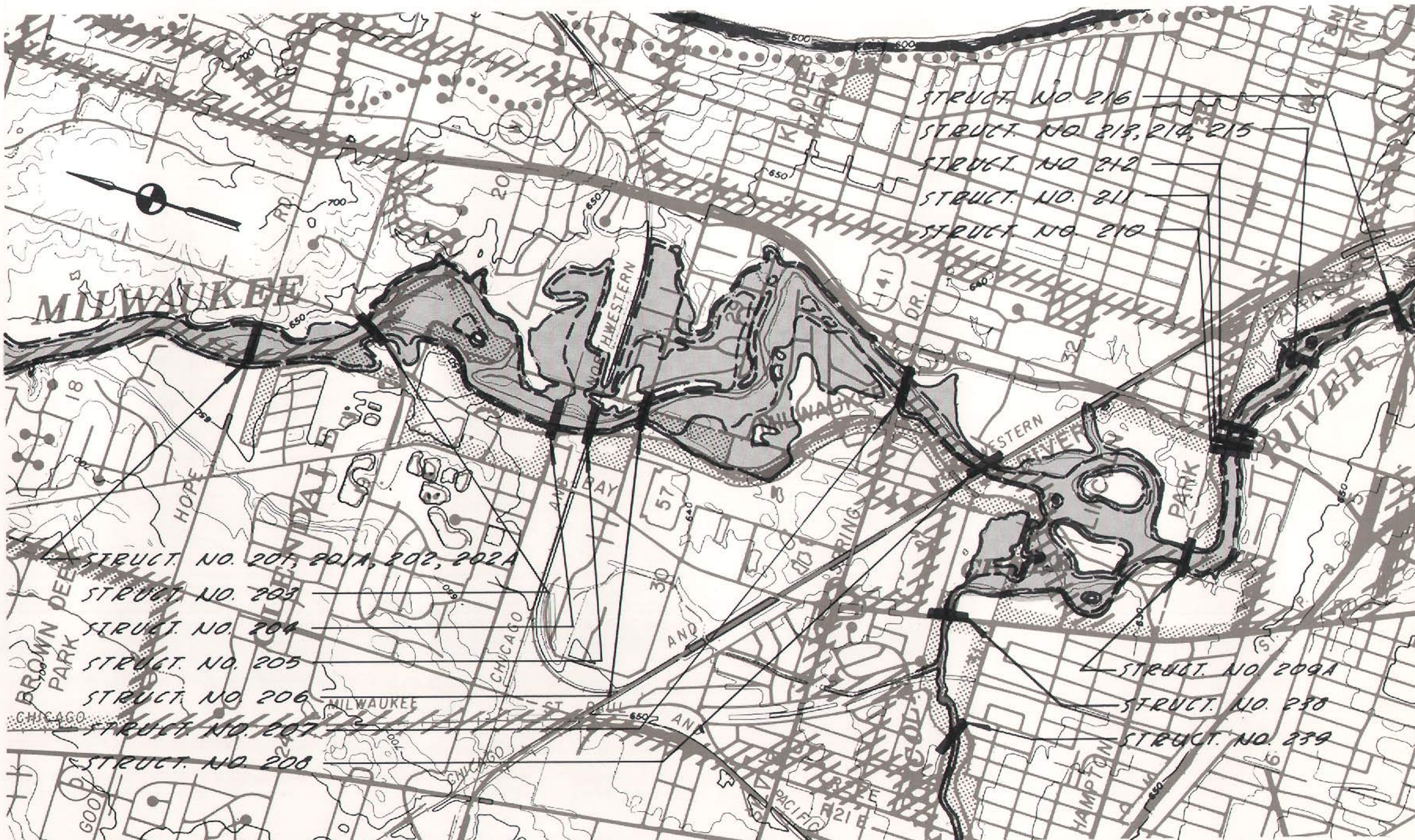
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

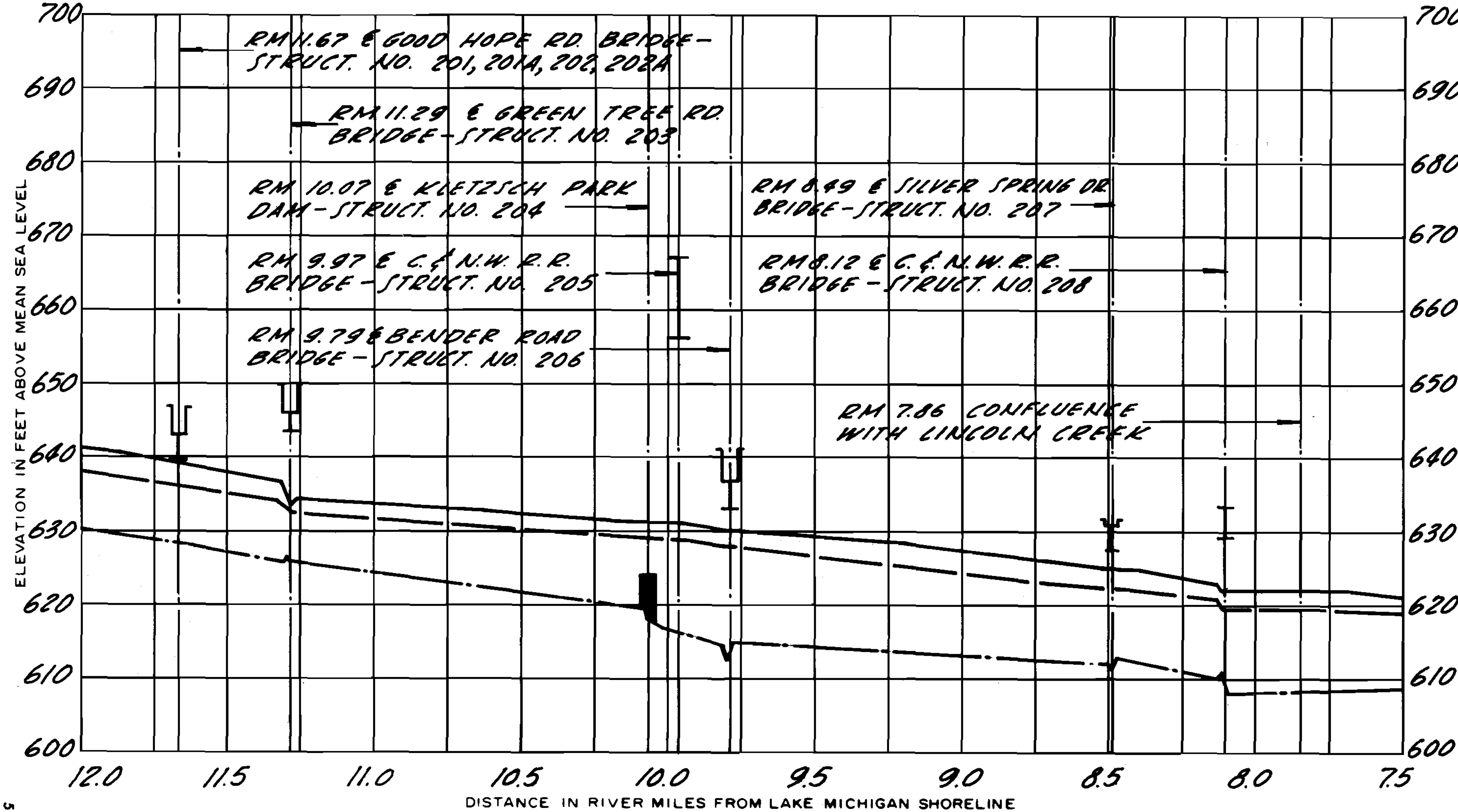
Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



NOTE: CITY OF MILWAUKEE DATUM AND CITY OF GLENDALE DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 580.60'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP

SHOWING

AREAS SUBJECT TO FLOODING

ALONG

MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

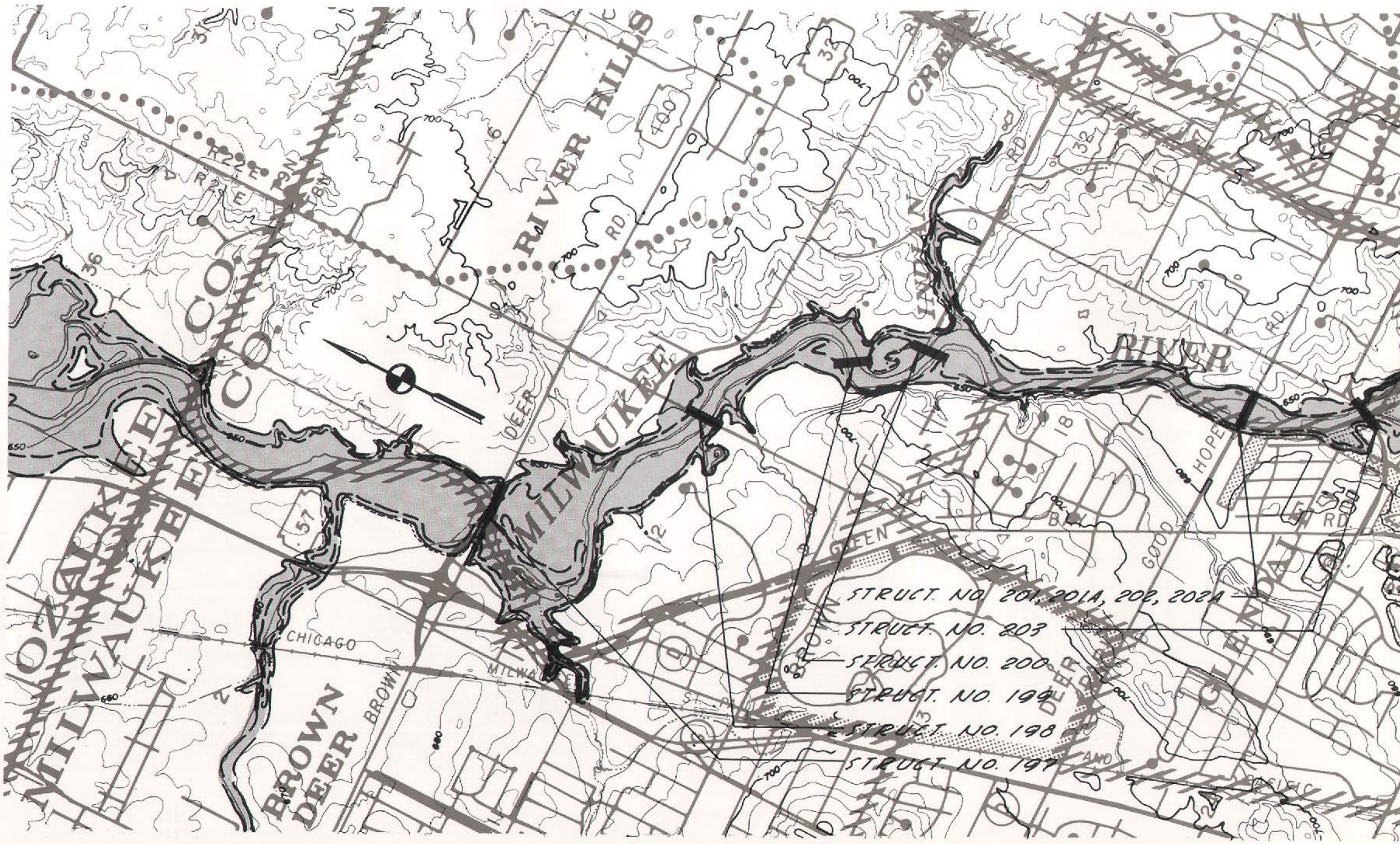
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

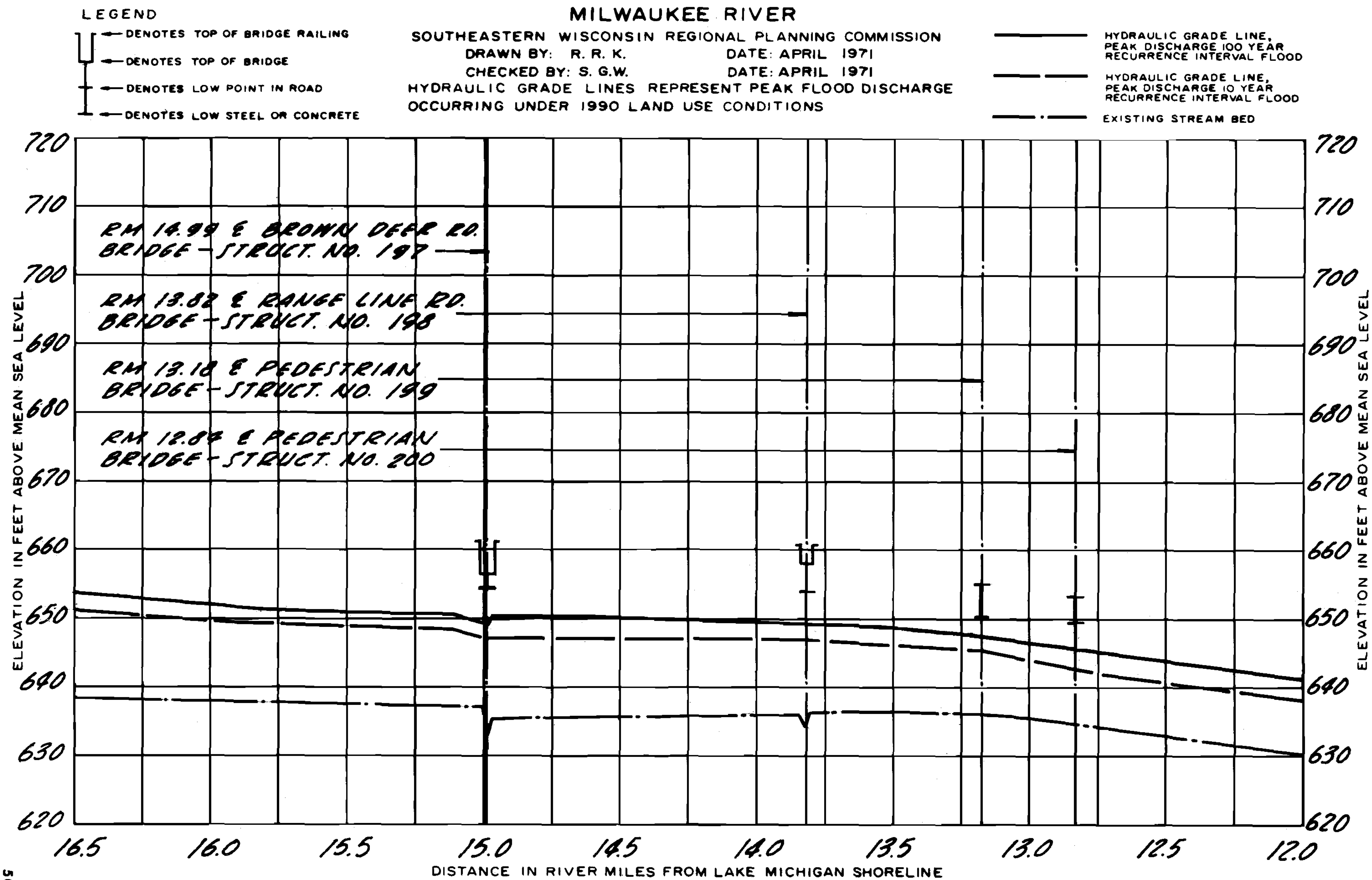
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



NOTE: VILLAGE OF RIVER HILLS DATUM AND VILLAGE OF BROWN DEER DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 580.60'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

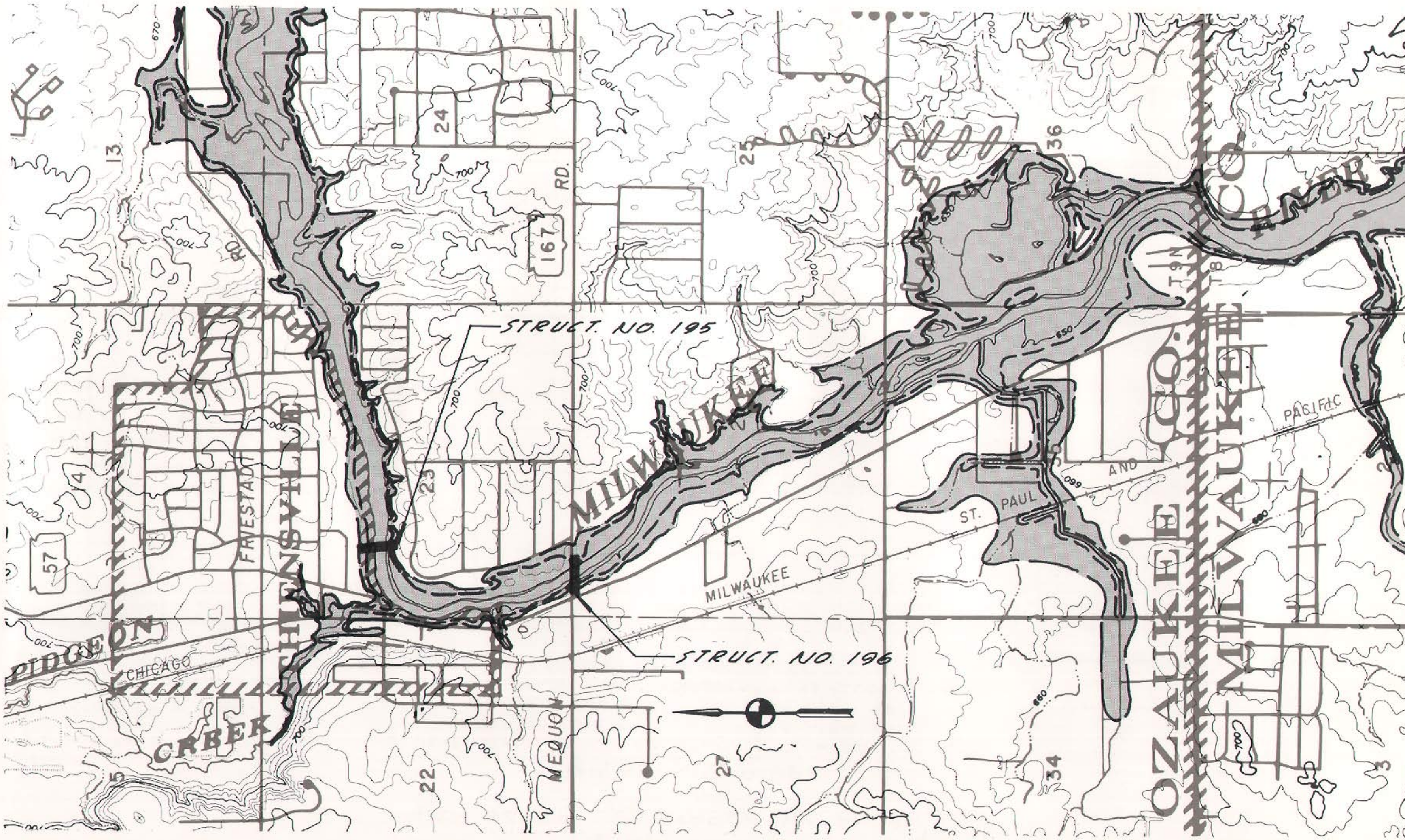
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-I (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

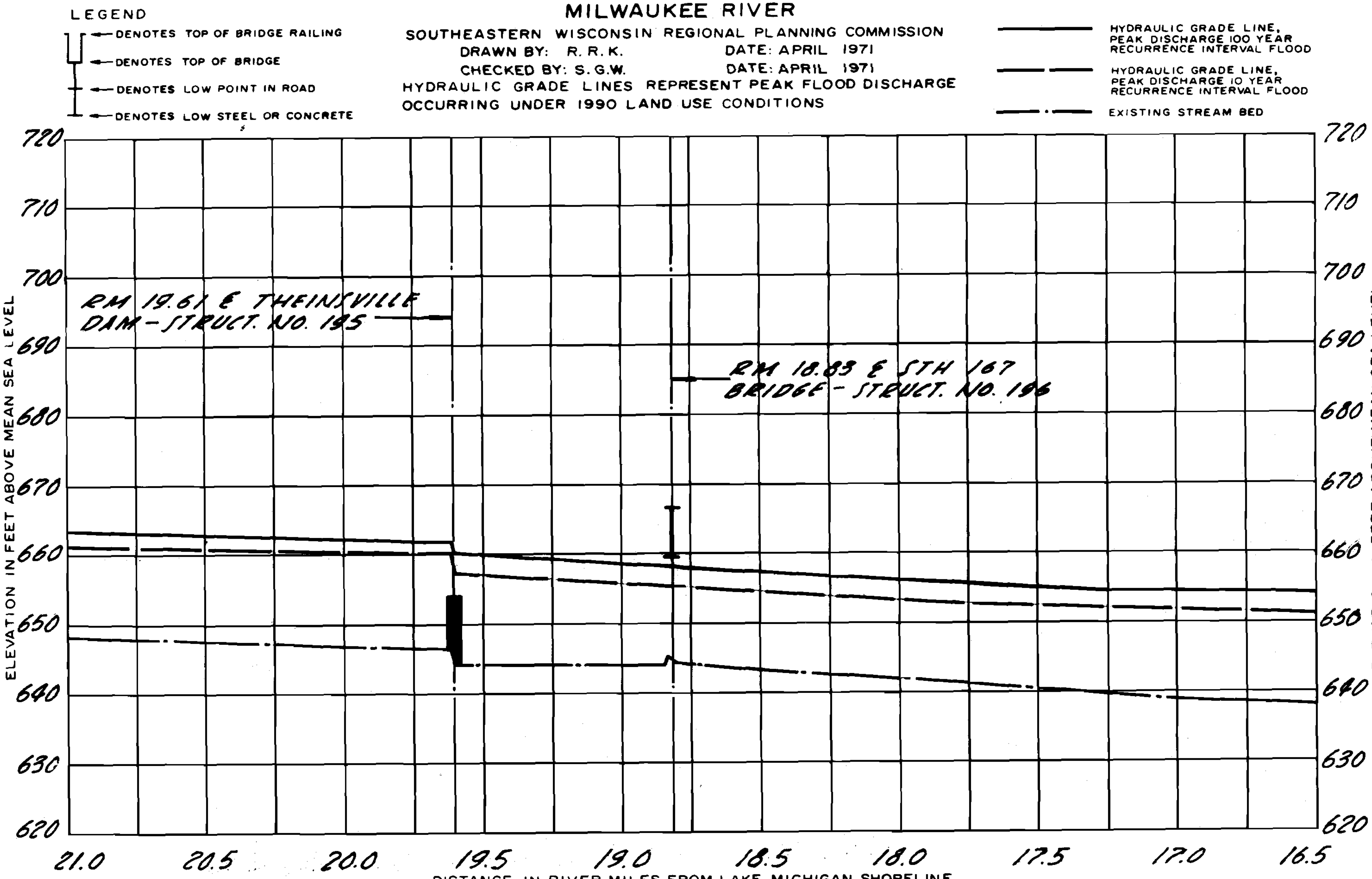
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



NOTE: CITY OF MEQUON DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 580.52'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

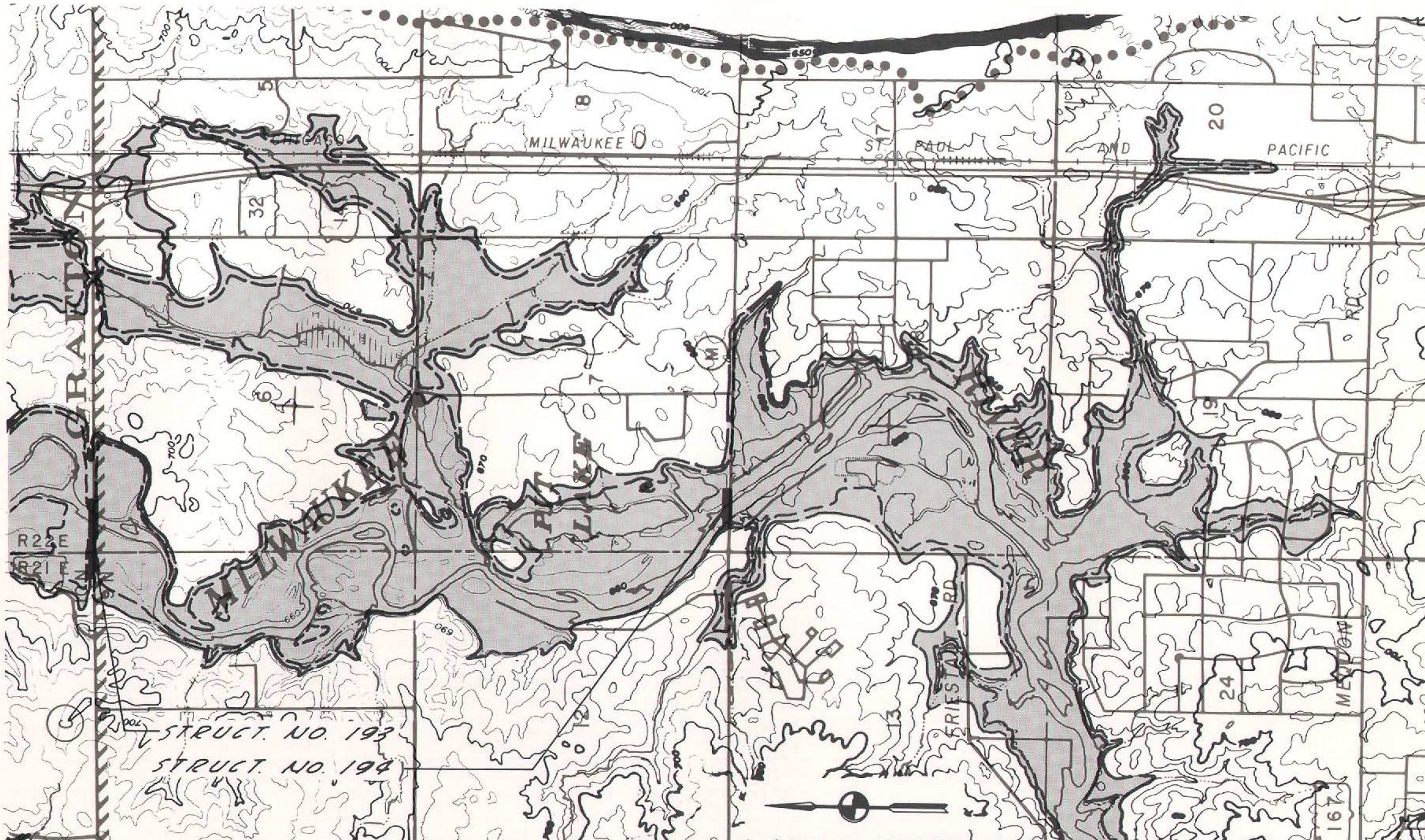
DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

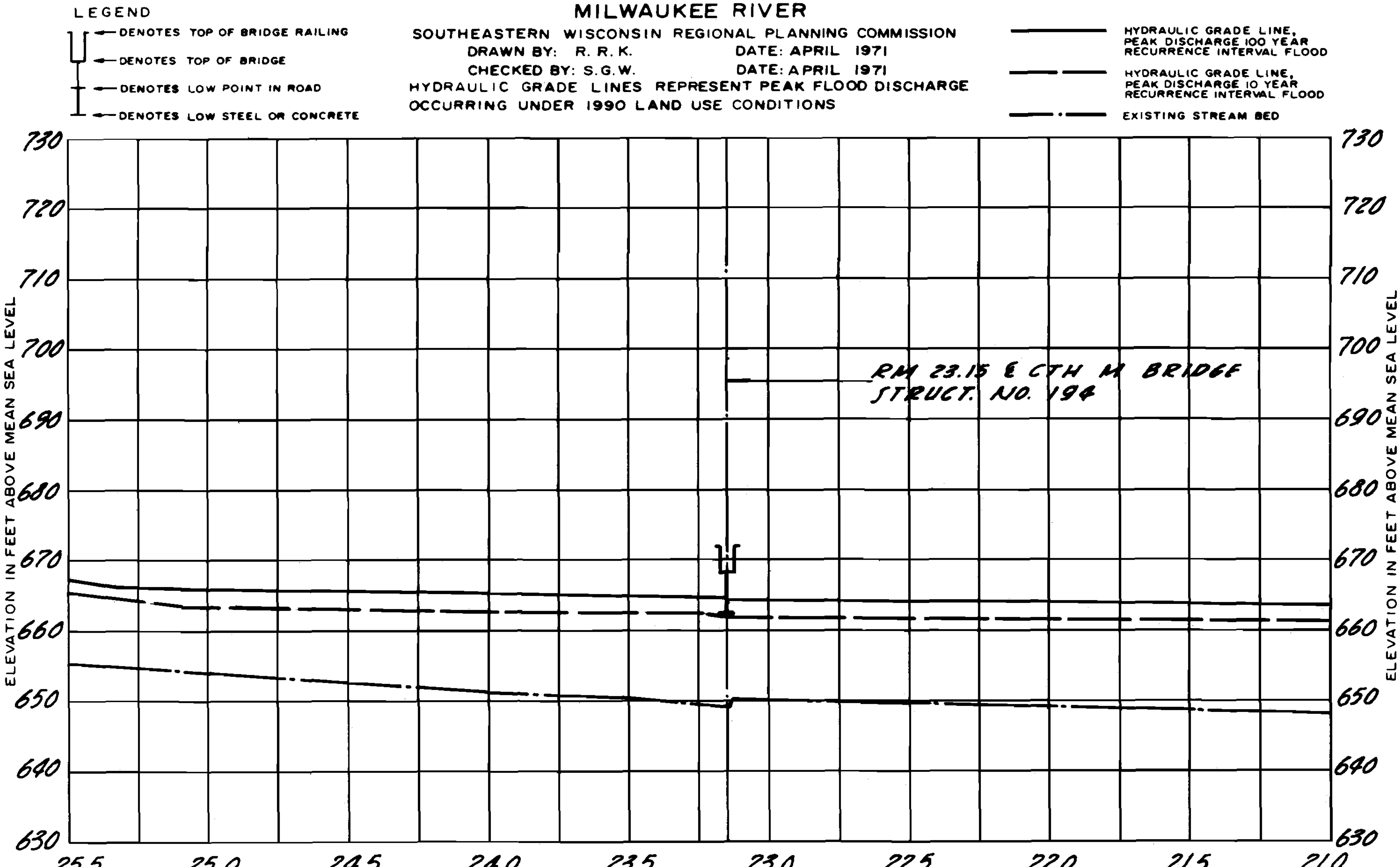
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



NOTE: CITY OF MEQUON DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 580.52'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

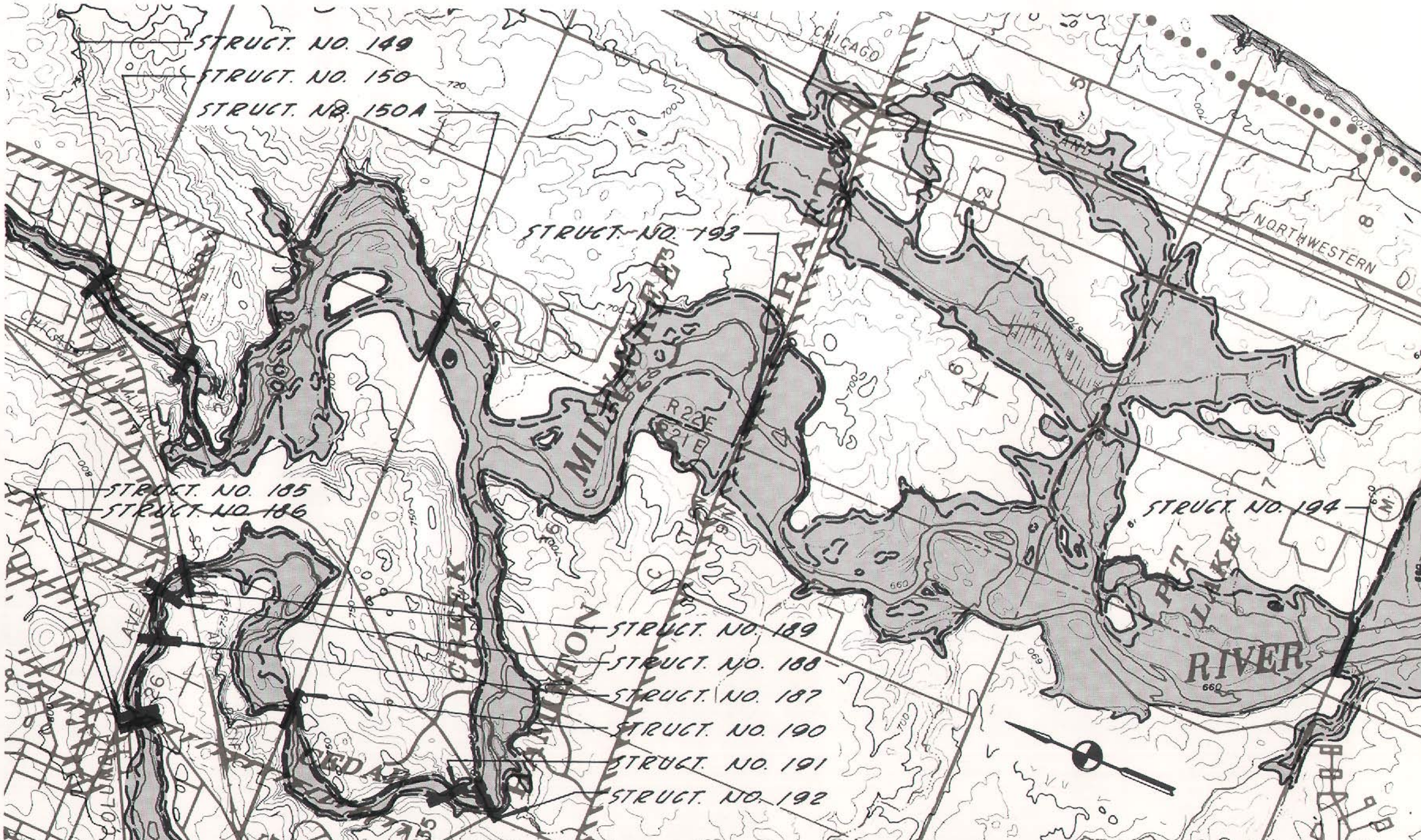
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

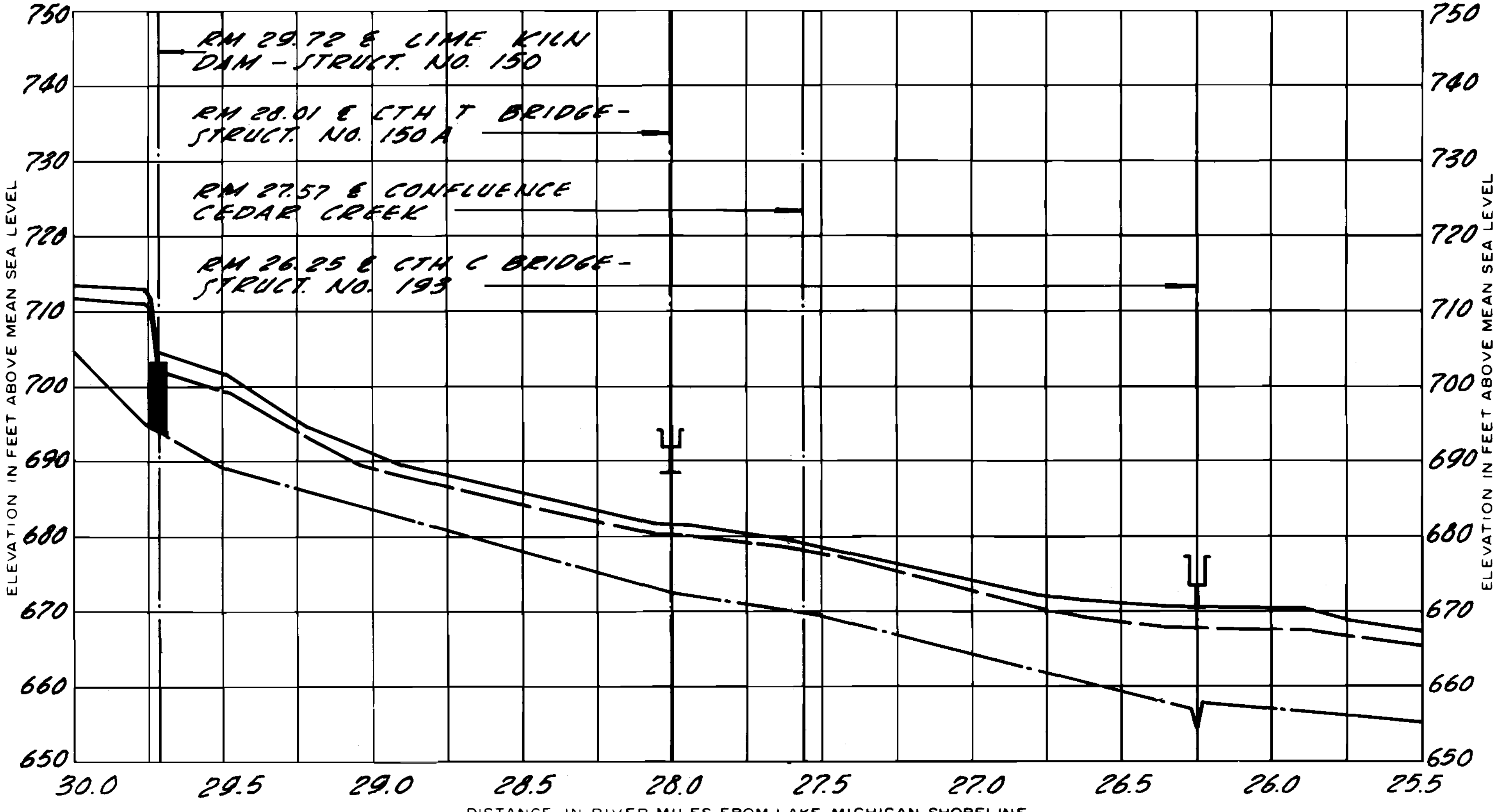
Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G.W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



NOTE: VILLAGE OF GRAFTON DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 615.49'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

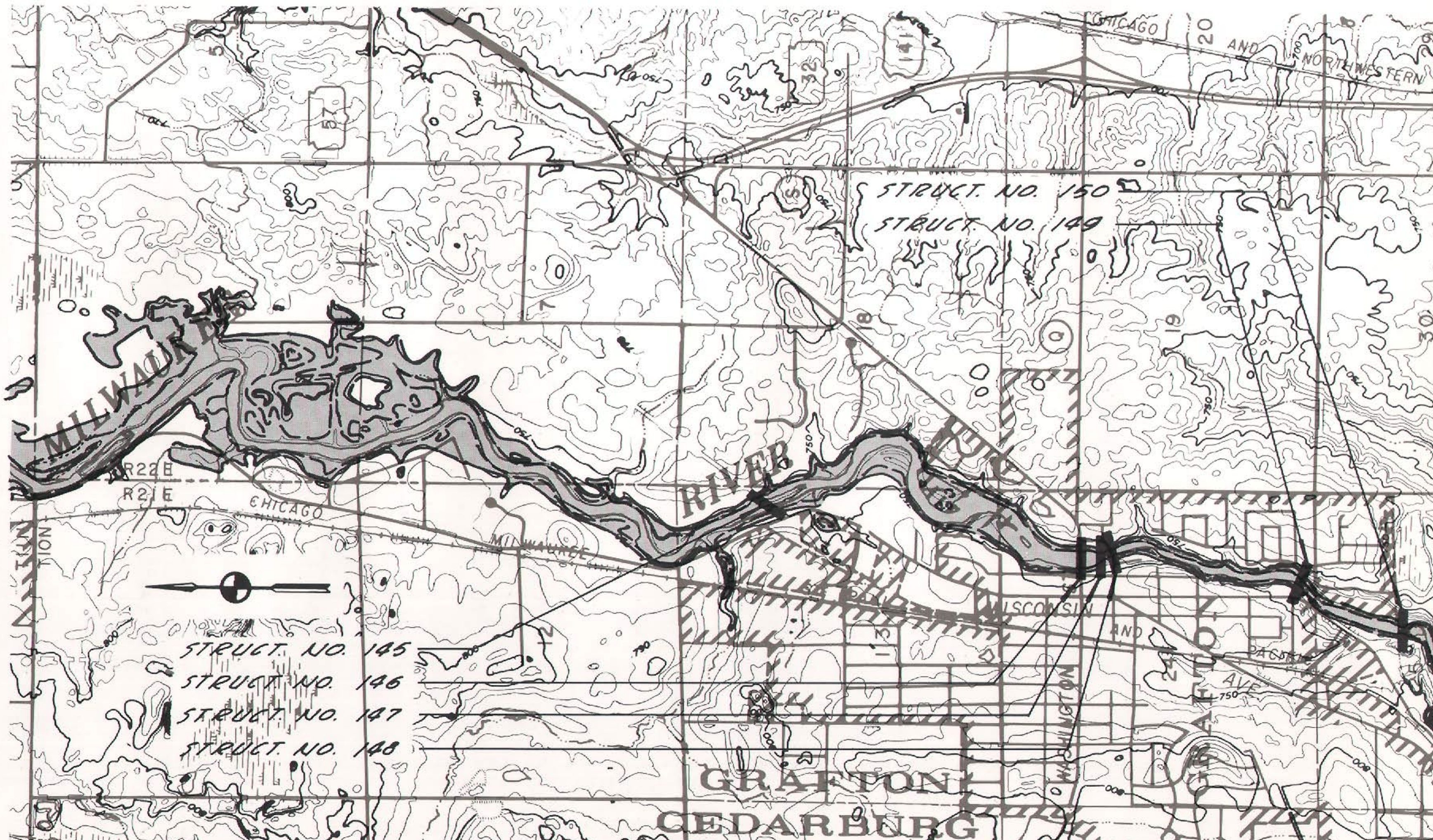
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

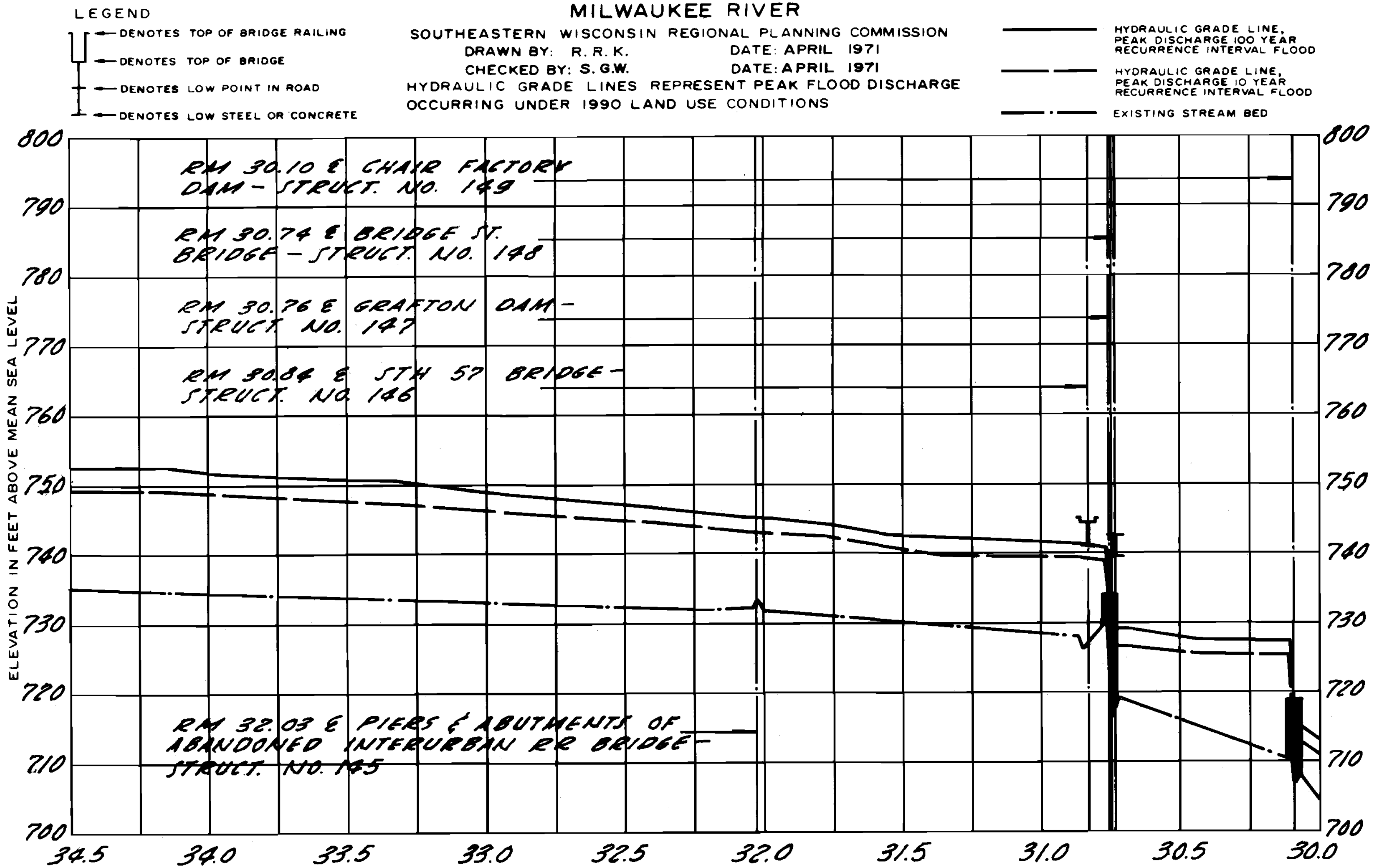
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



NOTE: VILLAGE OF GRAFTON DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 615.49'

Source: Harza Engineering Company and SEWRPC

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

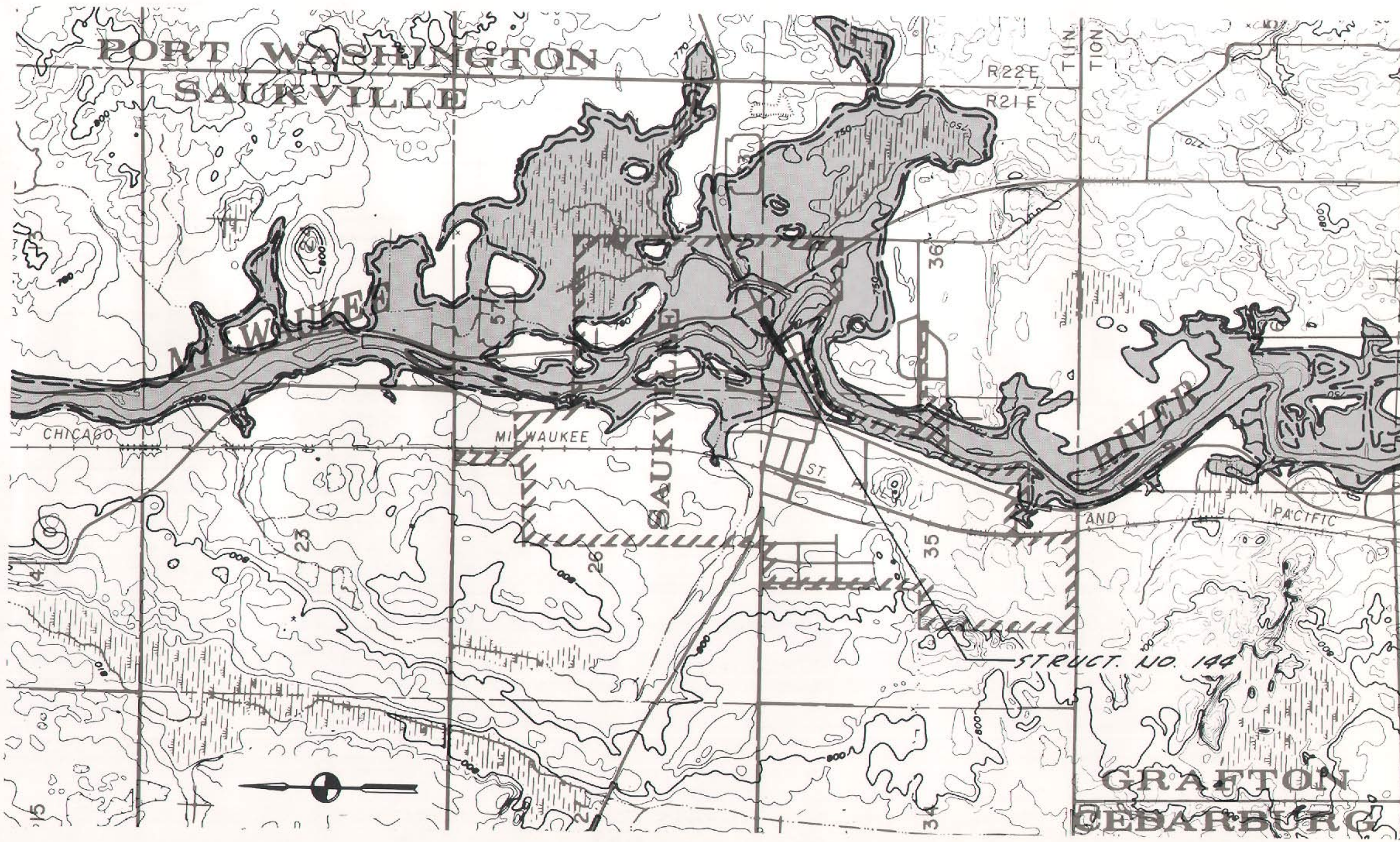
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

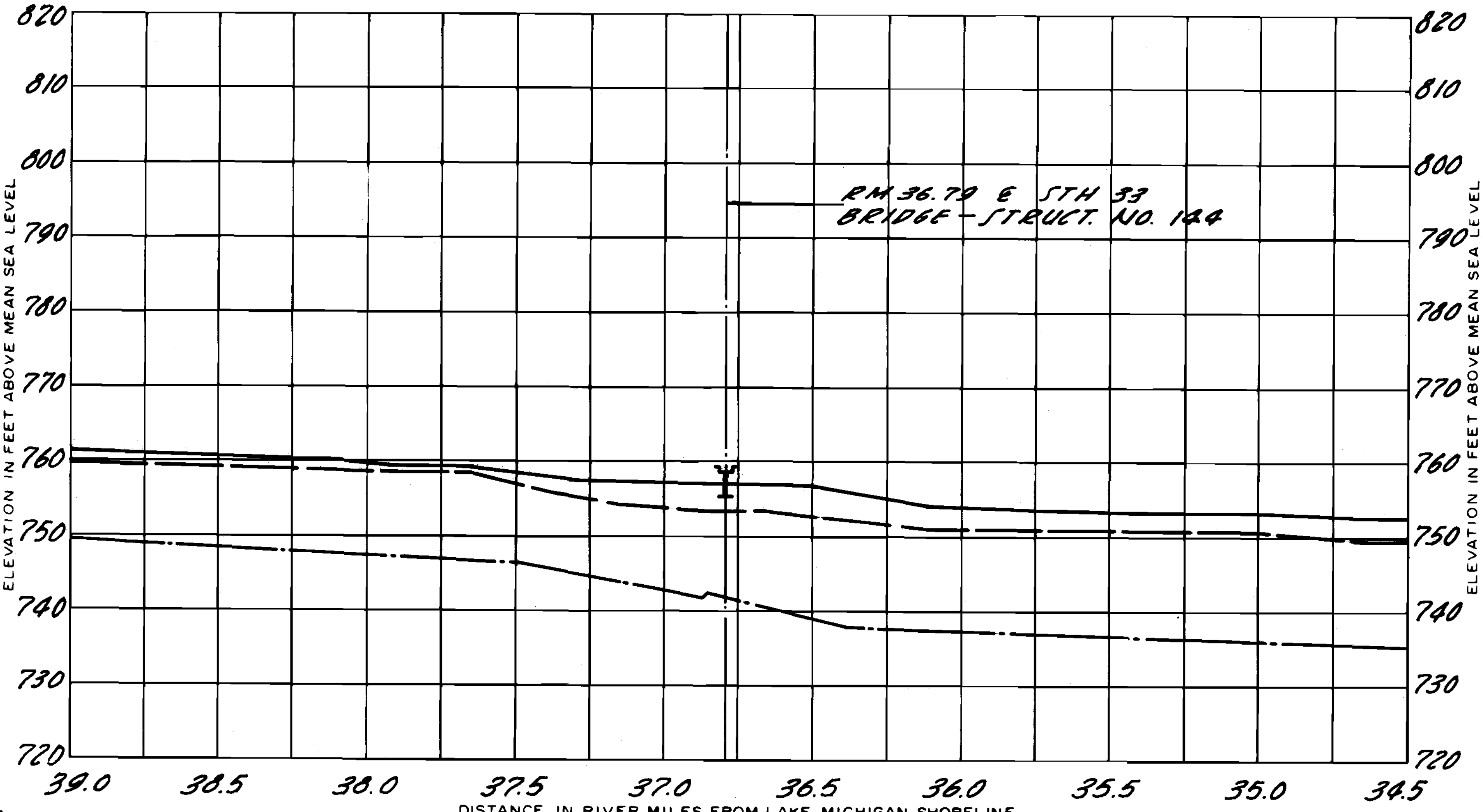
Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G.W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



NOTE: VILLAGE OF SAUKVILLE DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 0.13'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

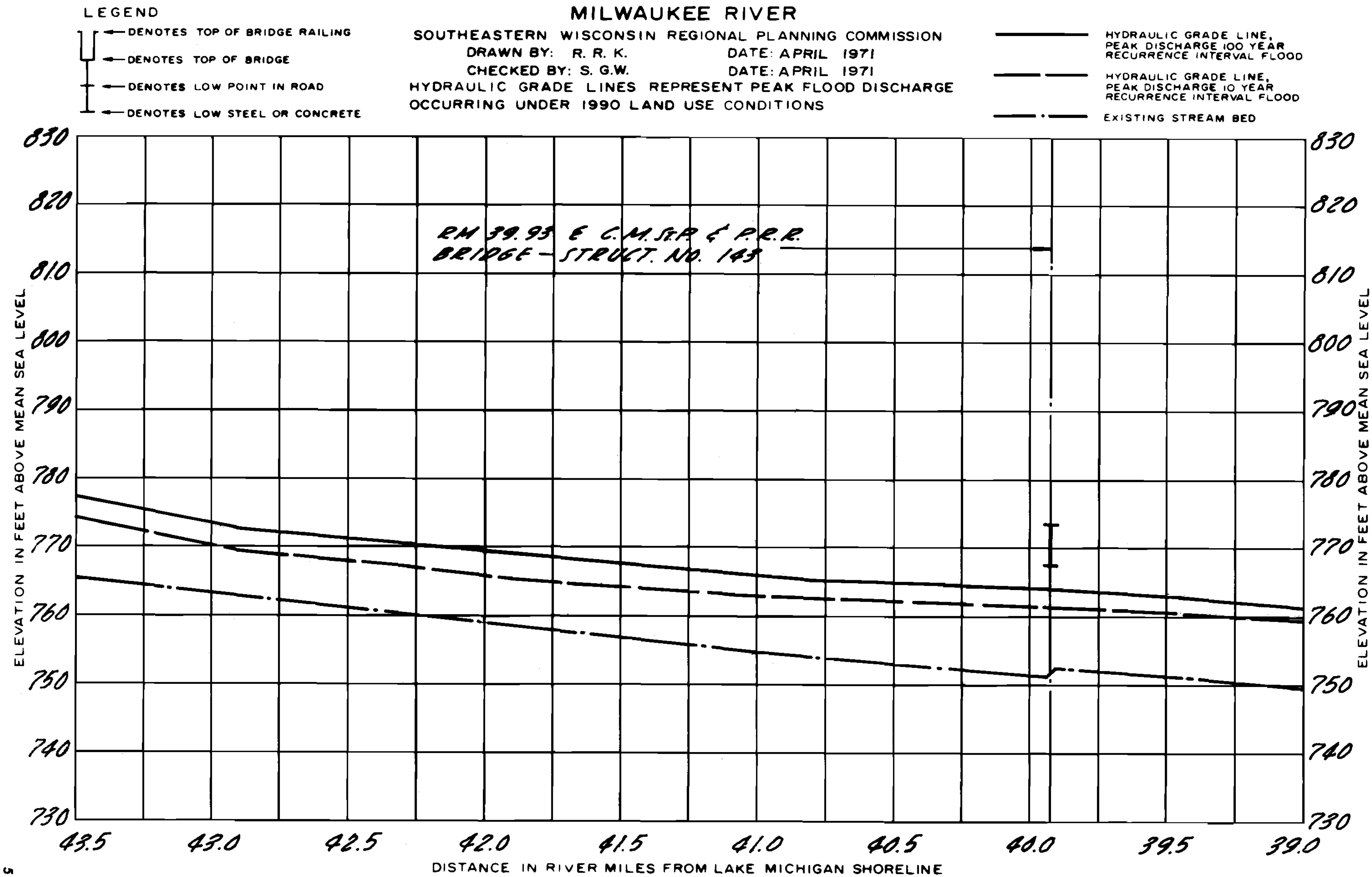
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

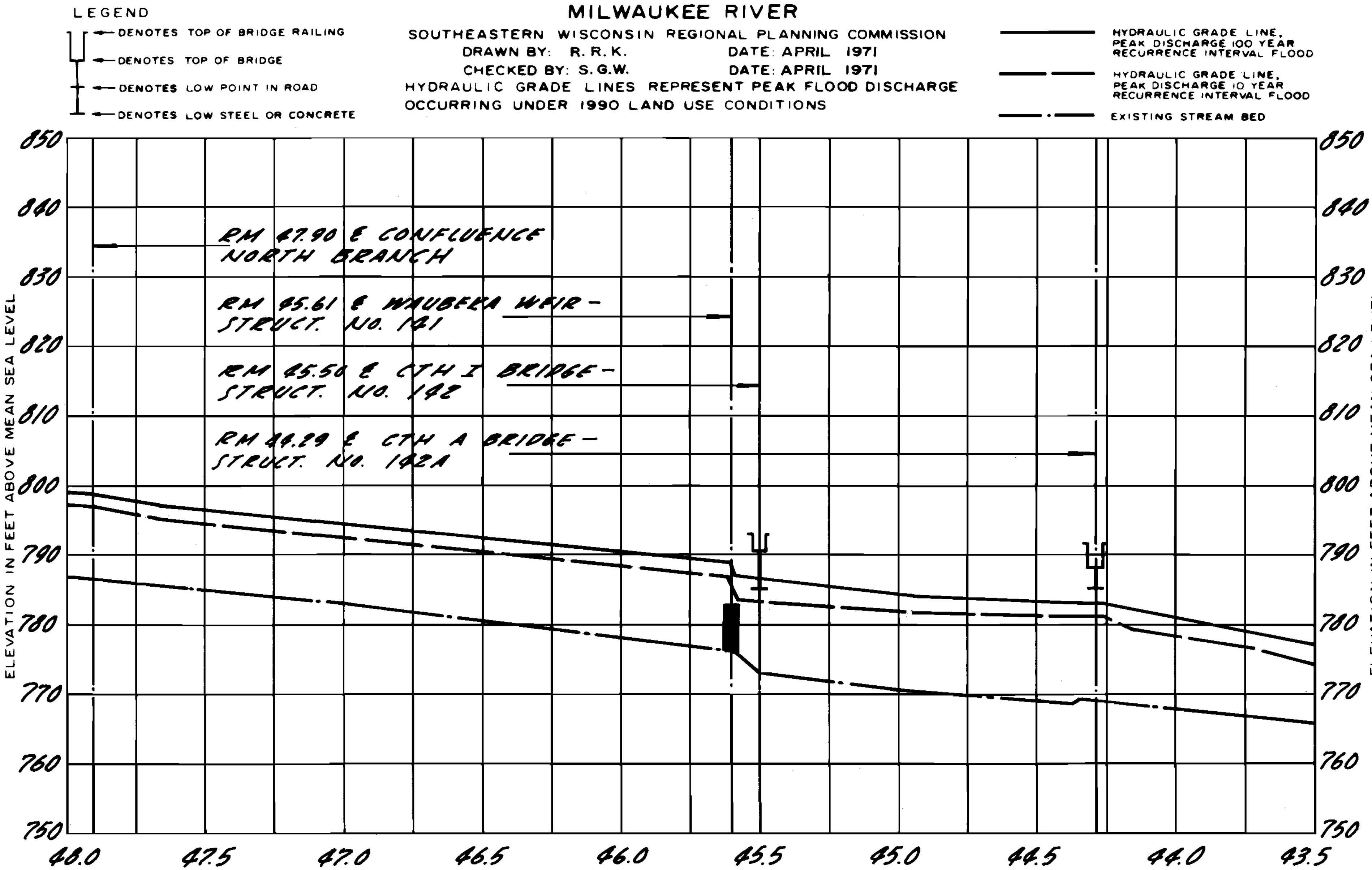
ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G.W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



NOTE: VILLAGE OF FREDONIA DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 0.29'

Source: Harza Engineering Company and SEWRPC

Map F-1 (continued)

TOPOGRAPHIC MAP

SHOWING

AREAS SUBJECT TO FLOODING

ALONG

MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

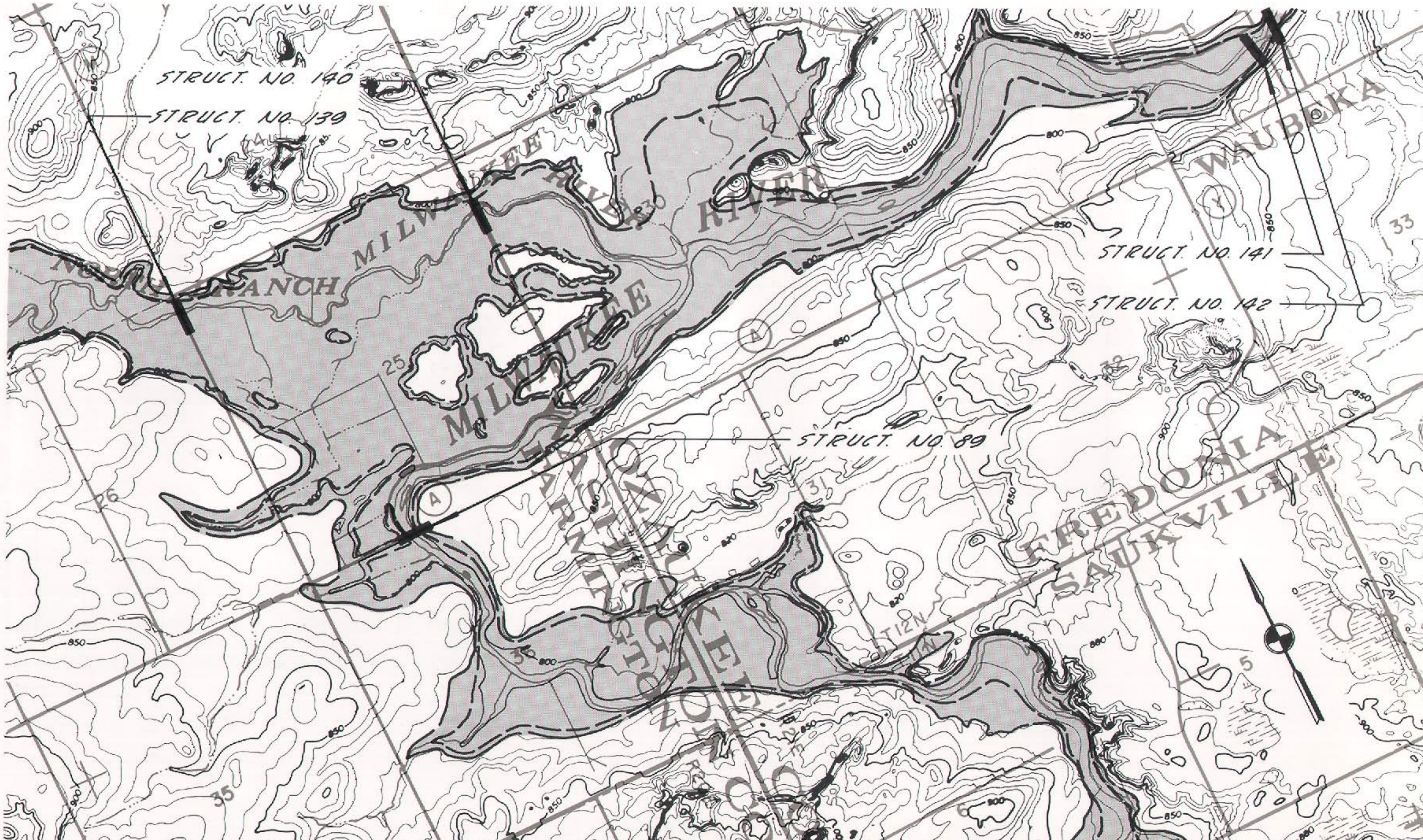
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

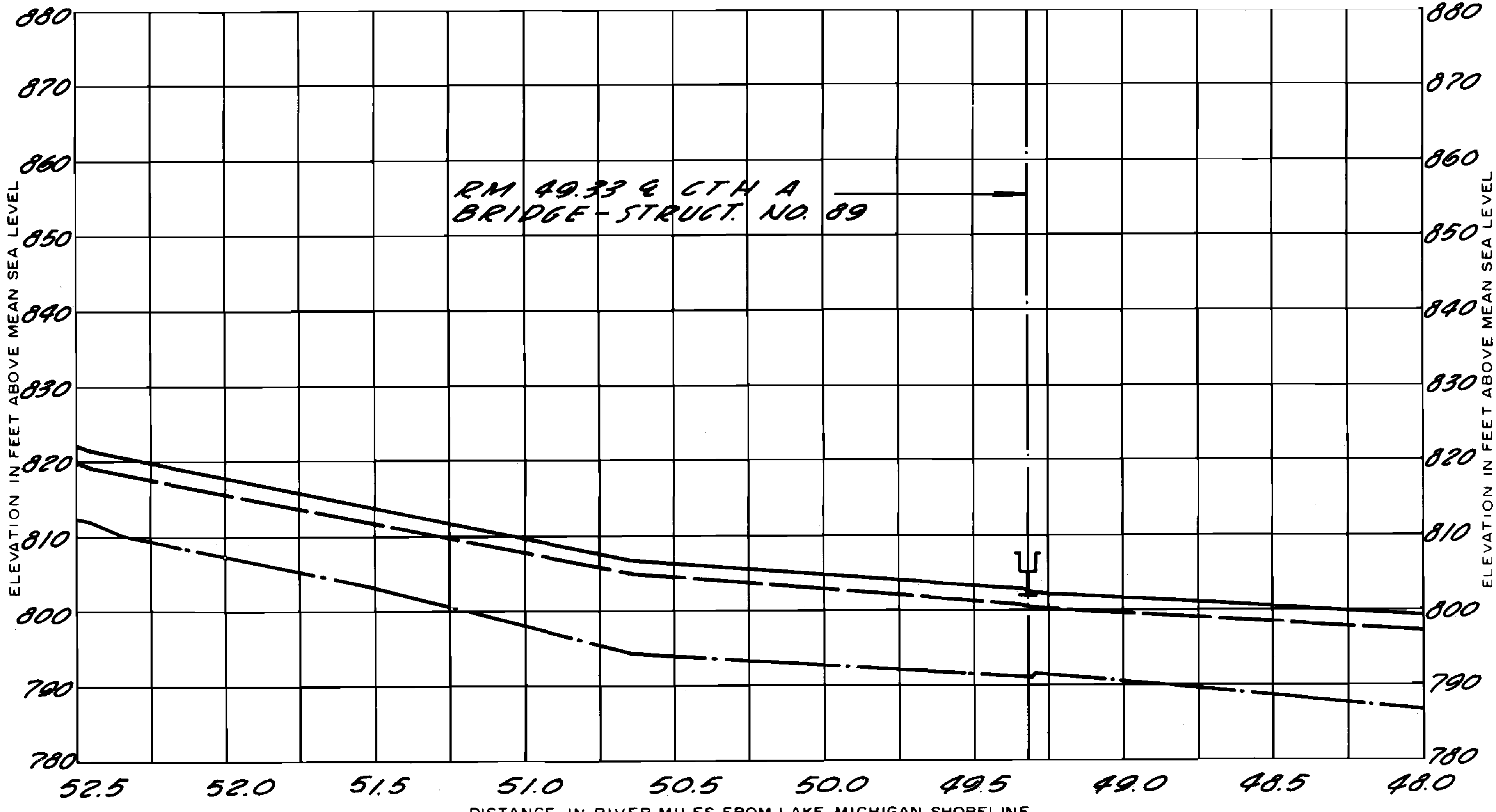
CHECKED BY: S. G. W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

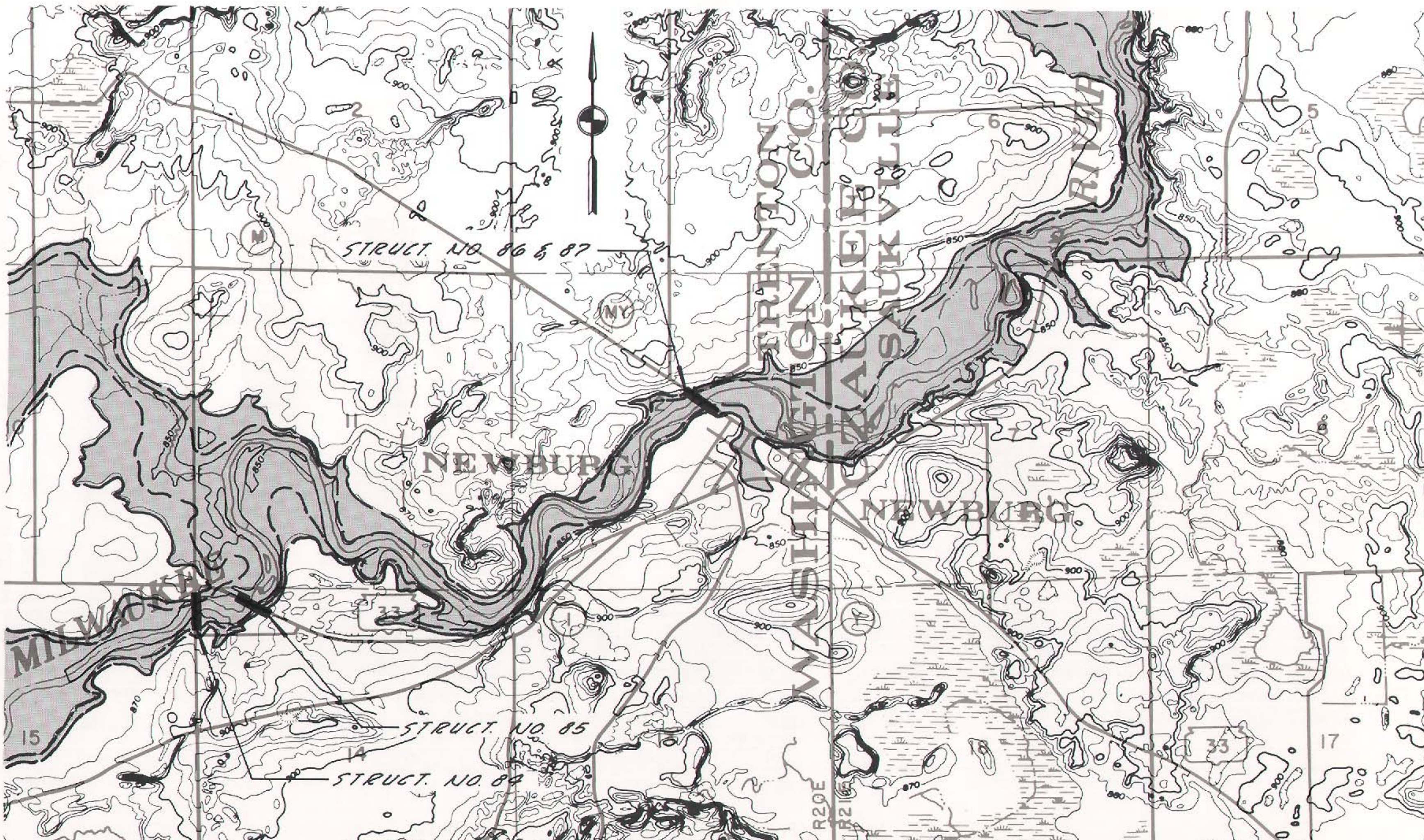
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

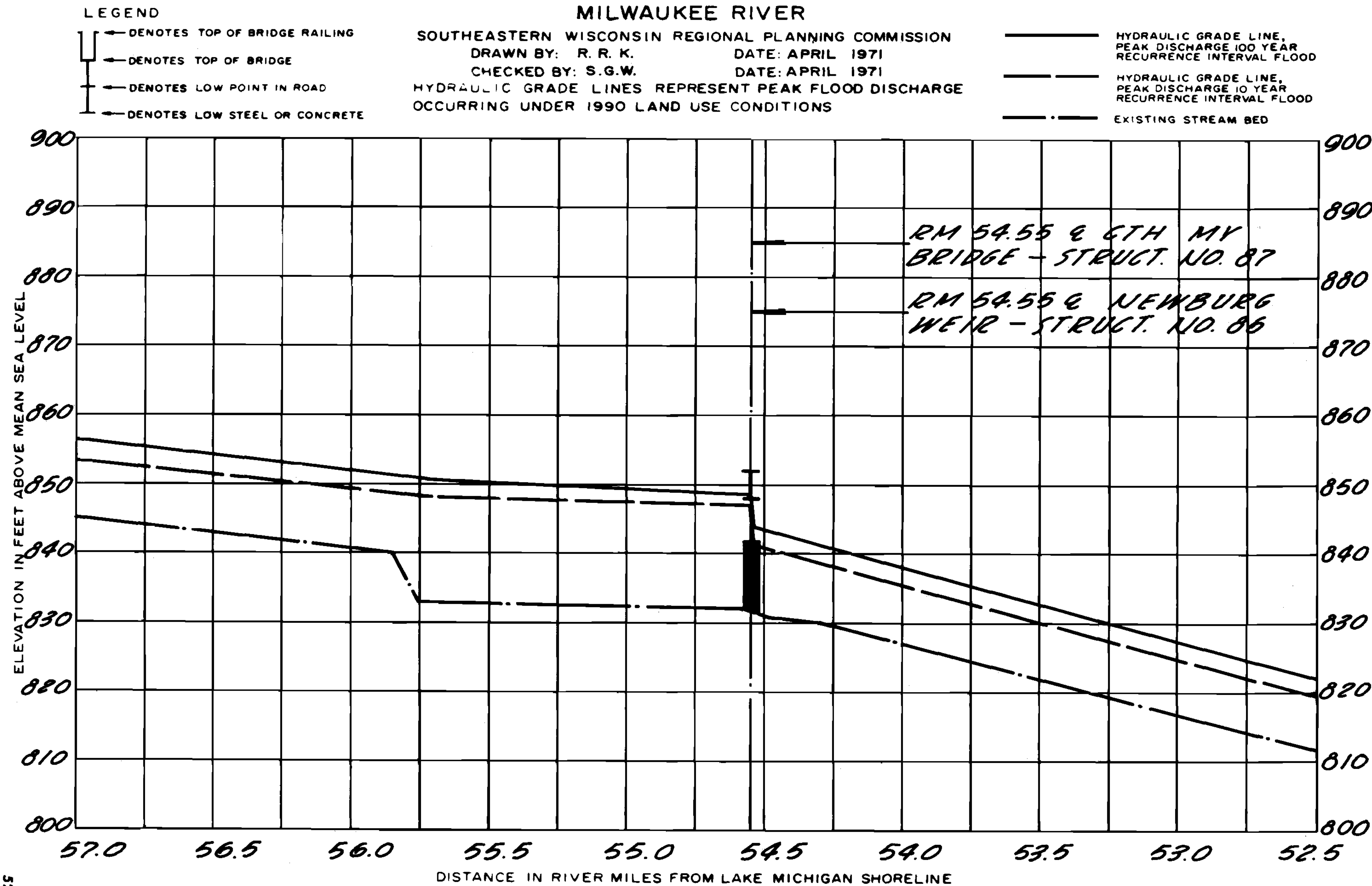
NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

MILWAUKEE RIVER



Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

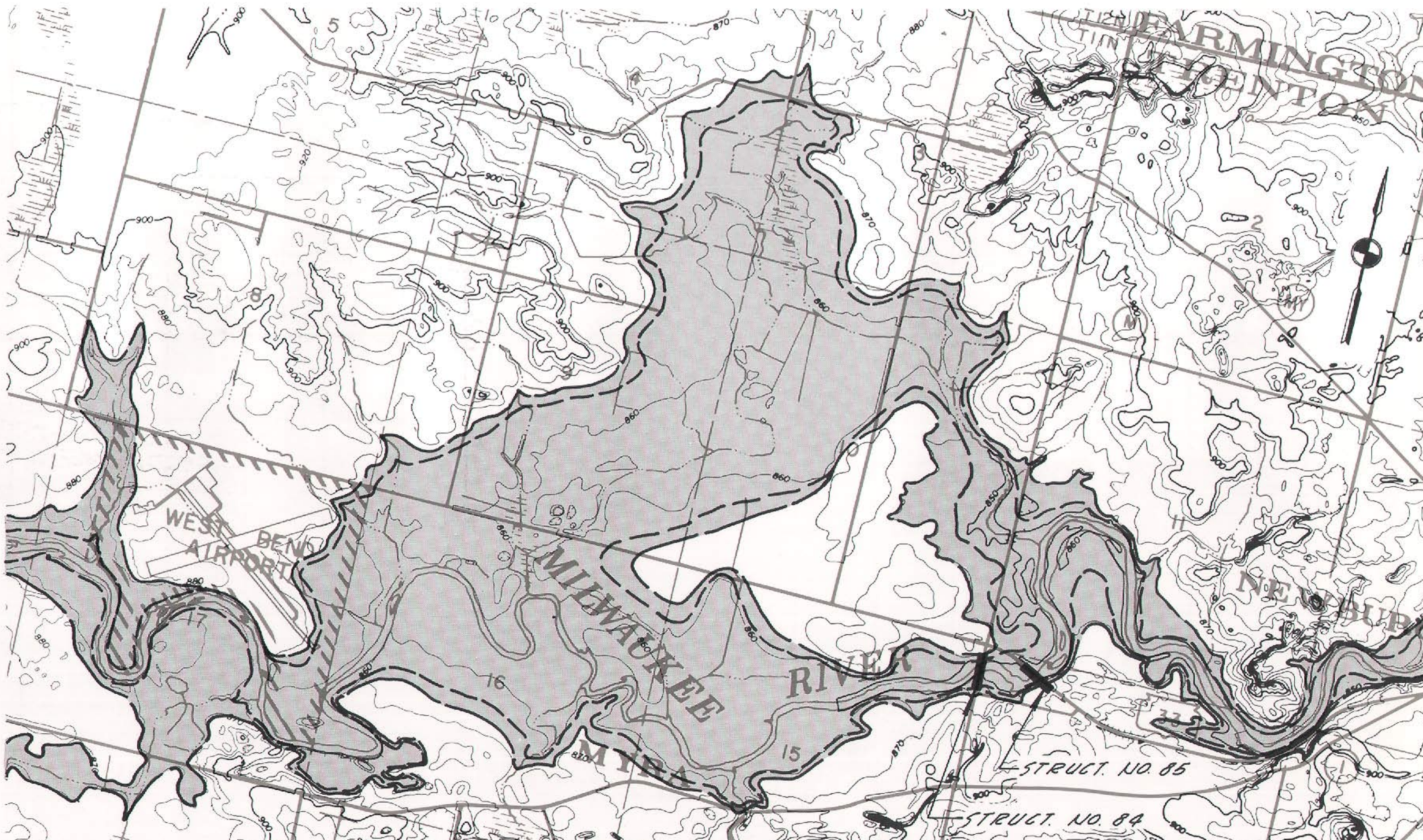
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

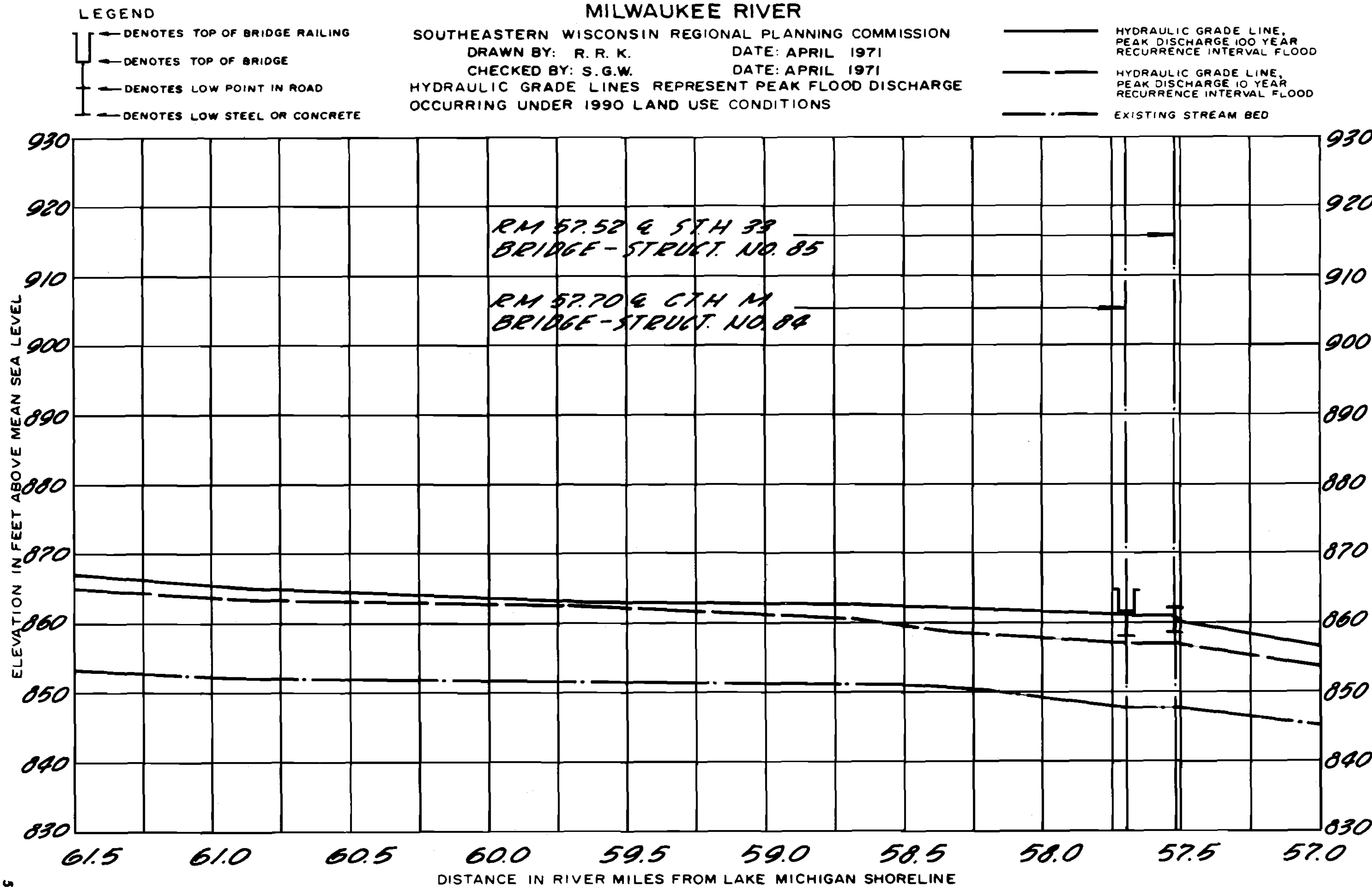
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES FOR MILWAUKEE RIVER



Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

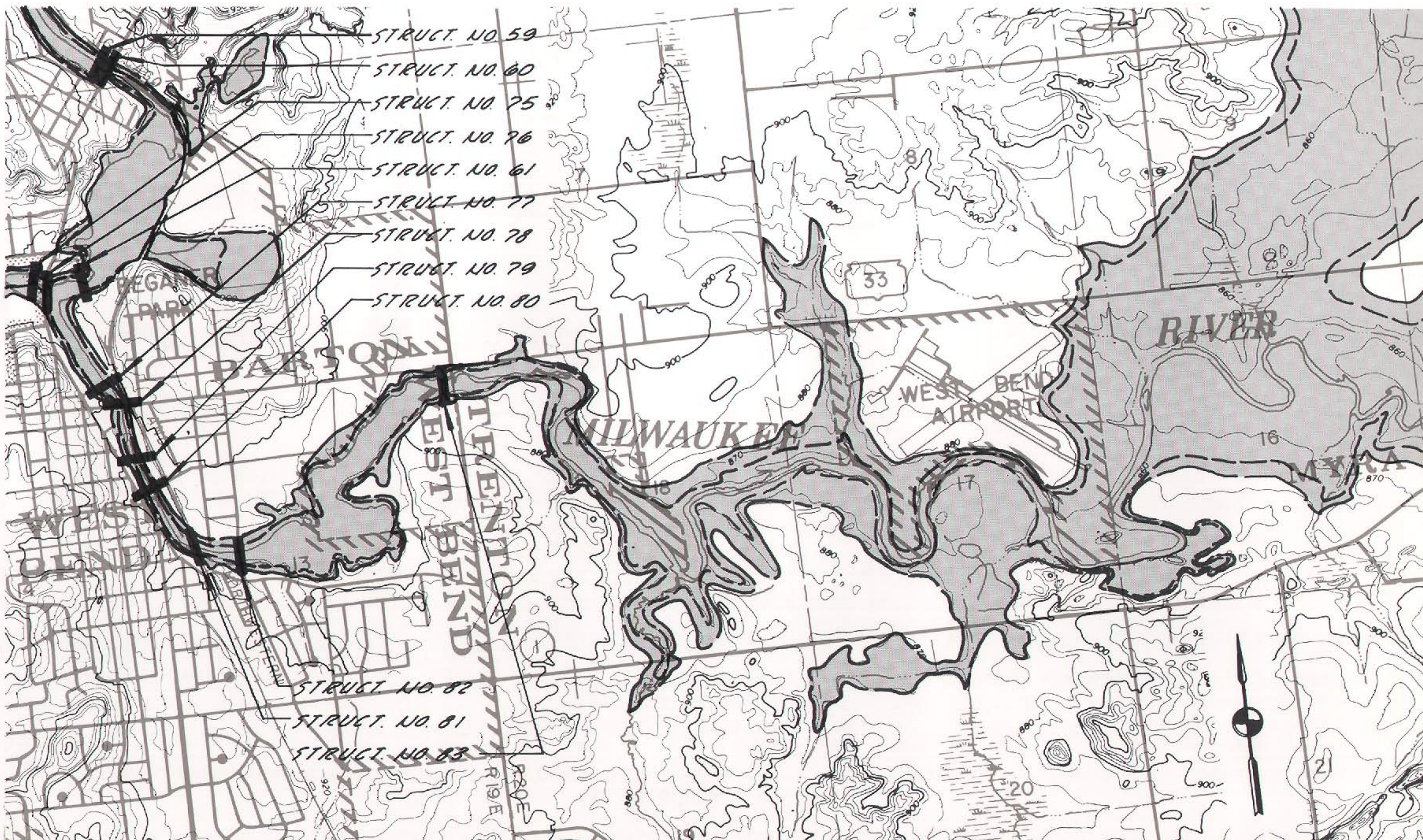
DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

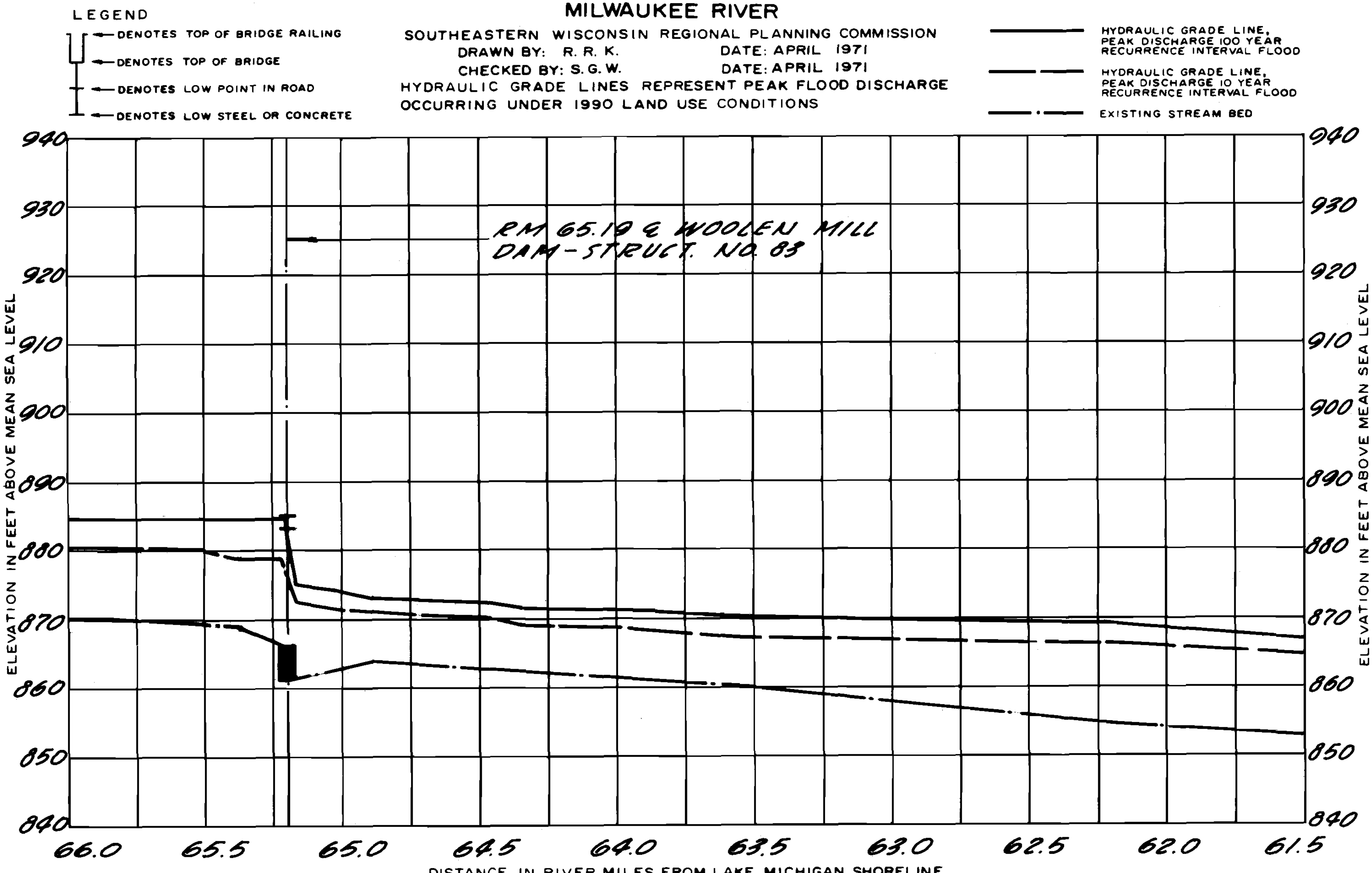
ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



NOTE: CITY OF WEST BEND DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 871.16'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

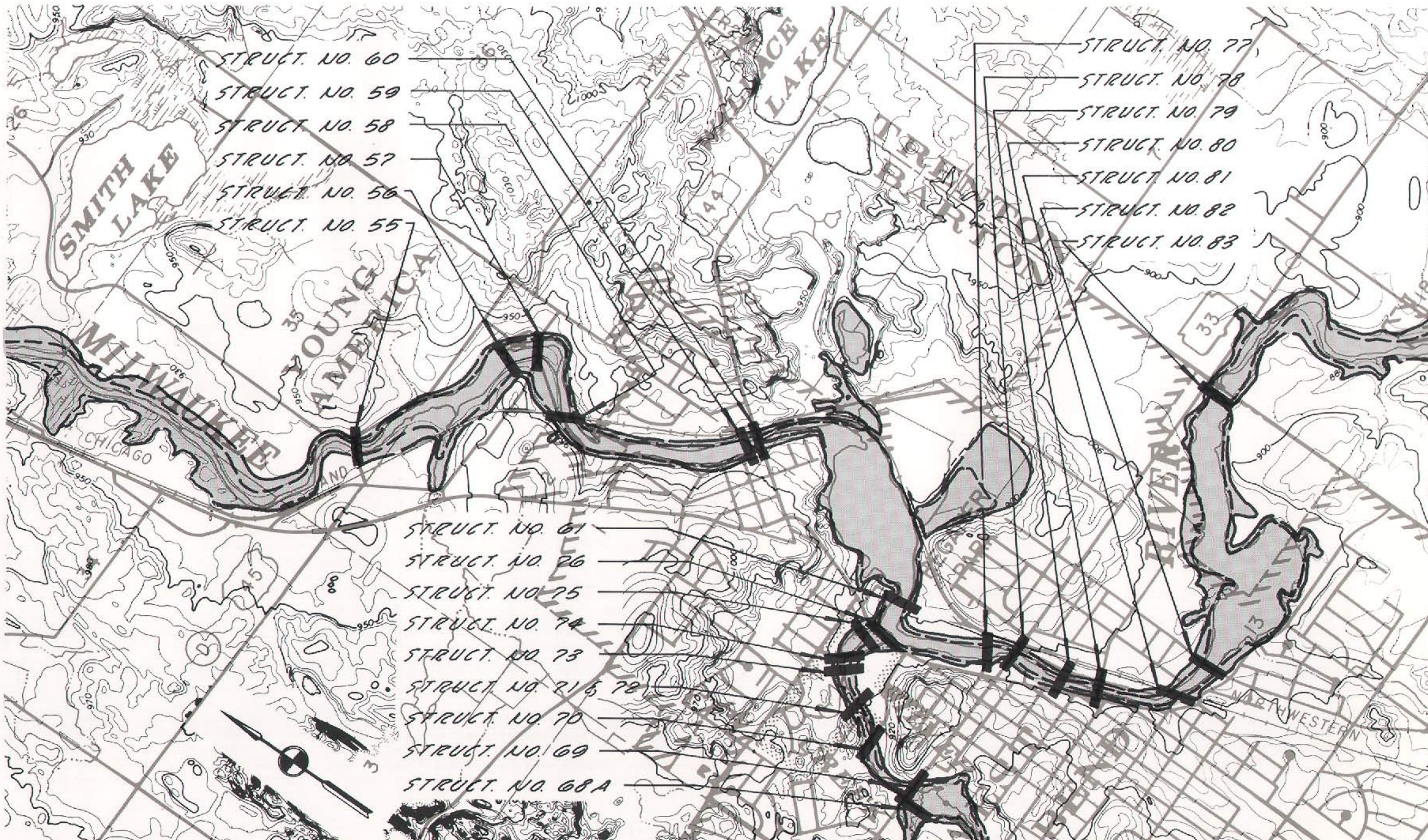
DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

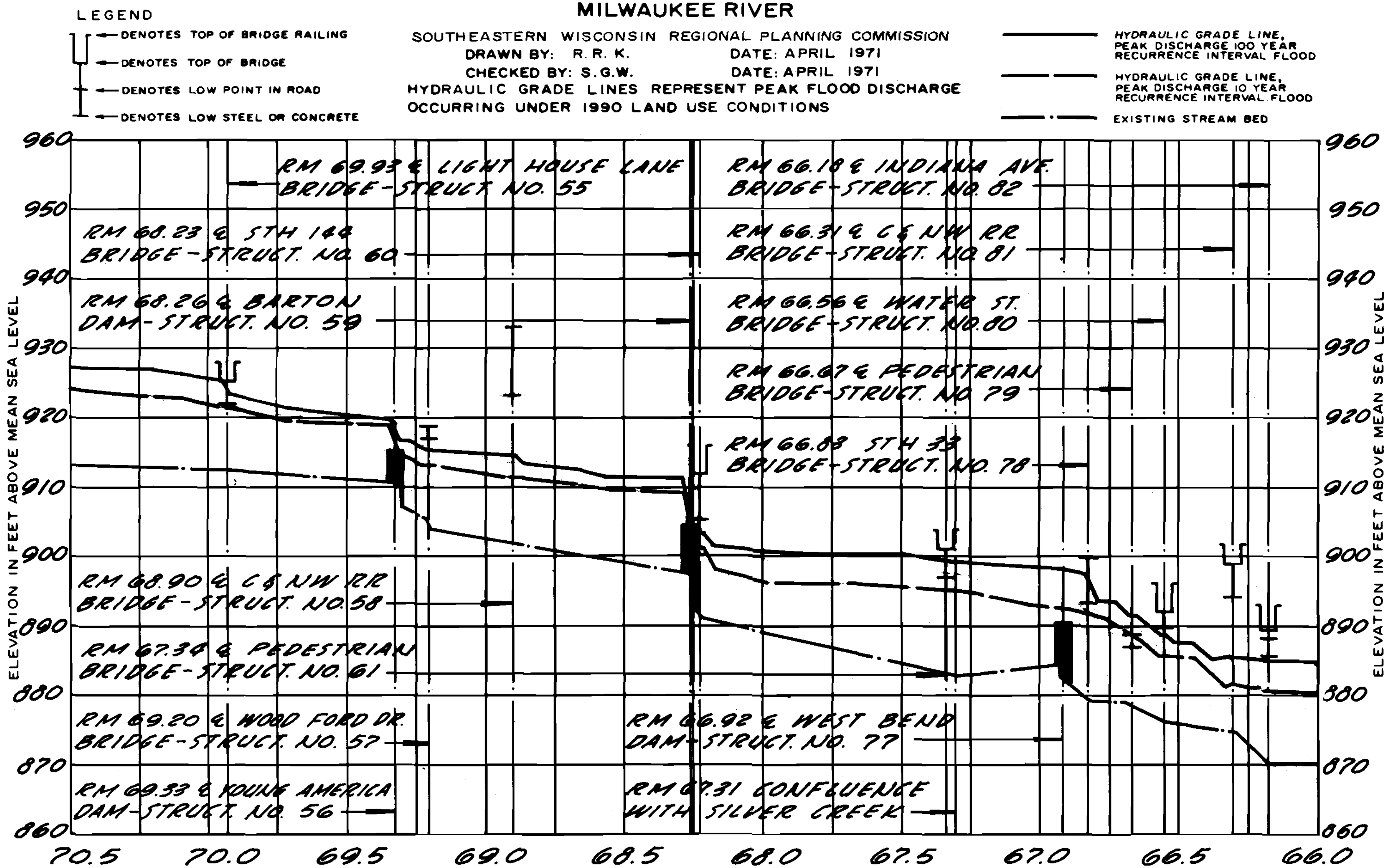
ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES FOR MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S.G.W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



NOTE: CITY OF WEST BEND DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 871.16'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

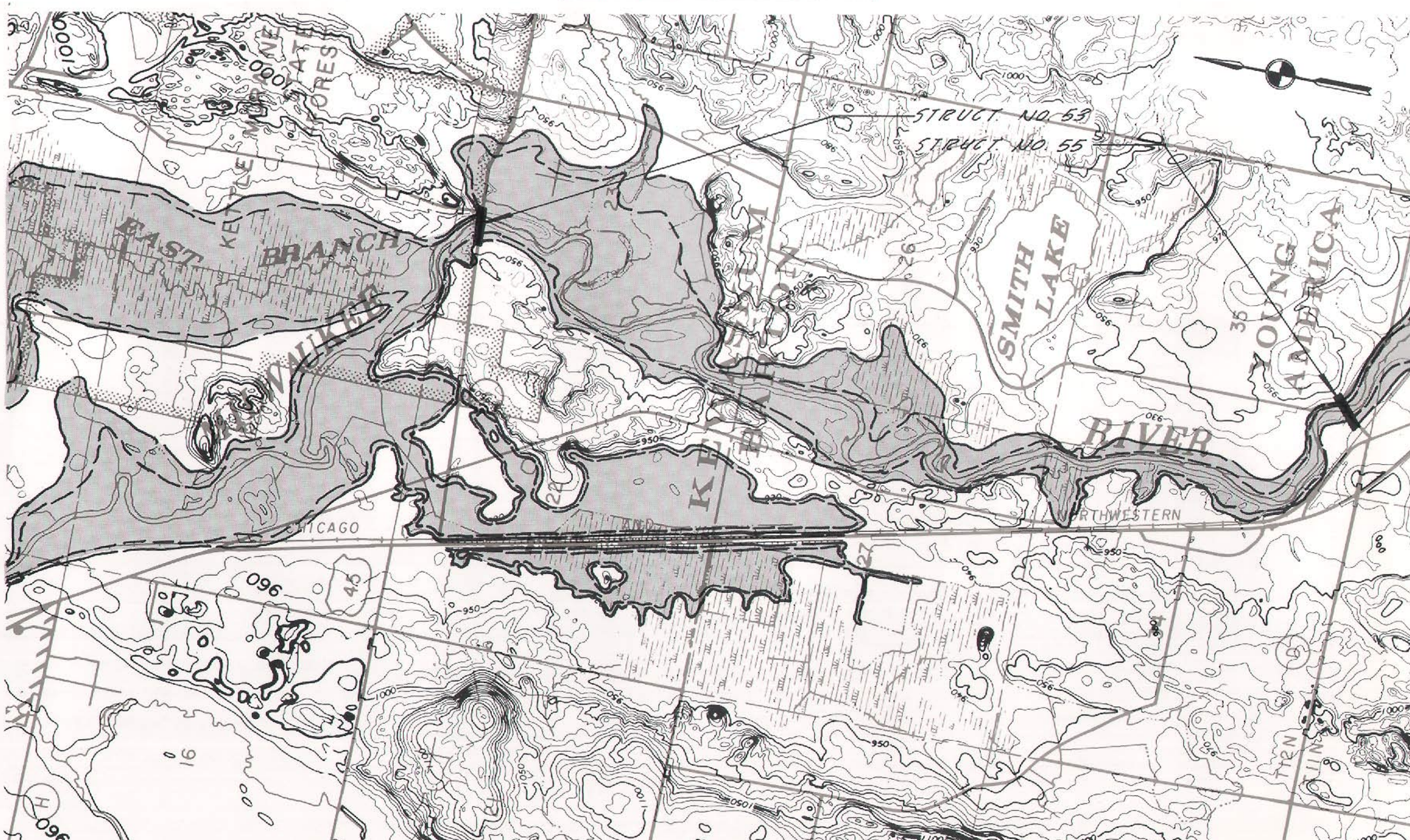
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

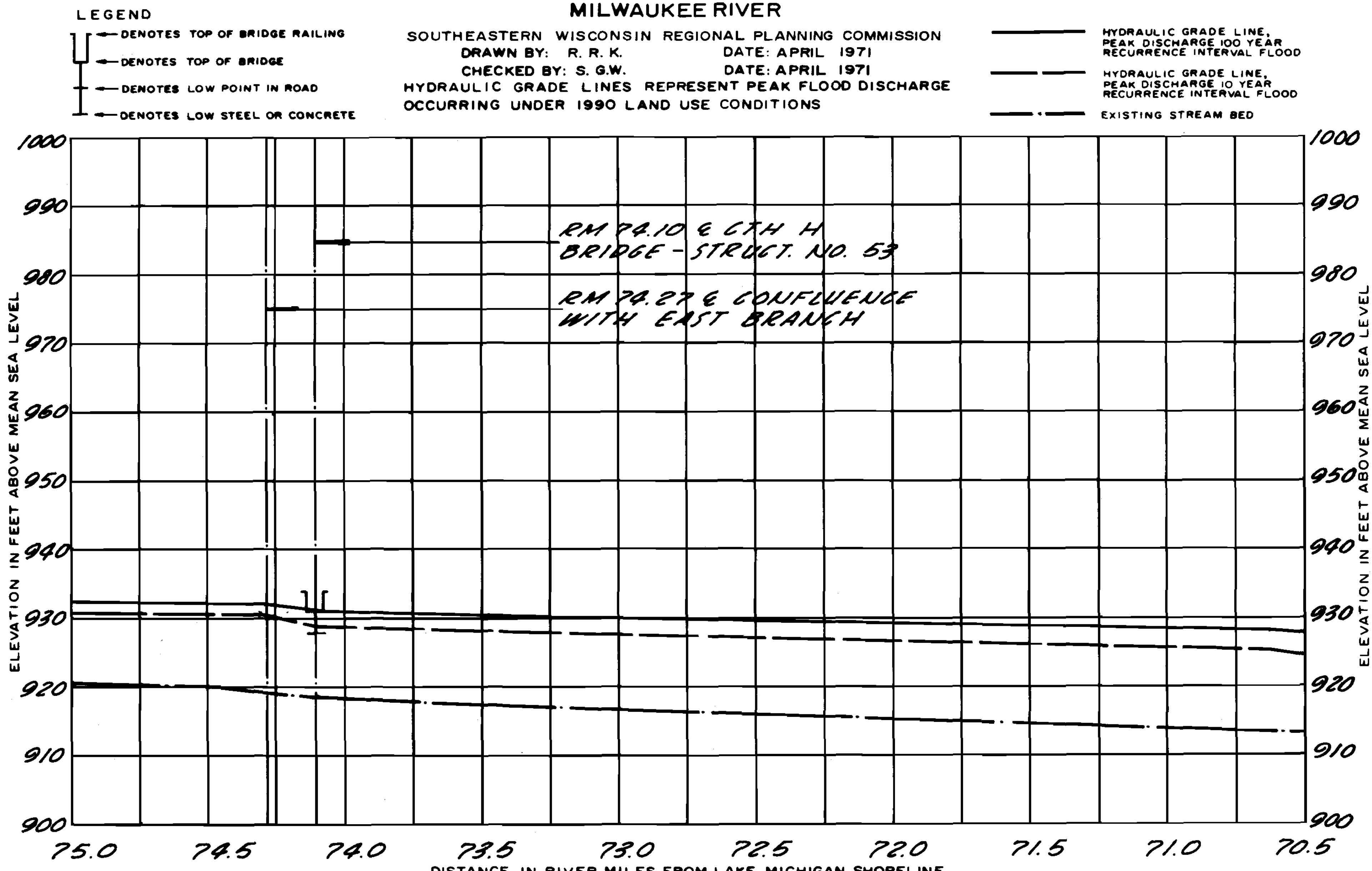
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 AND 20 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER



Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

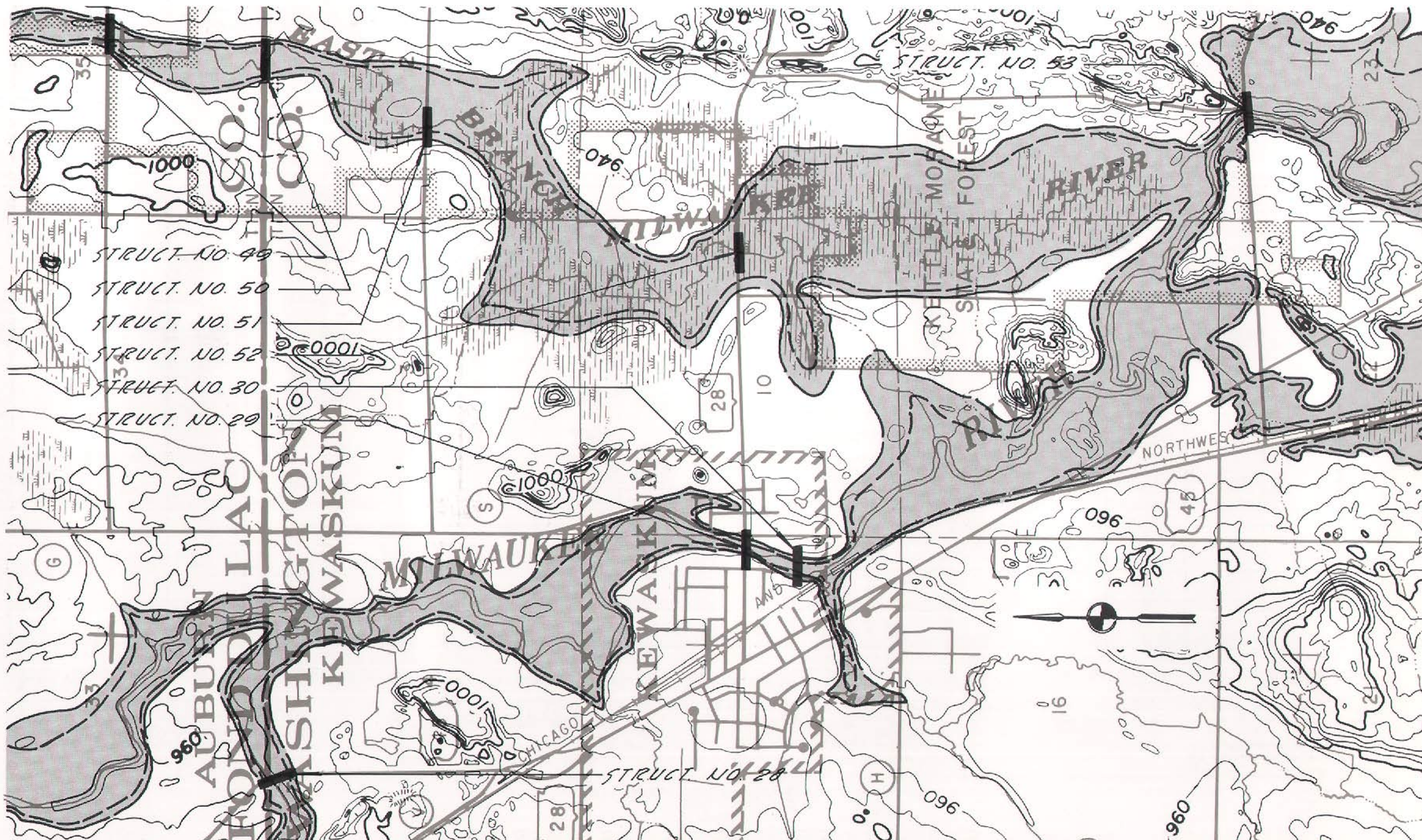
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

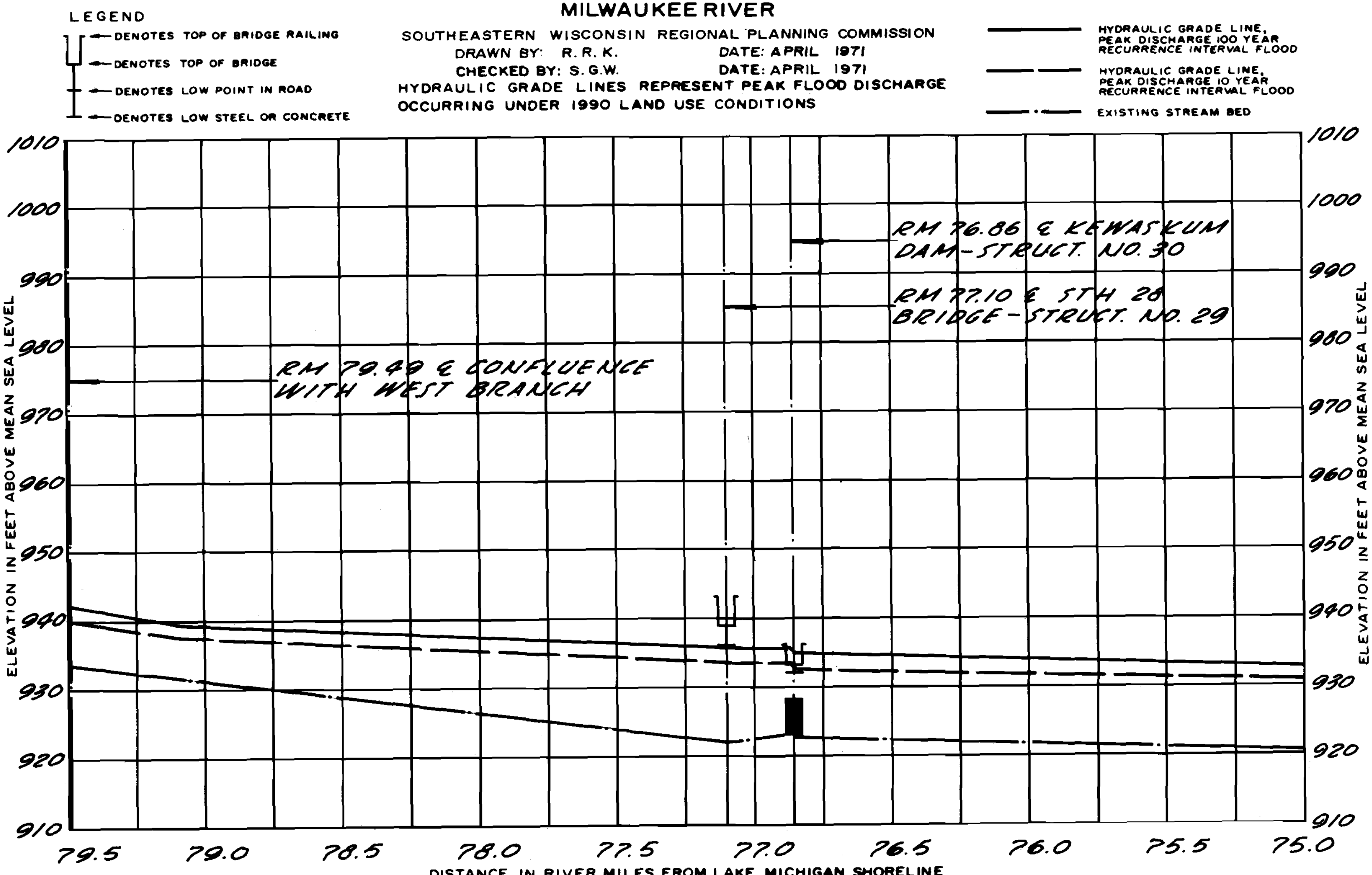
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 AND 20 FEET

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES FOR MILWAUKEE RIVER



Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

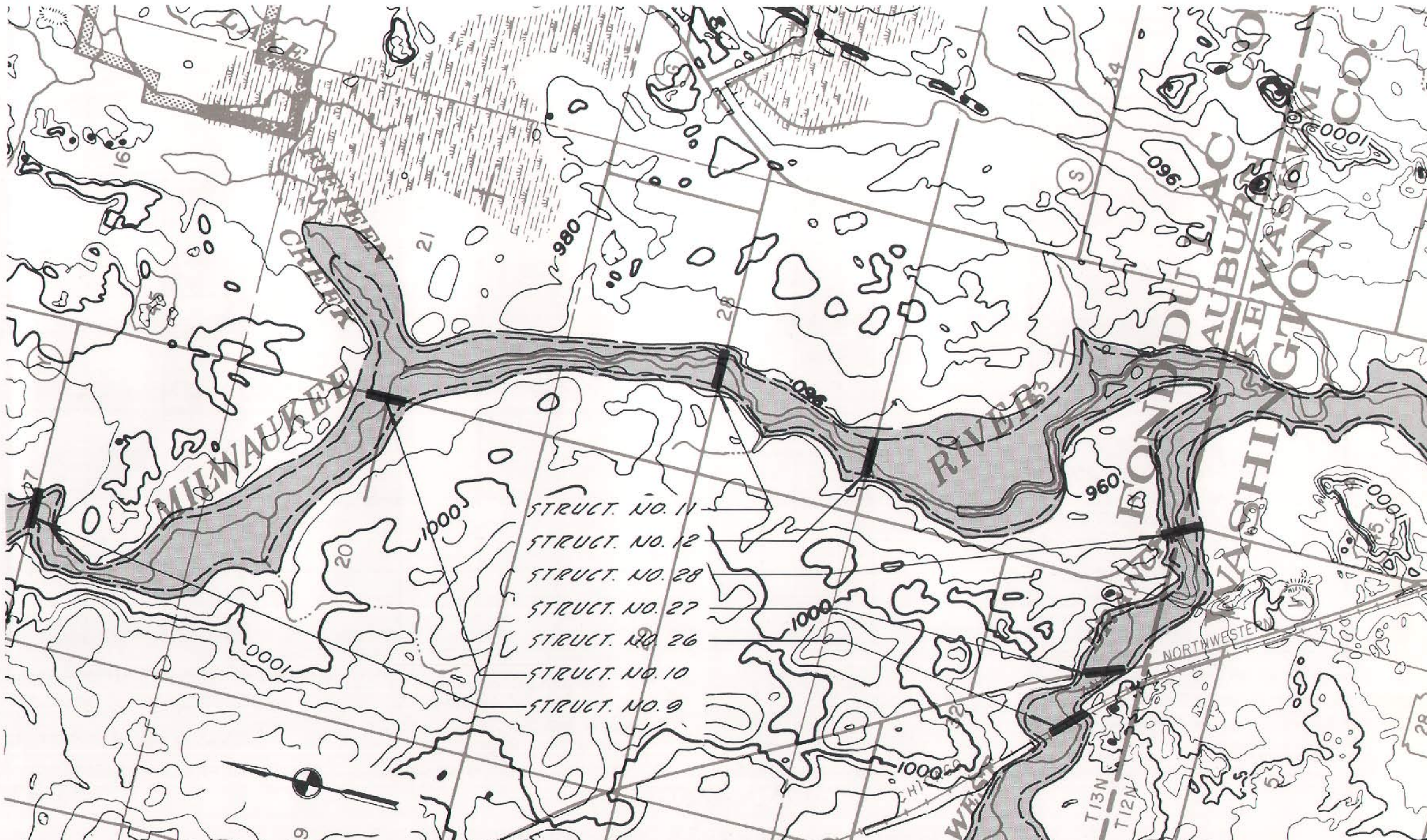
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

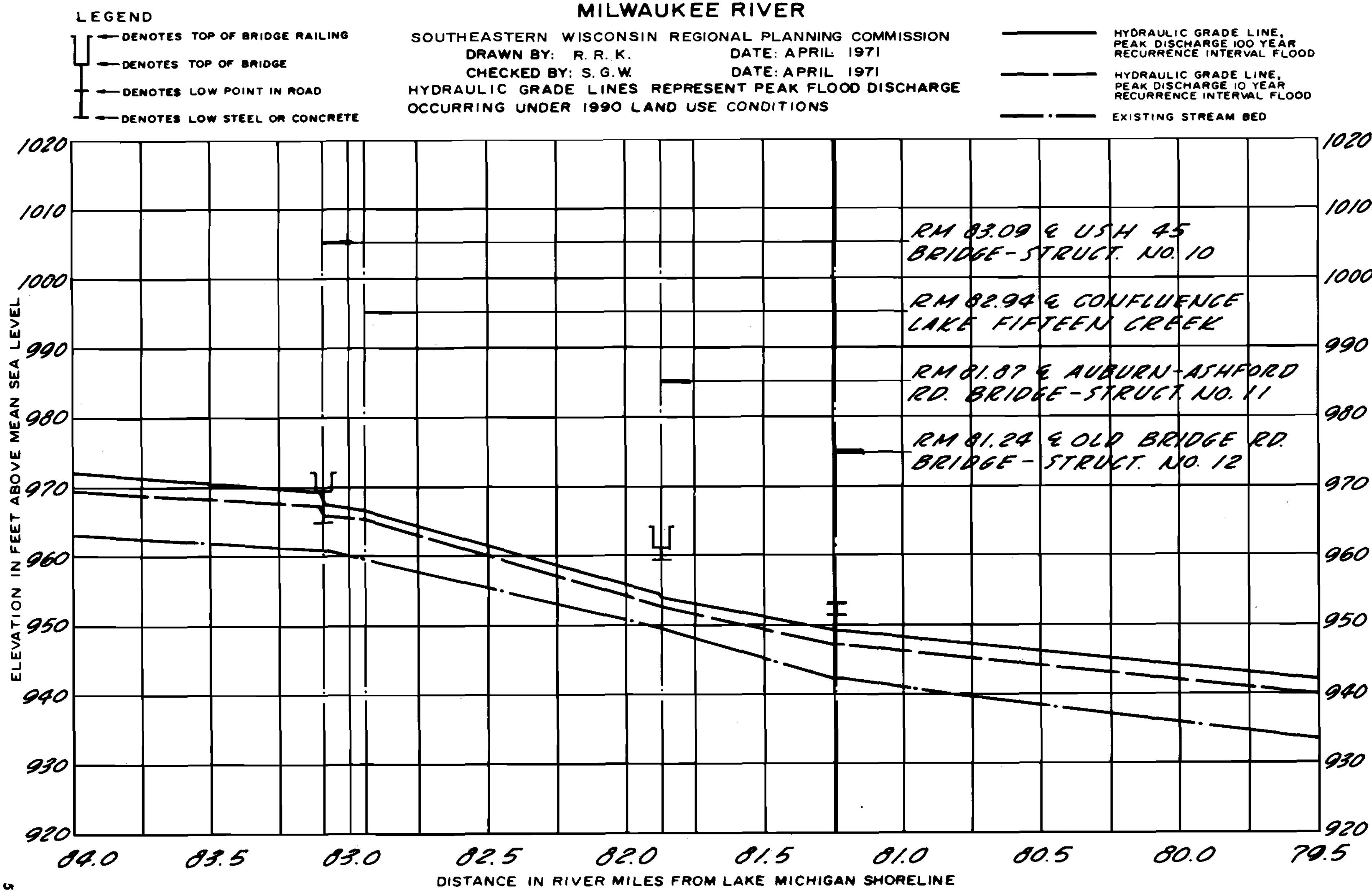
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F—I (continued)

HIGH WATER AND STREAM BED PROFILES FOR MILWAUKEE RIVER



Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

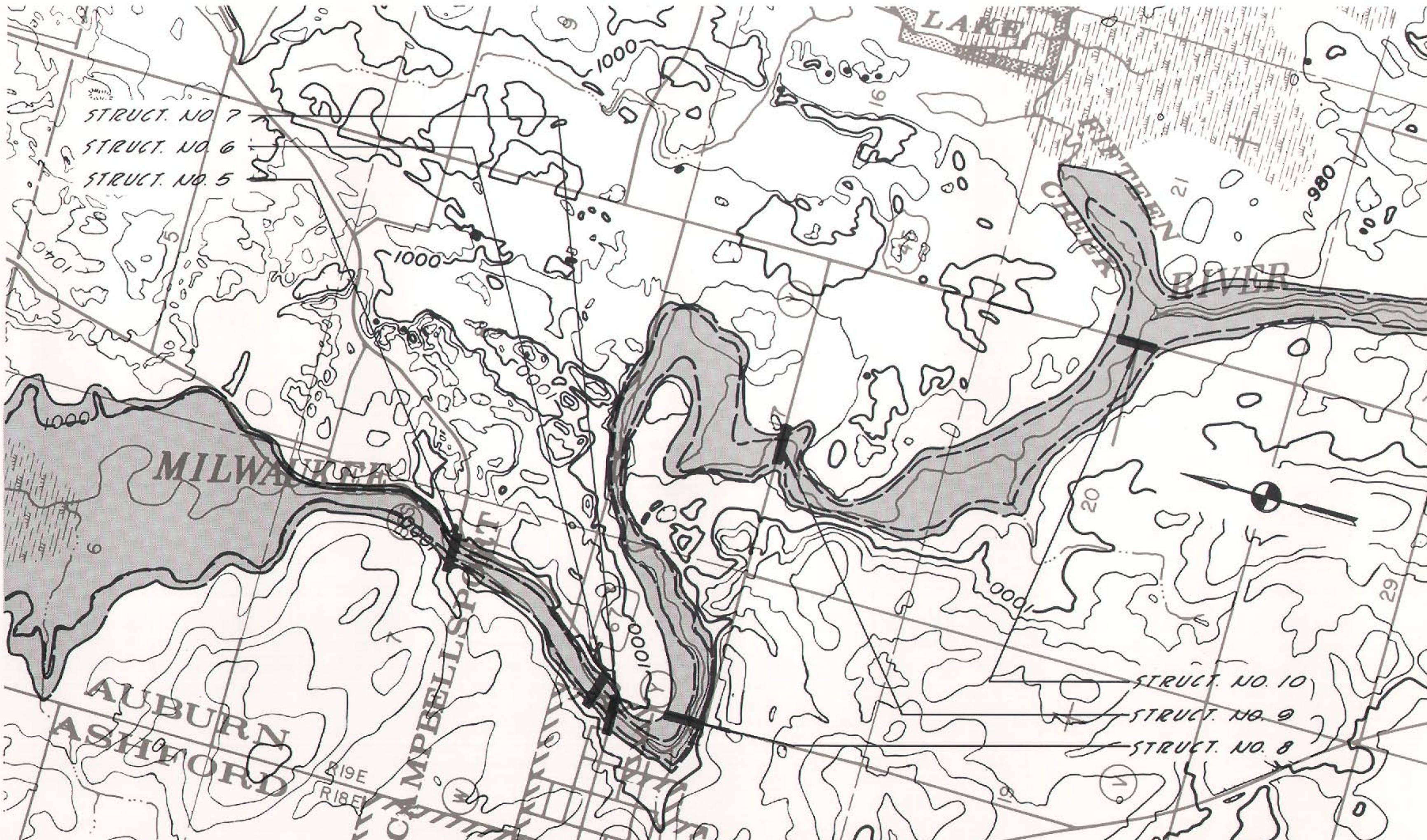
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

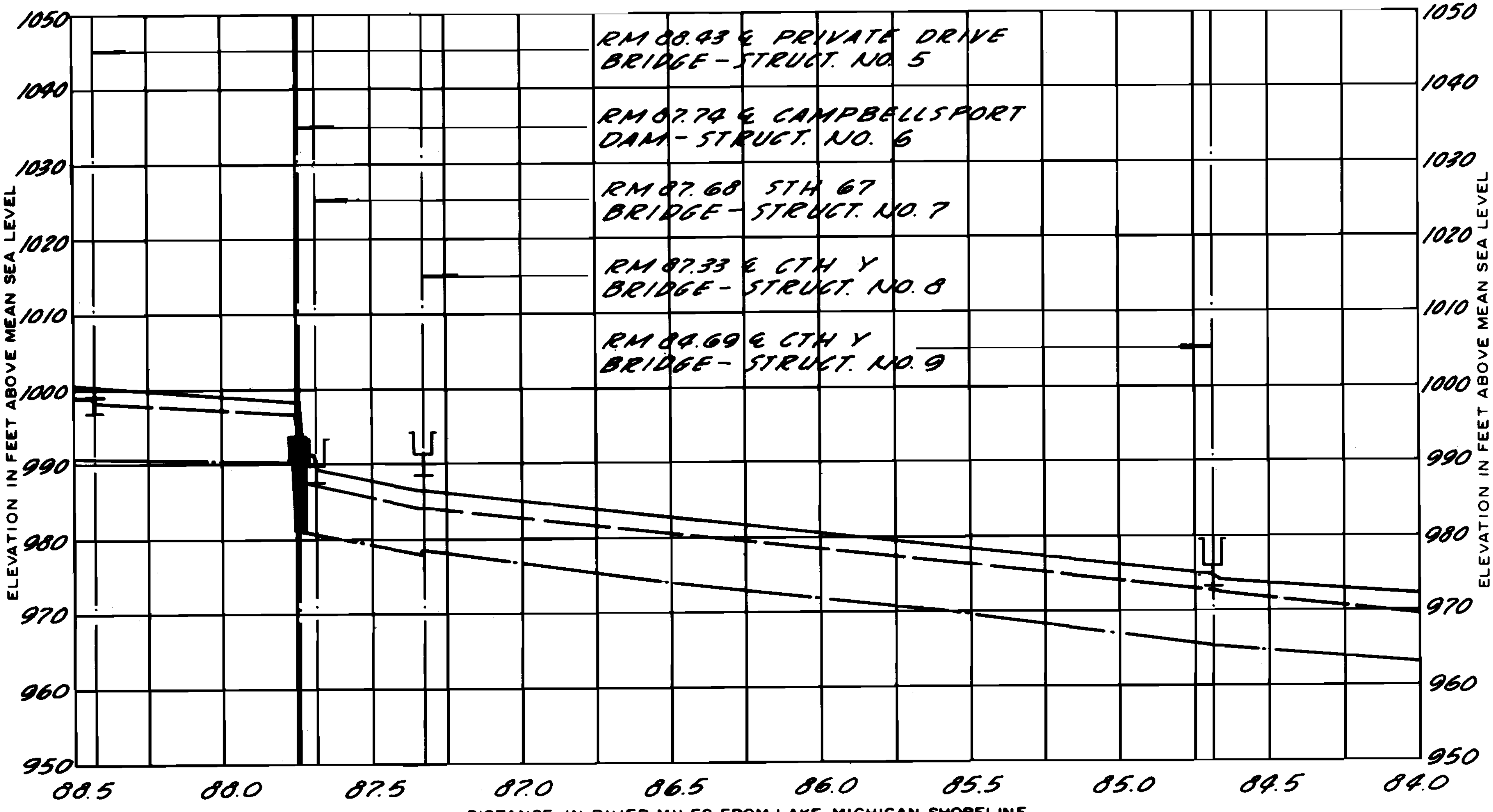
Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S.G.W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



NOTE: VILLAGE OF CAMPBELLSPORT DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 904.55'

Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

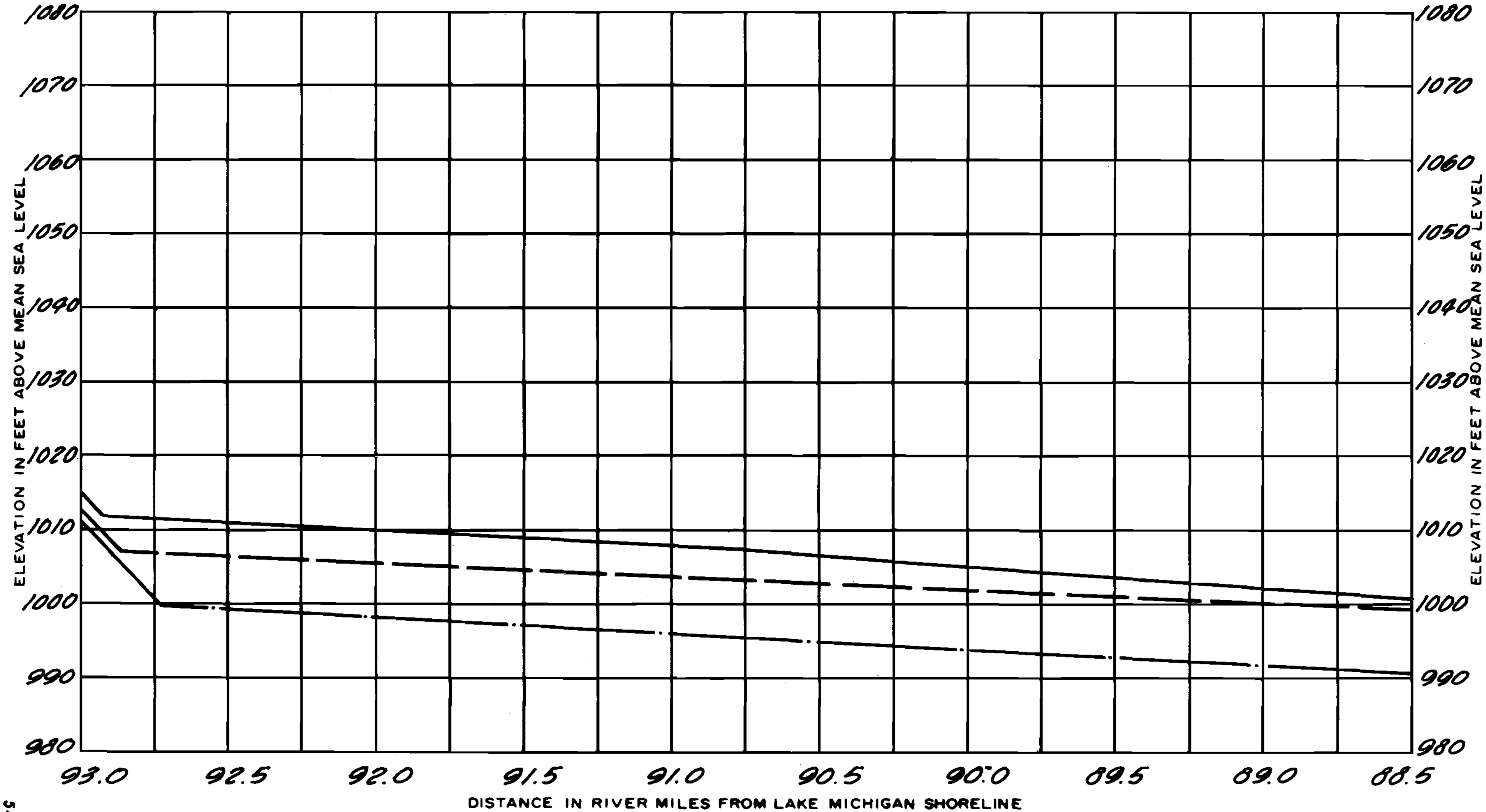
Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-1 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

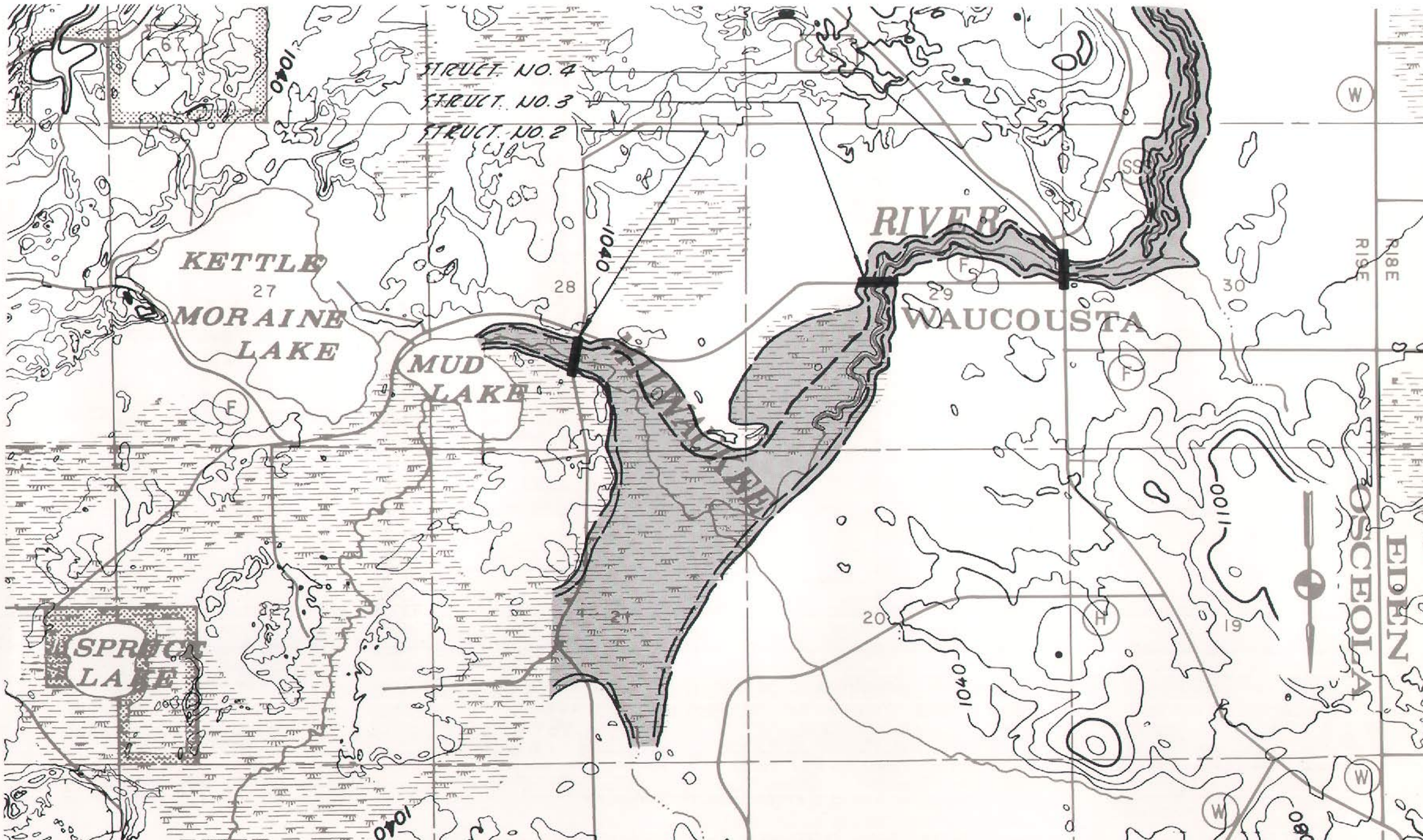
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

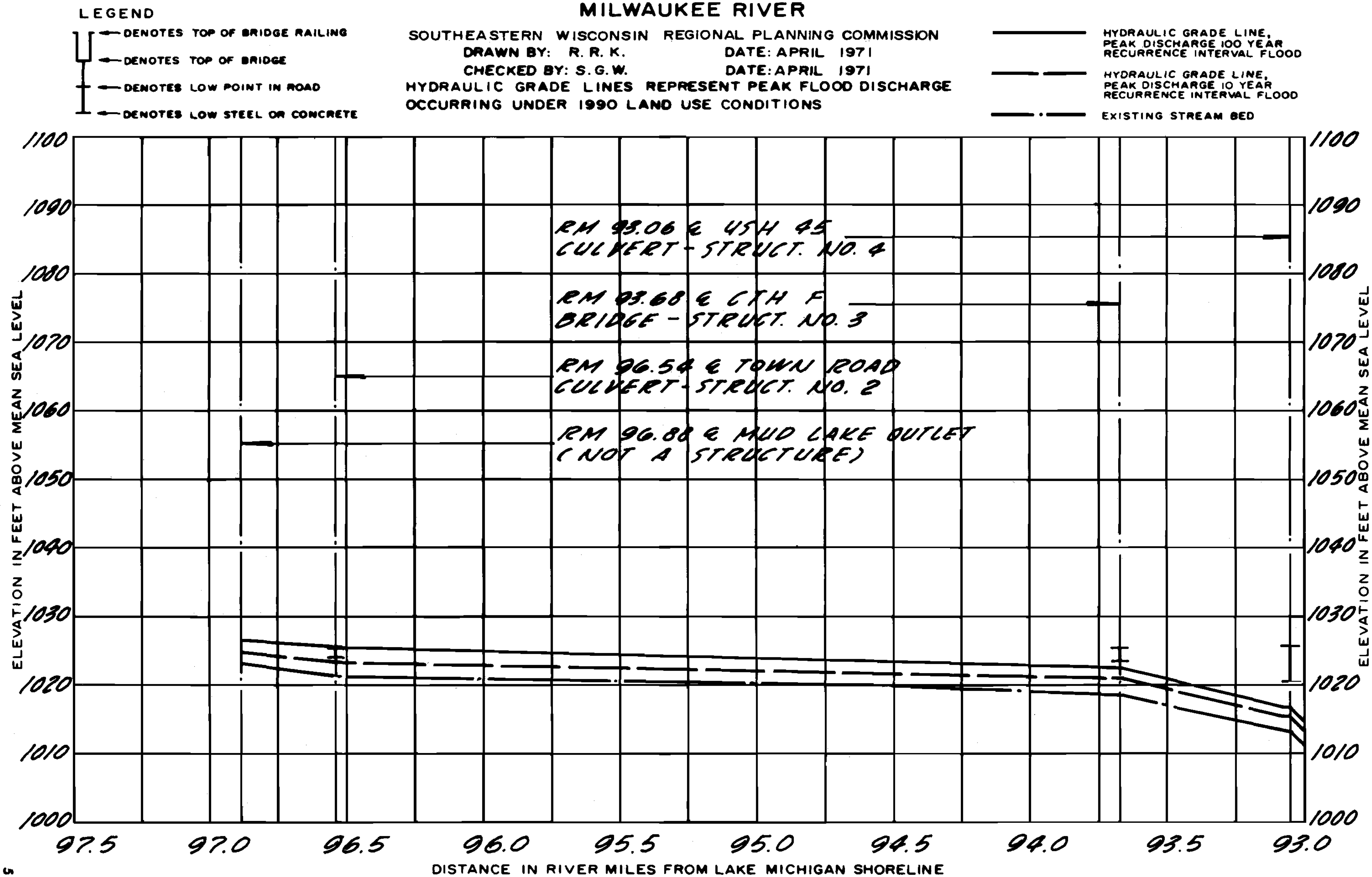
ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-1 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



Source: Harza Engineering Company and SEWRPC.

Map F-2
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
LINCOLN CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

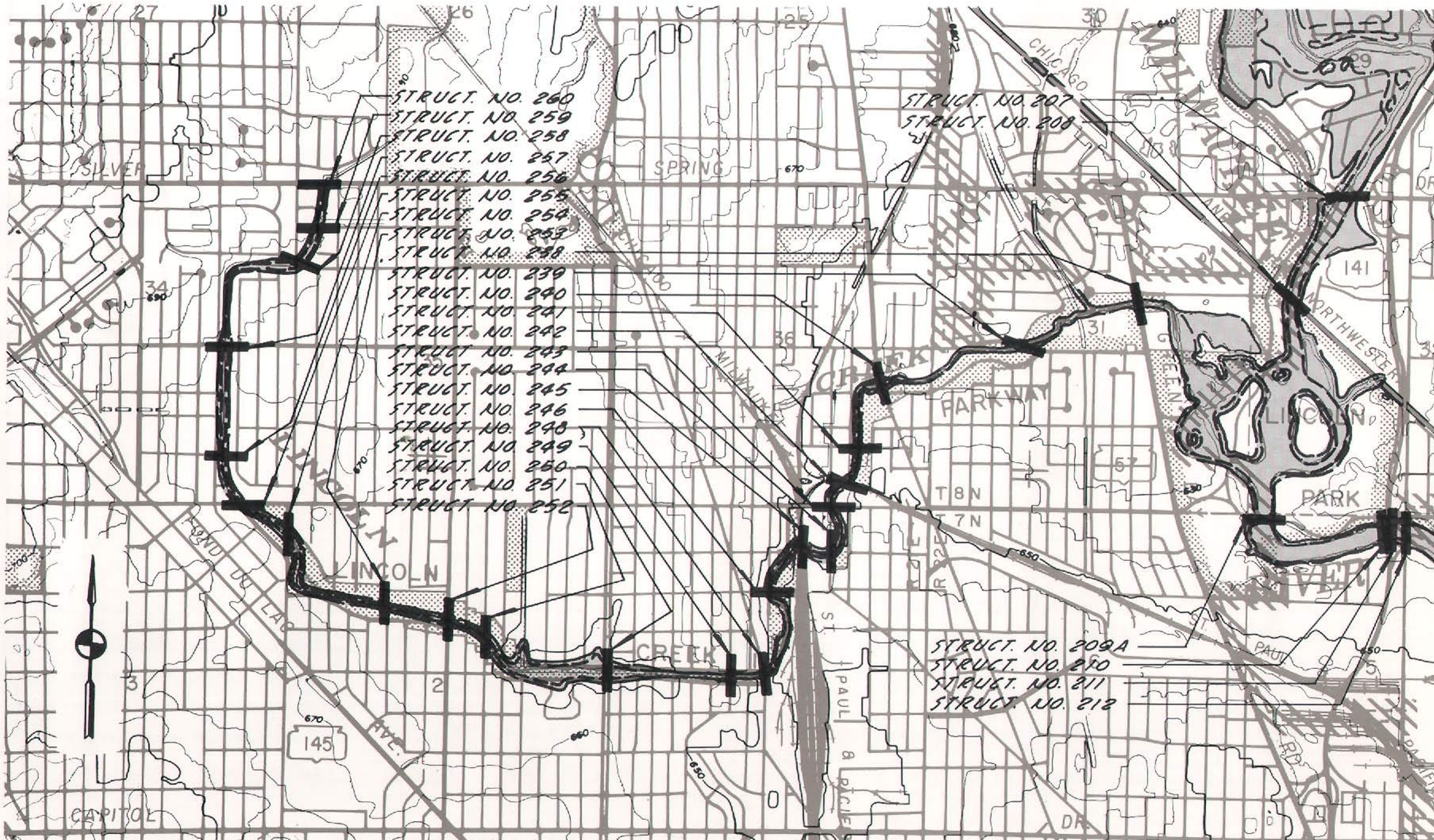
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-2

HIGH WATER AND STREAM BED PROFILES

FOR

LINCOLN CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

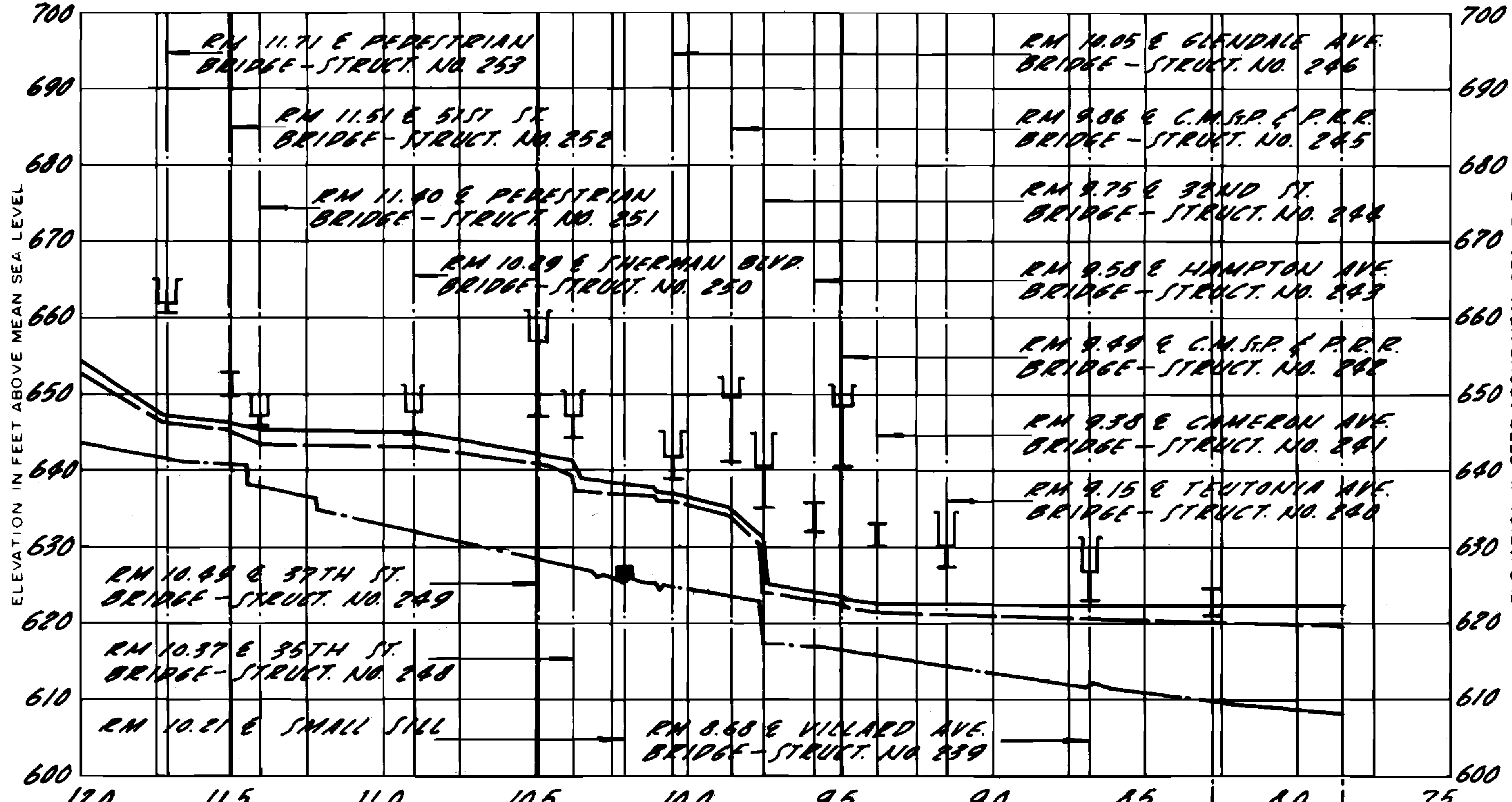
LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD

HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD

EXISTING STREAM BED



DISTANCE IN RIVER MILES FROM LAKE MICHIGAN SHORELINE

NOTE: CITY OF MILWAUKEE DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 580.60'

Source: Harza Engineering Company and SEWRPC.

RM 8.28 ℄ GREEN BAY AVE. BRIDGE-STRUCT. NO. 238

RM 7.86 ℄ CONFLUENCE WITH MILWAUKEE RIVER

Map F-2 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
LINCOLN CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

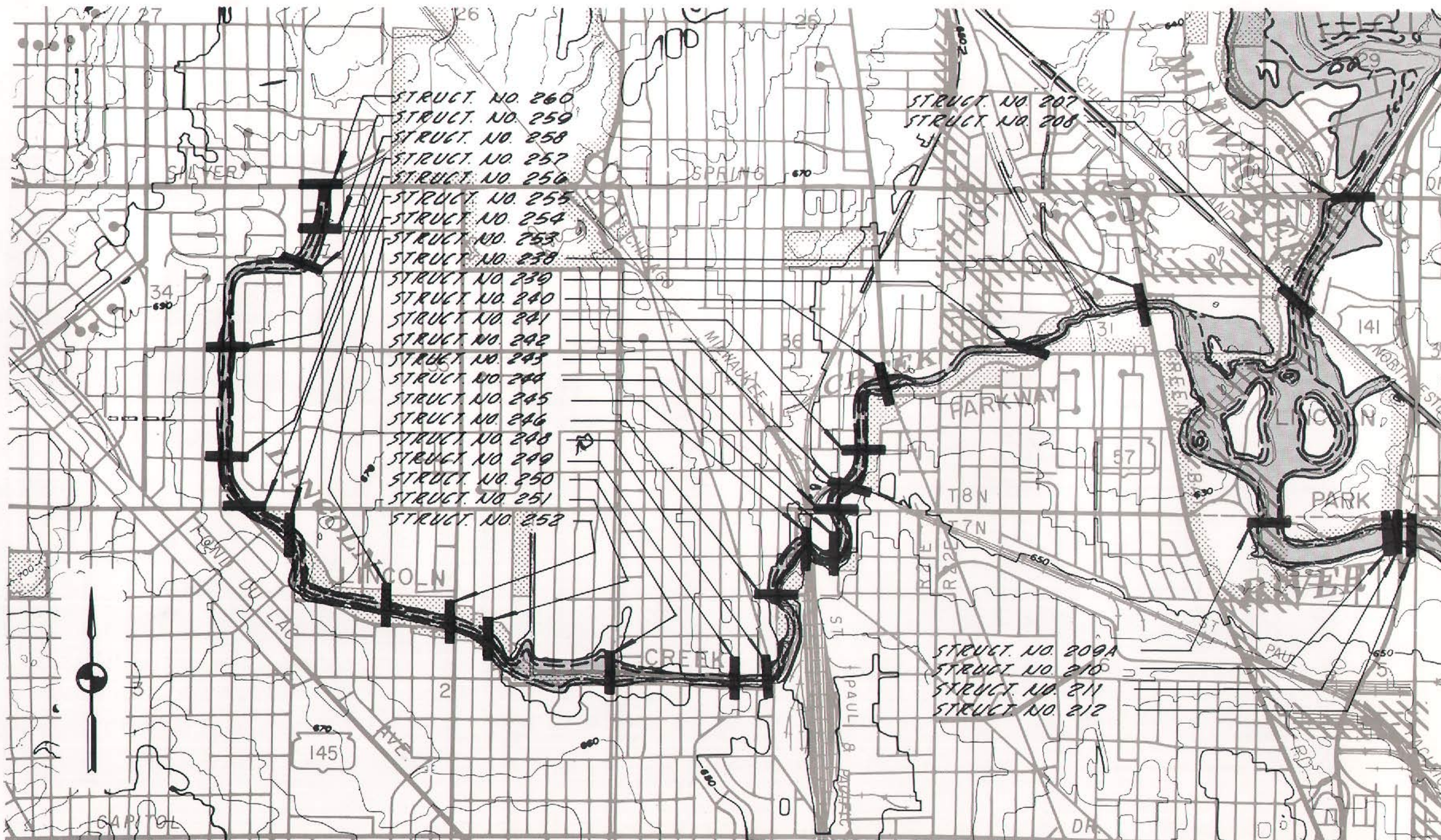
DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

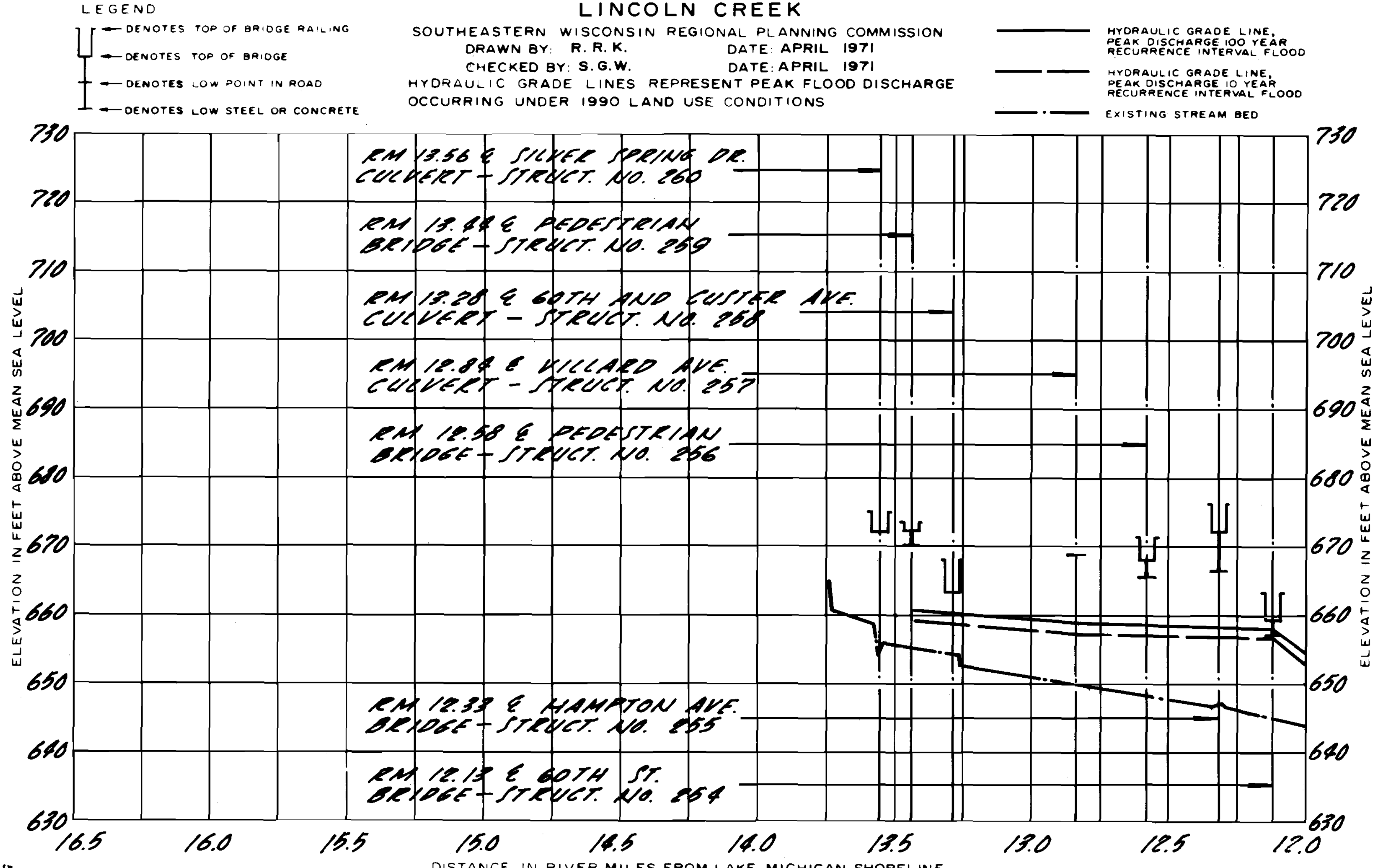
NOTE: CONTOUR INTERVAL 10 FEET

Figure F-2 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

LINCOLN CREEK



NOTE: CITY OF MILWAUKEE DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 580.60'

Source: Harza Engineering Company and SEWRPC

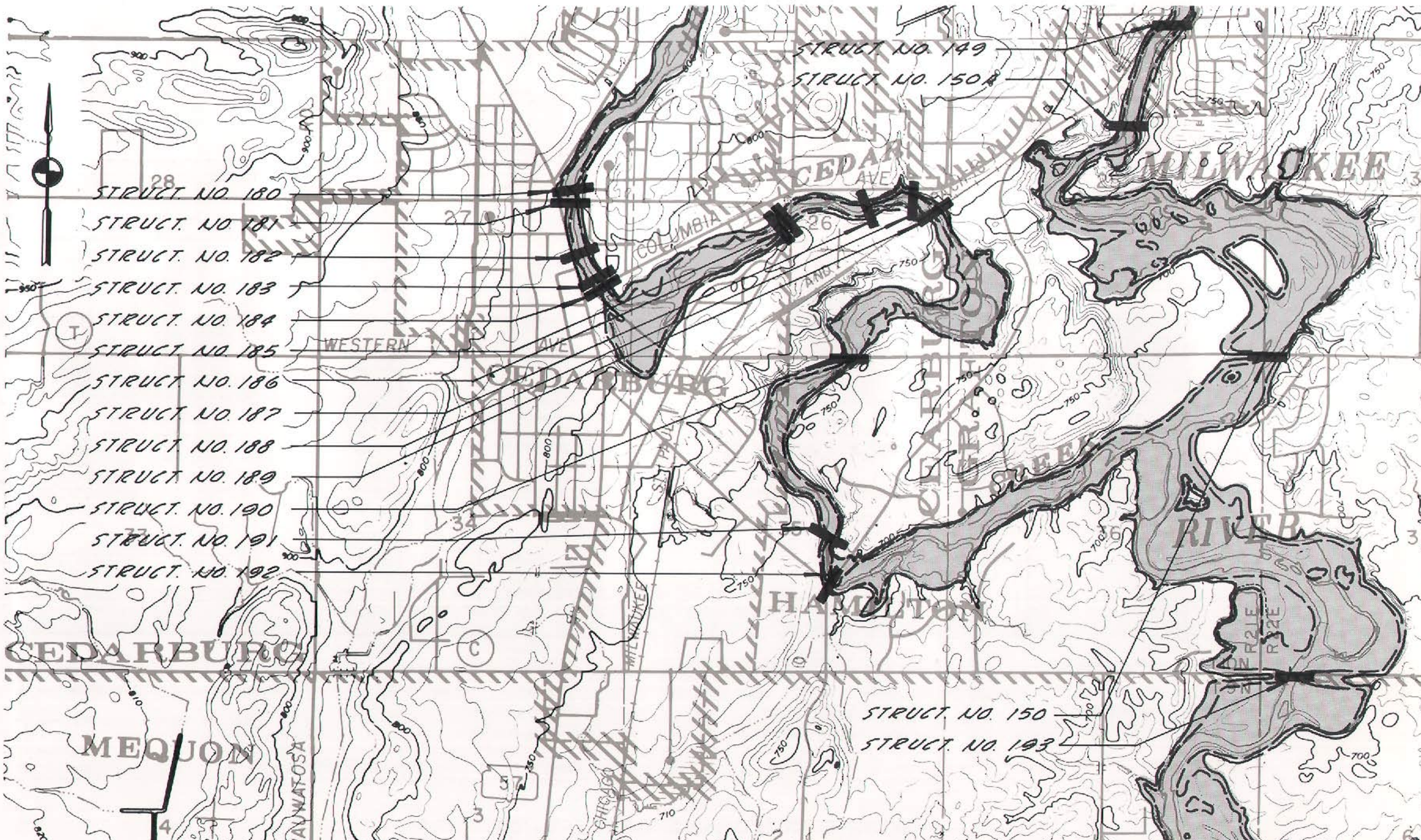
Map F-3

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R.R.K. DATE: APRIL 1971
CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE
0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

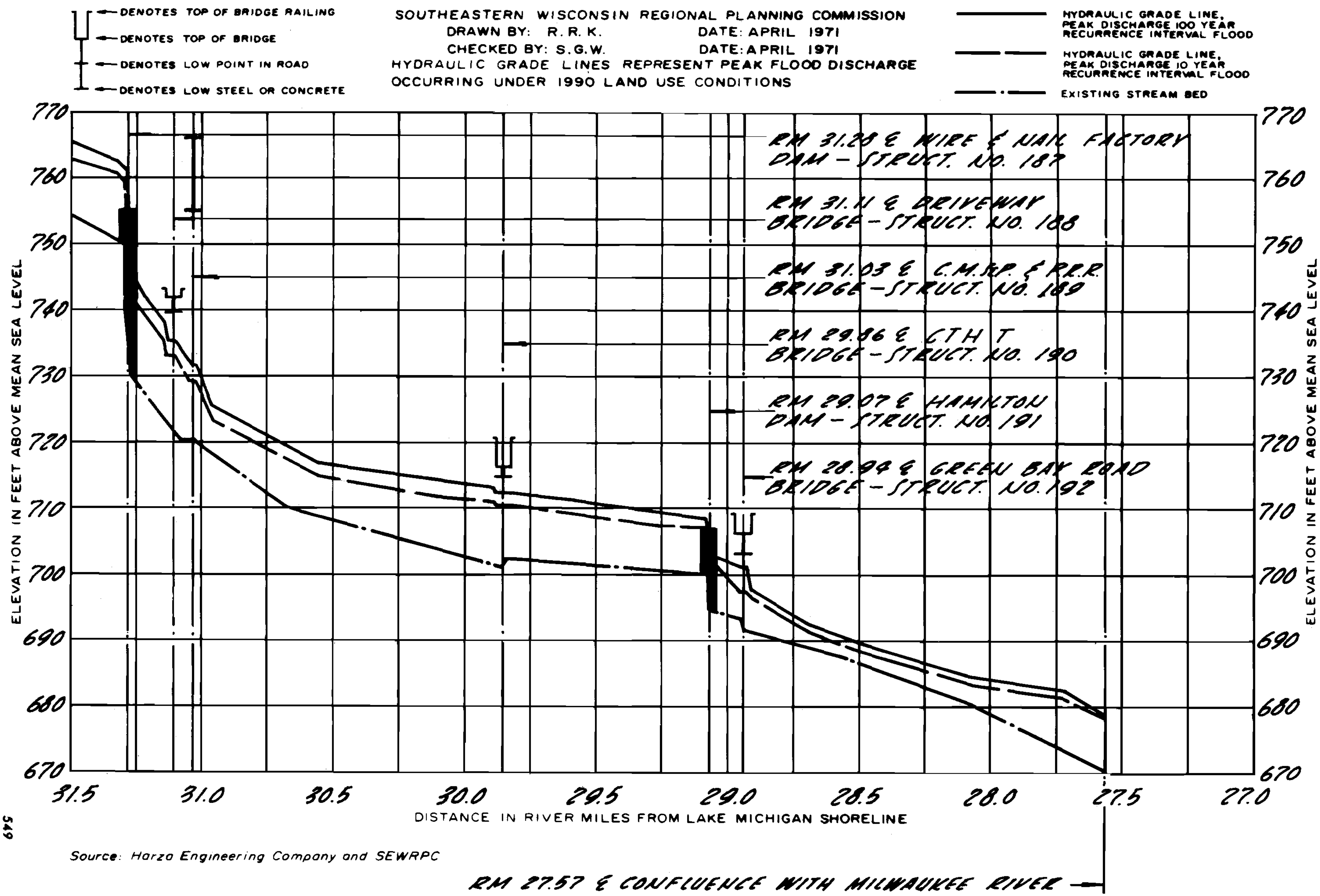
NOTE: CONTOUR INTERVAL 10 FEET

Figure F-3

HIGH WATER AND STREAM BED PROFILES

FOR

CEDAR CREEK



Source: Harza Engineering Company and SEWRPC

Map F-3 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

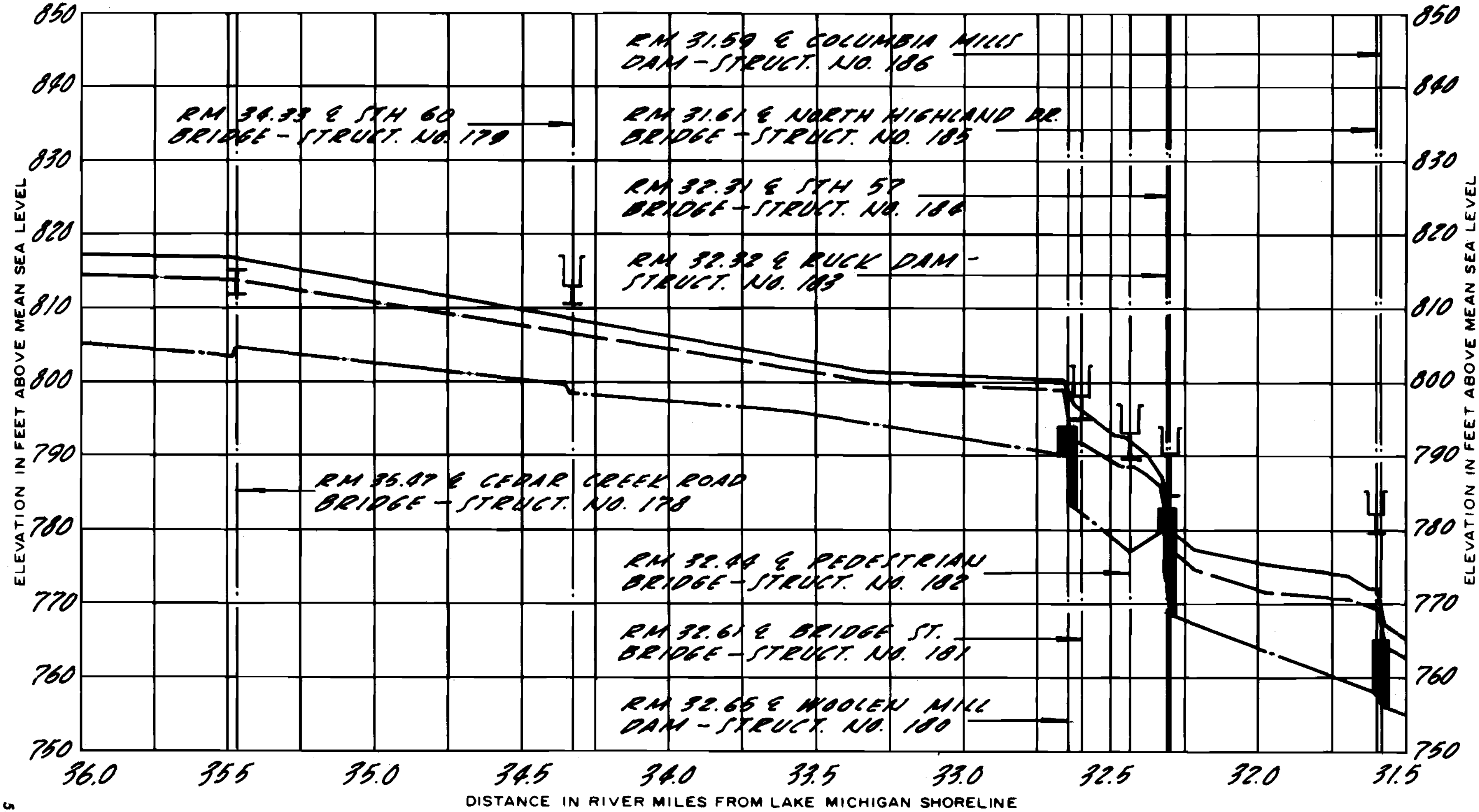
Figure F-3 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S.G.W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE
OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-3 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

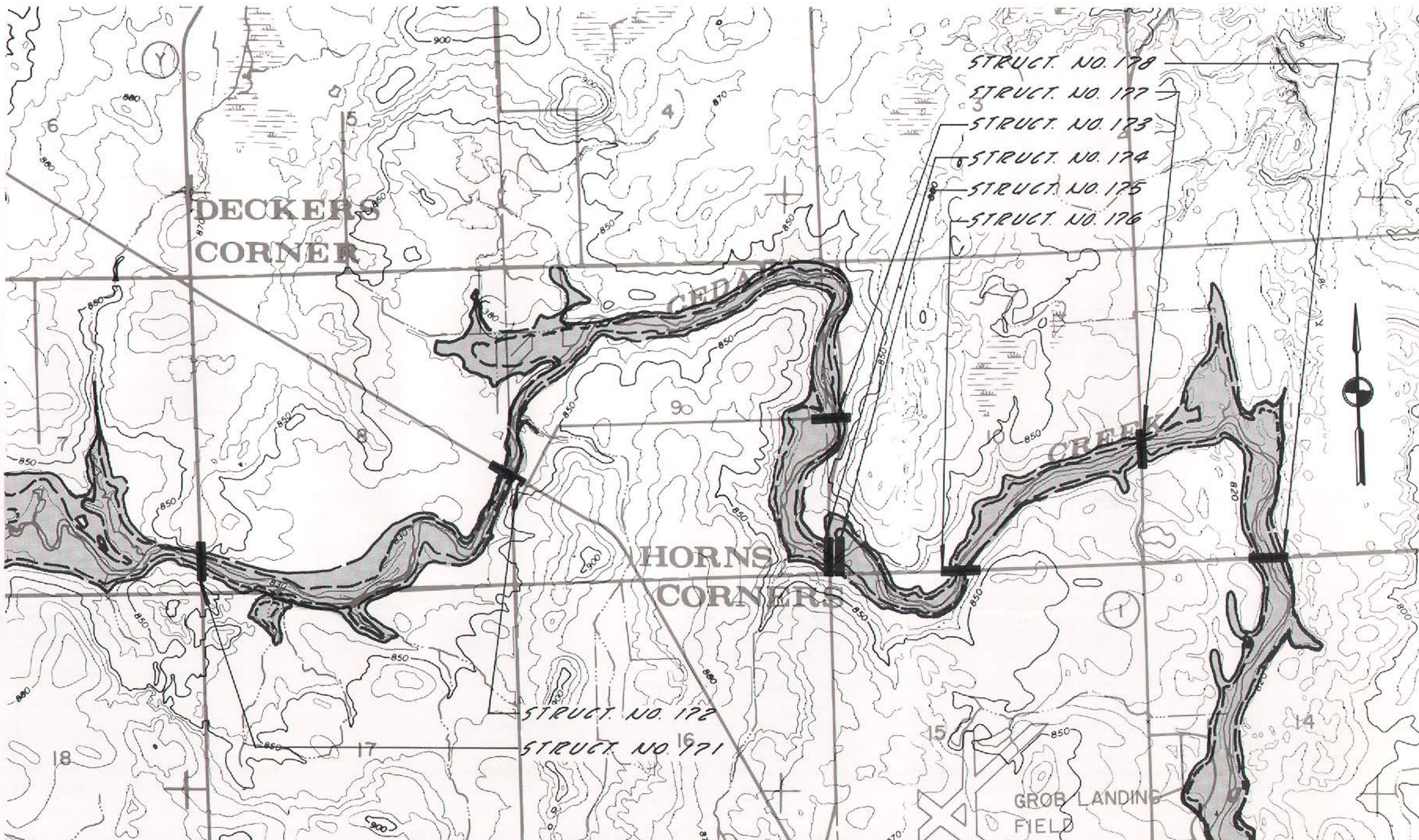
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

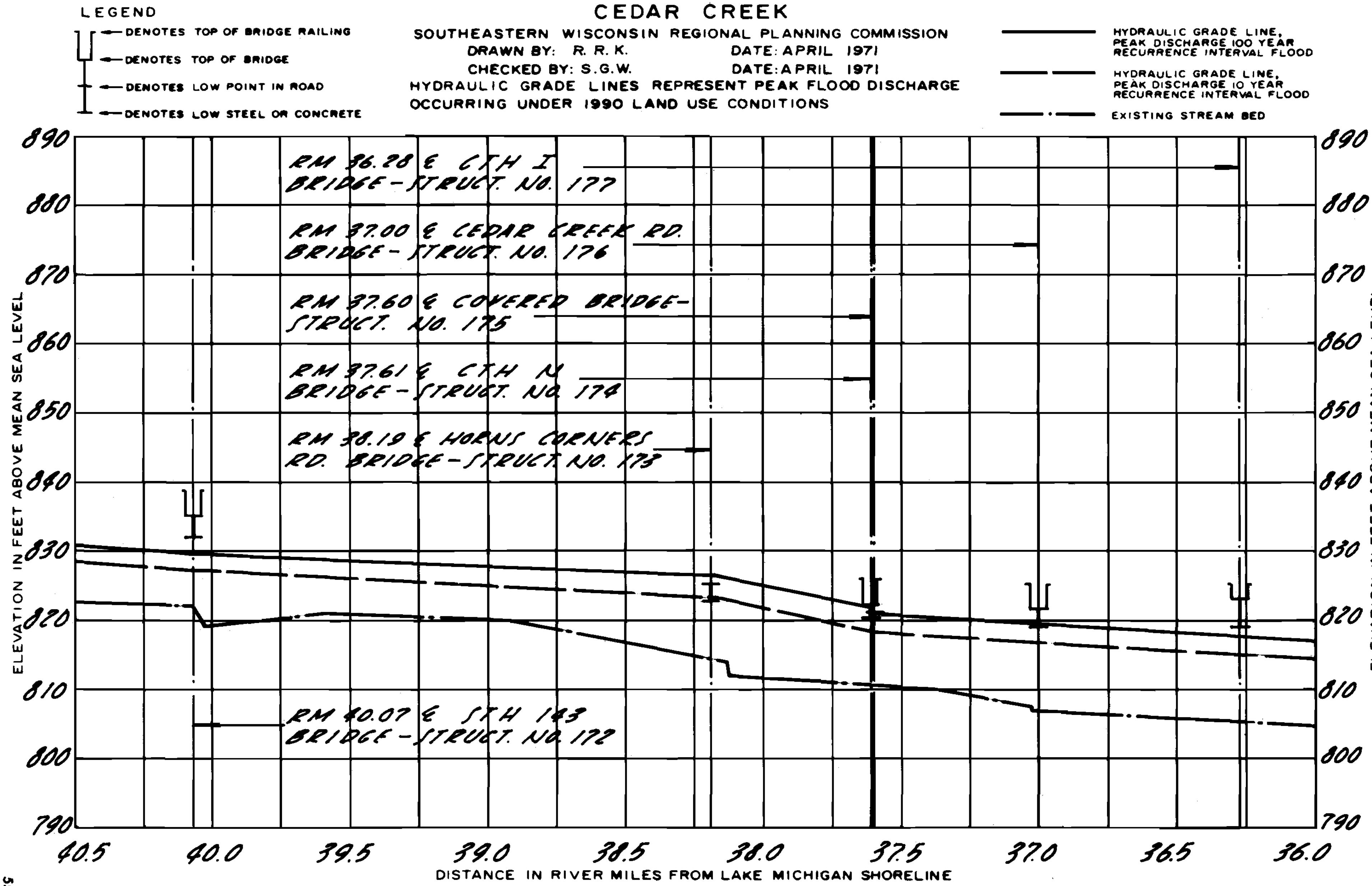
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-3 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
CEDAR CREEK



Source: Harza Engineering Company and SEWRPC.

Map F-3 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

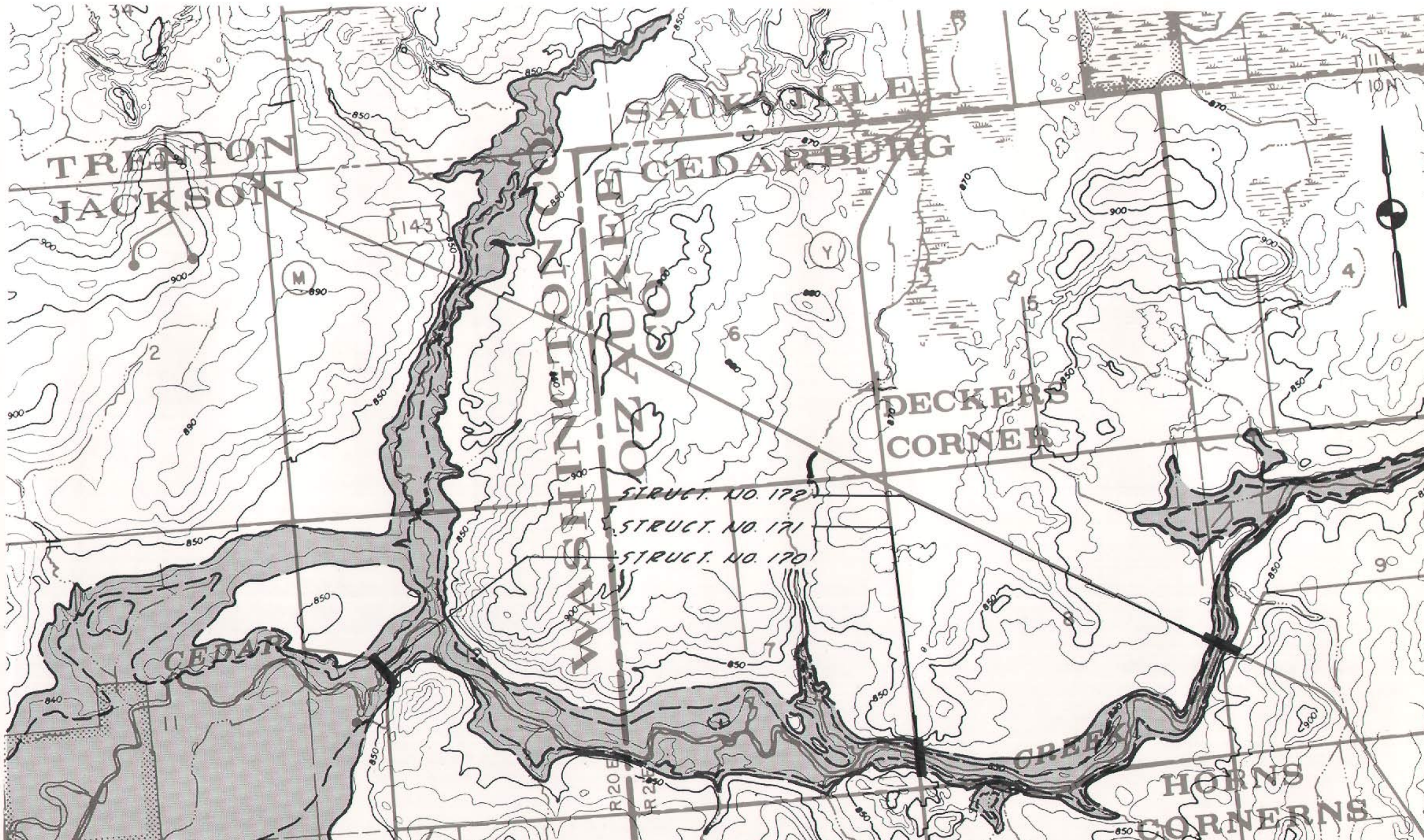
DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

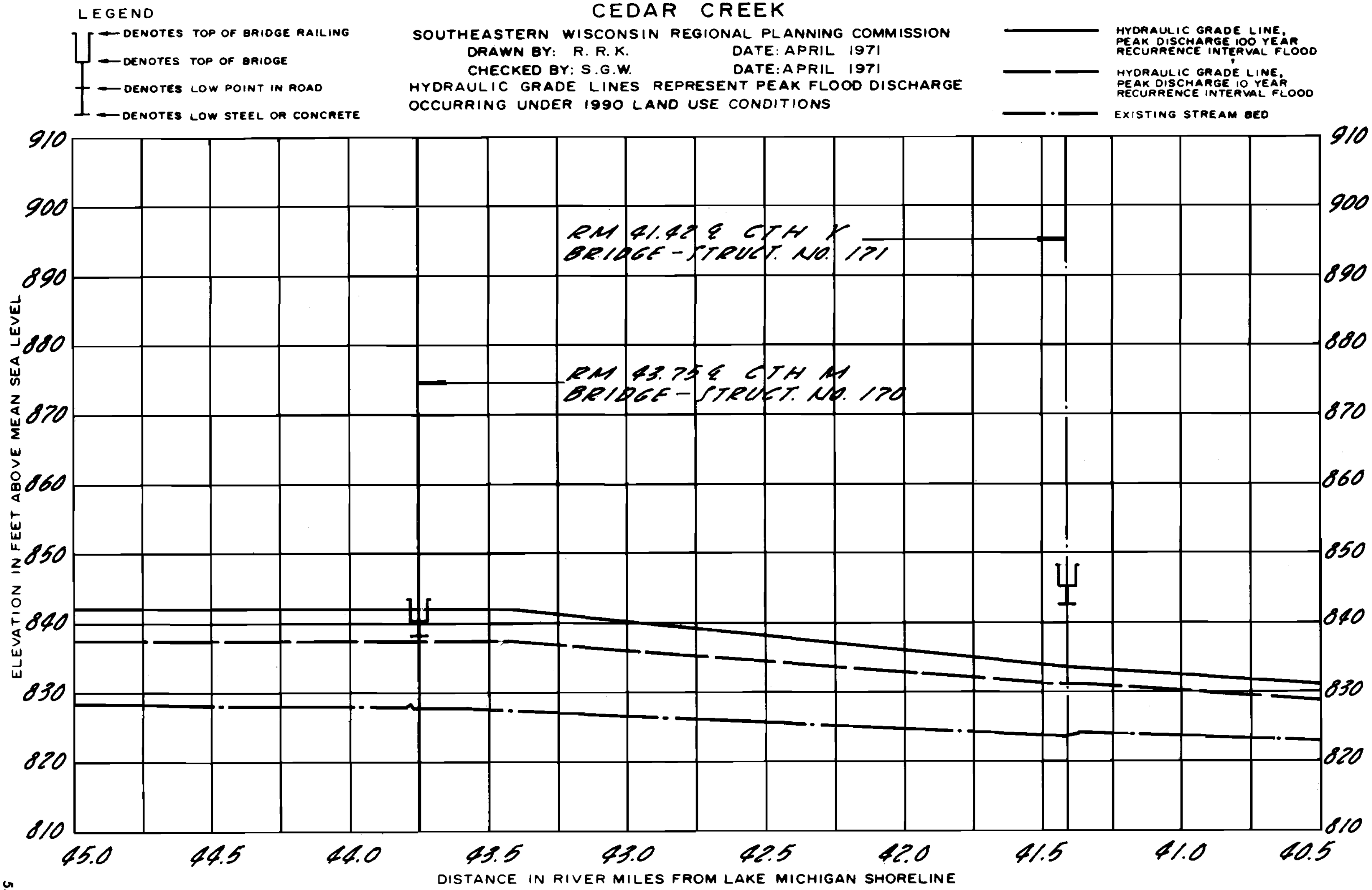
NOTE: CONTOUR INTERVAL 10 FEET

Figure F-3 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

CEDAR CREEK



Source: Harza Engineering Company and SEWRPC.

Map F-3 (continued)
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

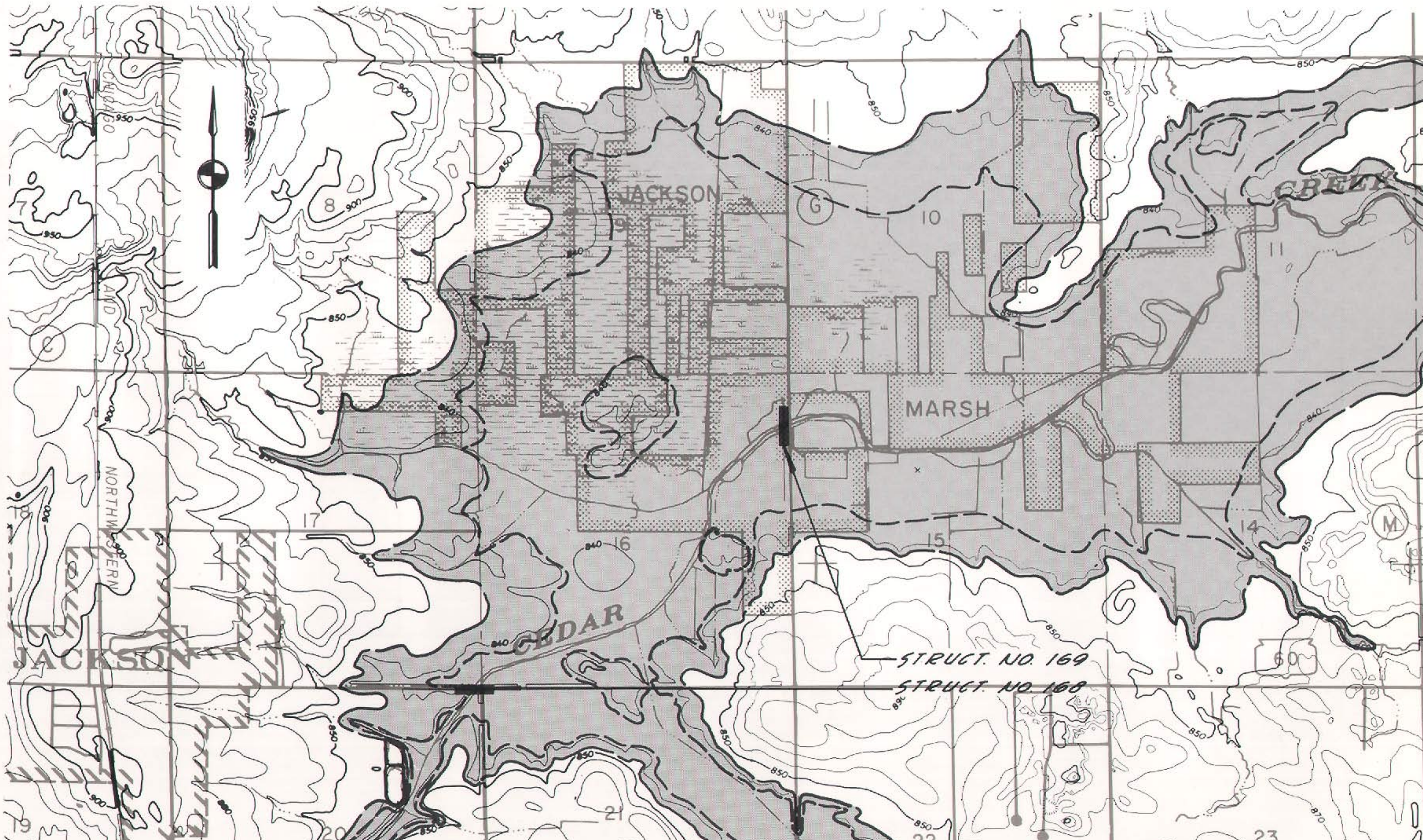
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-3 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

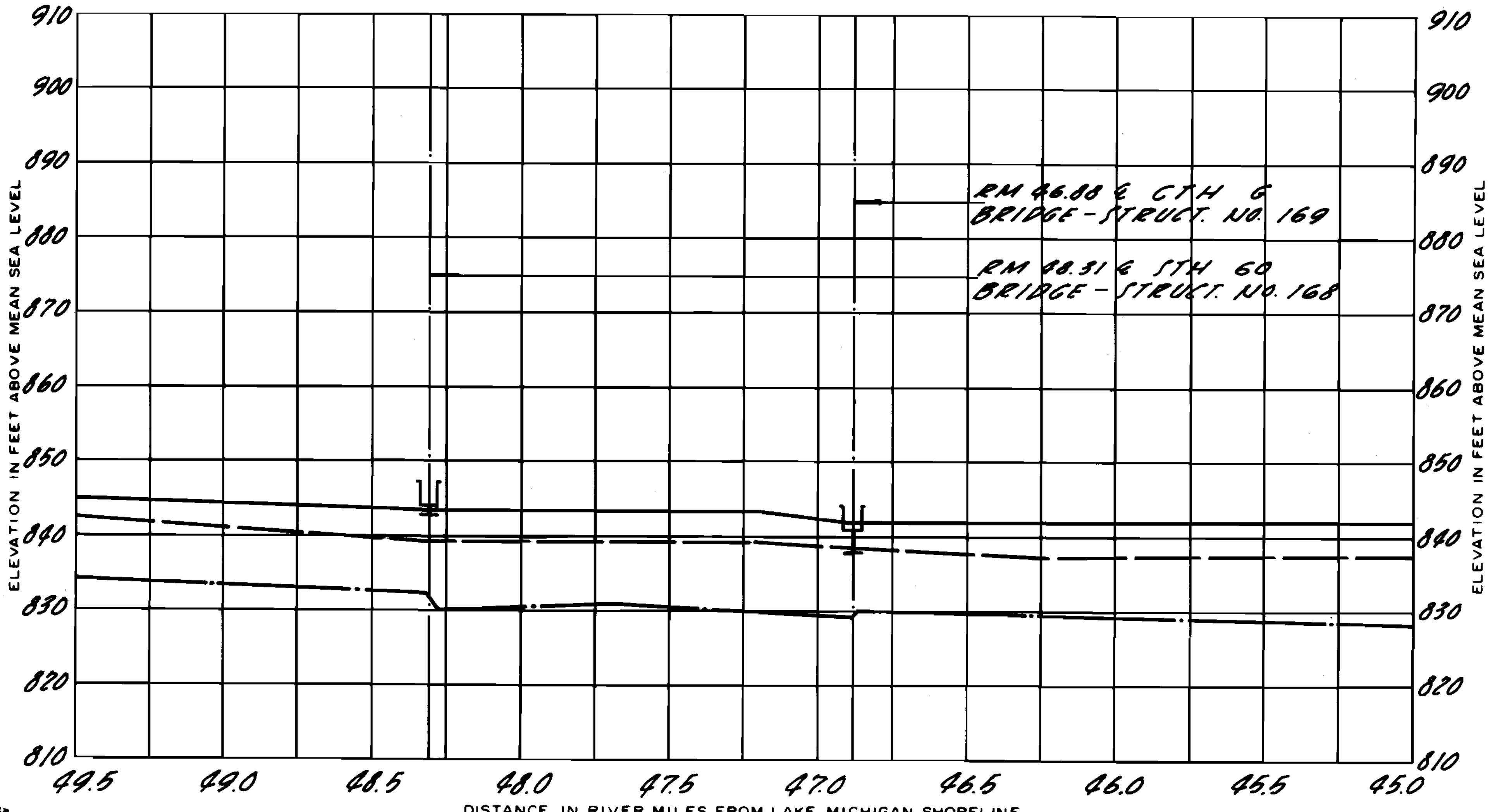
CHECKED BY: S. G. W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-3 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

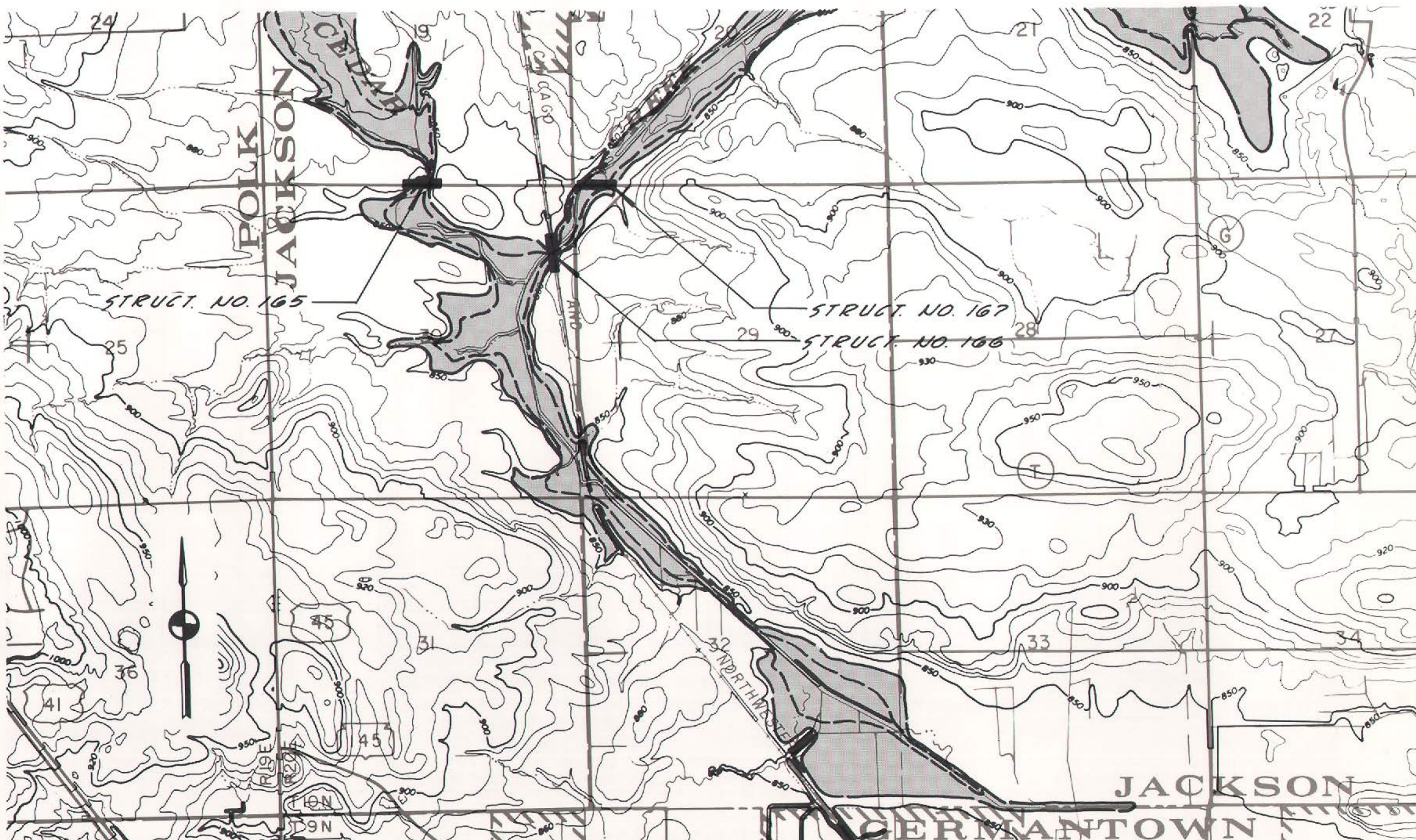
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

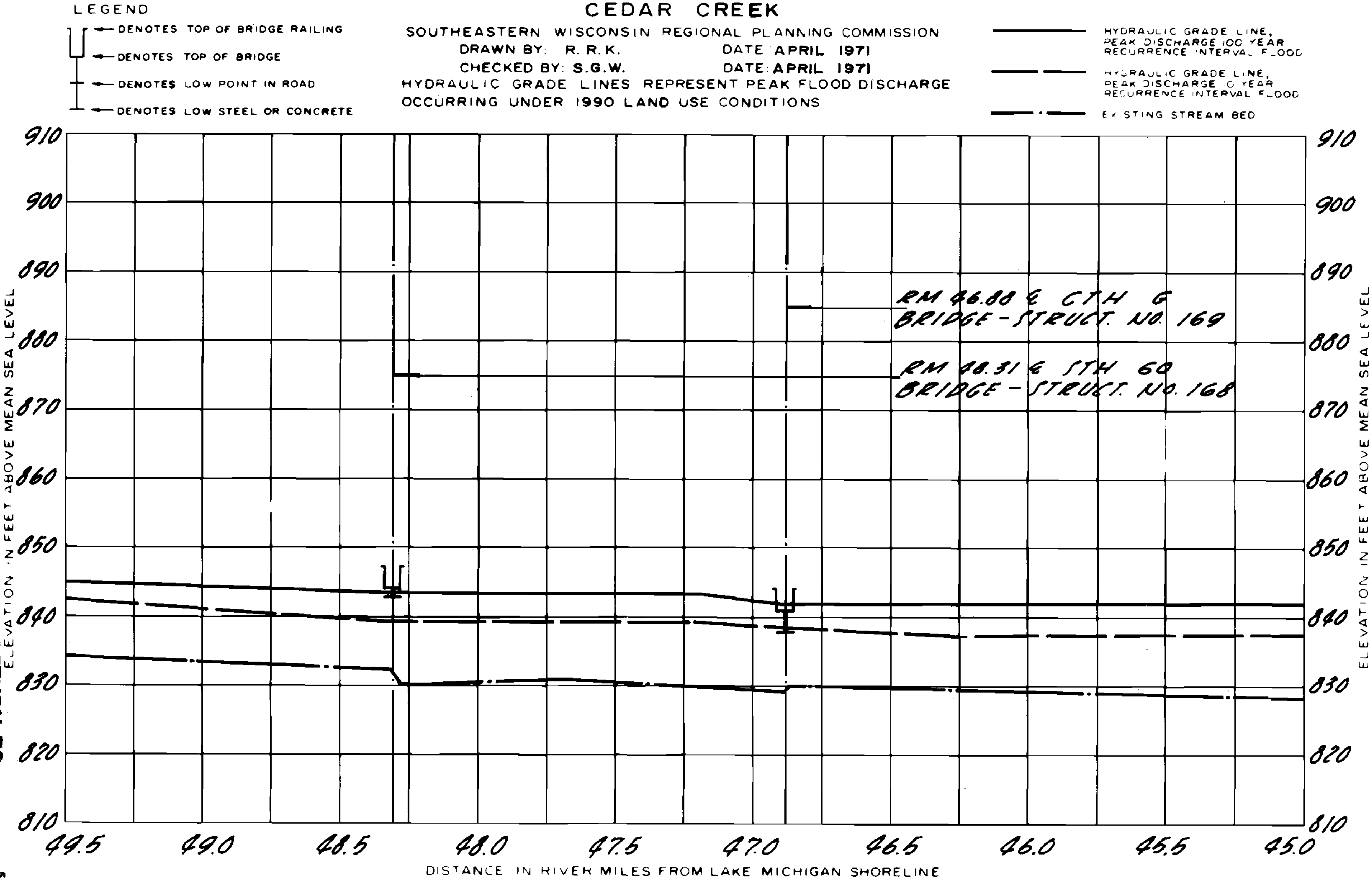
NOTE: CONTOUR INTERVAL 10 FEET

Figure F-3 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

CEDAR CREEK



Source: Harza Engineering Company and SEWRPC

Map F-3 (continued)

TOPOGRAPHIC MAP

SHOWING

AREAS SUBJECT TO FLOODING

ALONG

CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

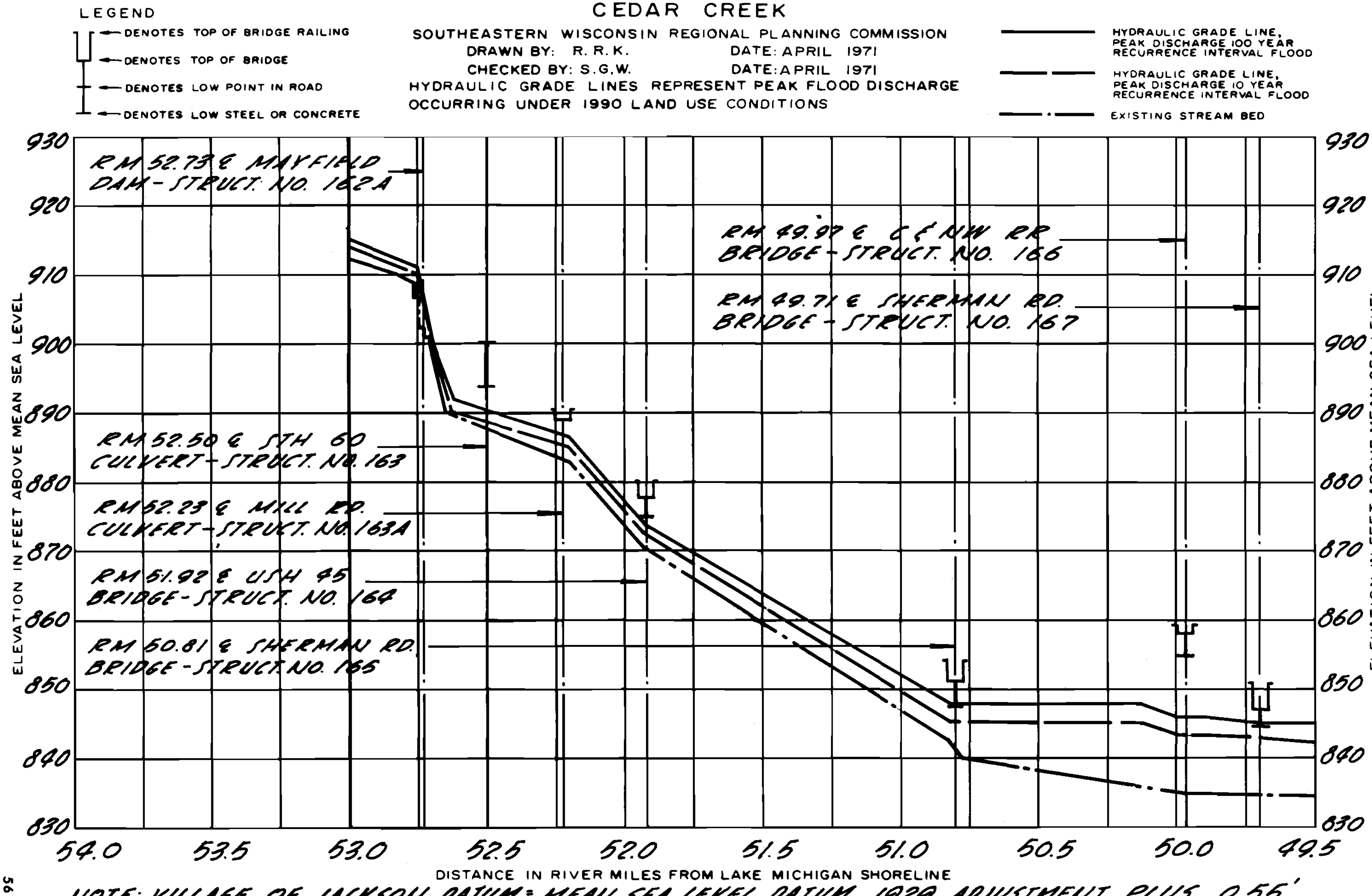
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-3 (continued)

HIGH WATER AND STREAM BED PROFILES FOR CEDAR CREEK



Source: Harza Engineering Company and SEWRPC.

Map F-3 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

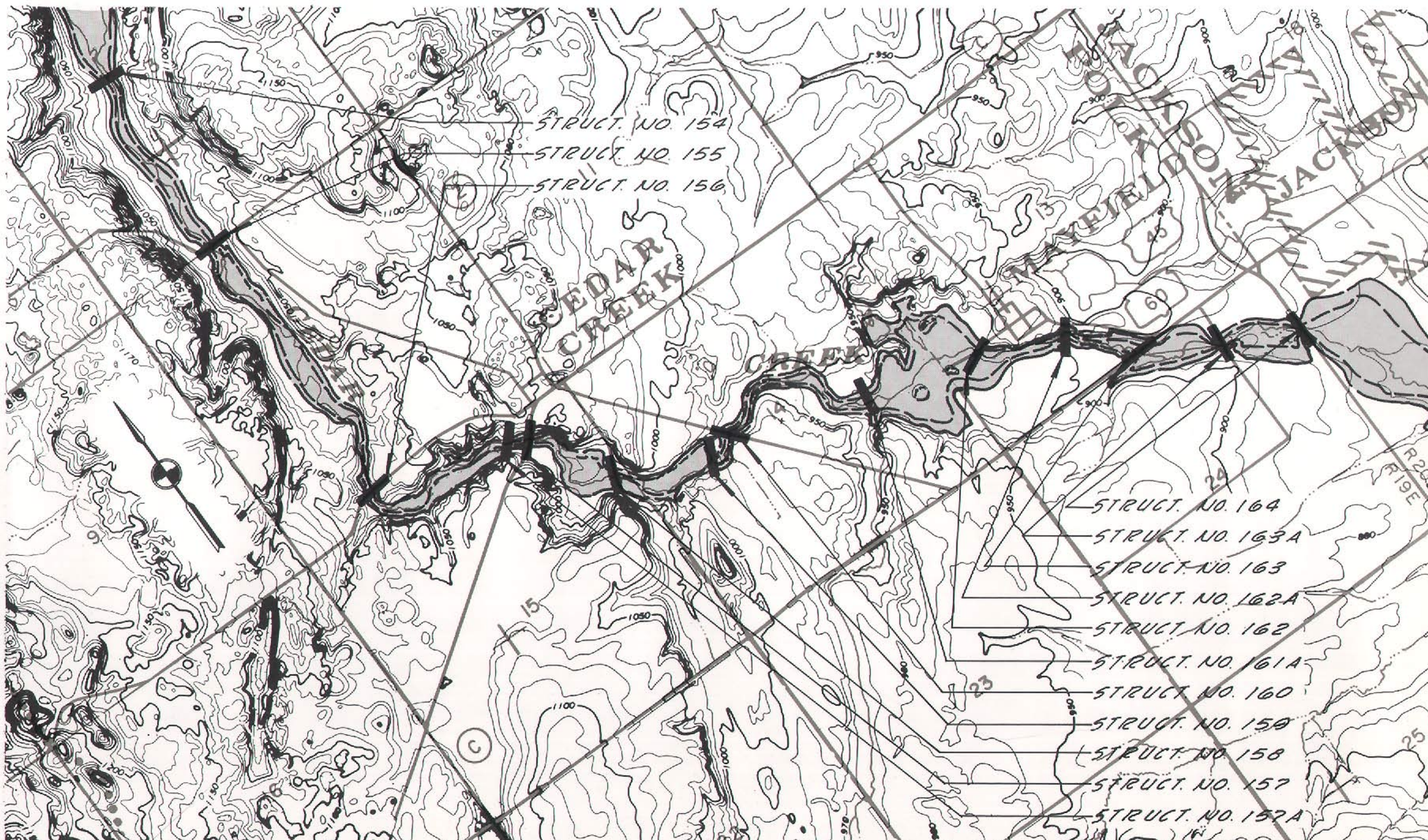
DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-3 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

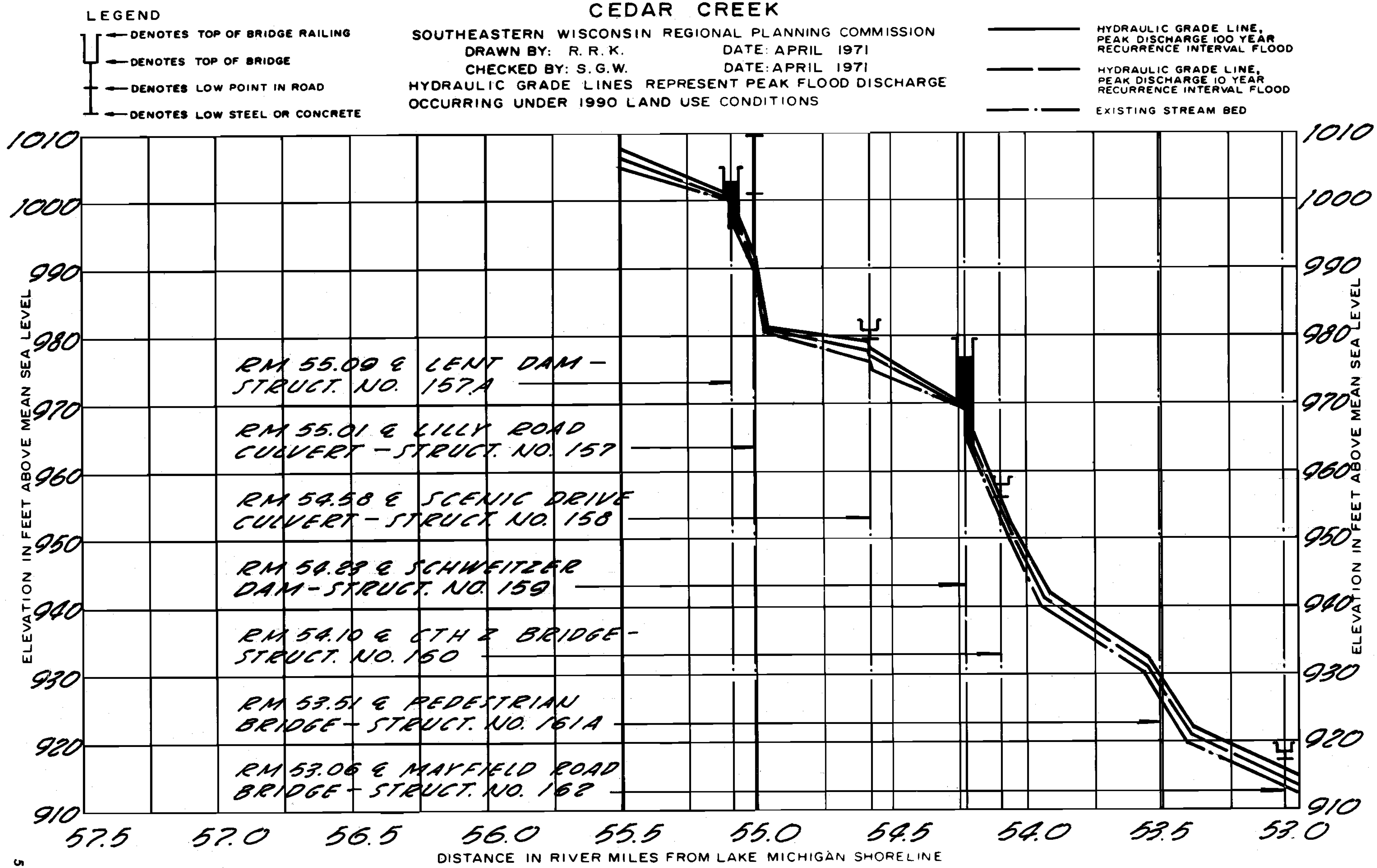
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



Source: Harza Engineering Company and SEWRPC.

Map F-3 (continued)

TOPOGRAPHIC MAP

SHOWING

AREAS SUBJECT TO FLOODING

ALONG

CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

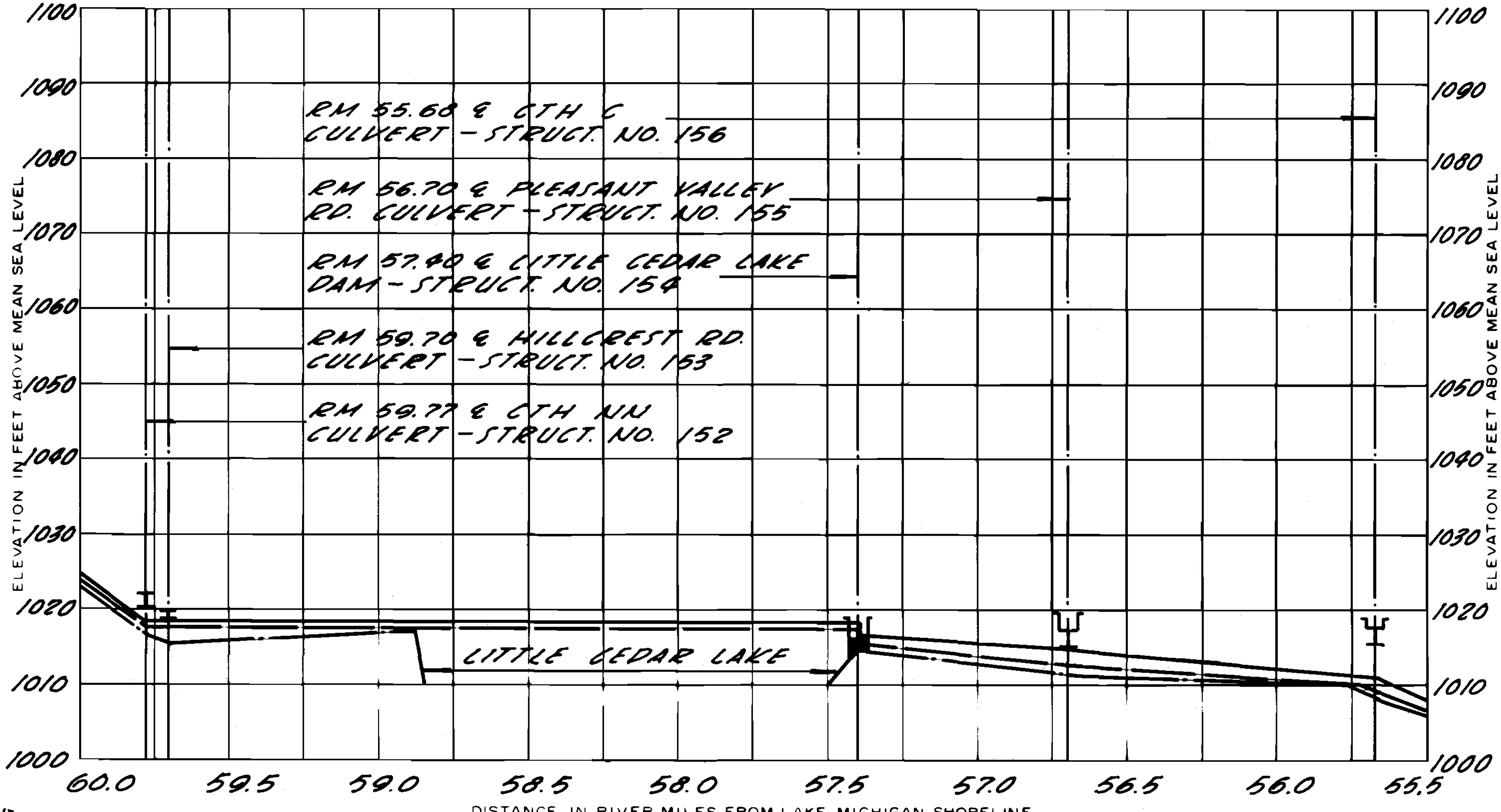
Figure F-3 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE
OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC

Map F-3 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

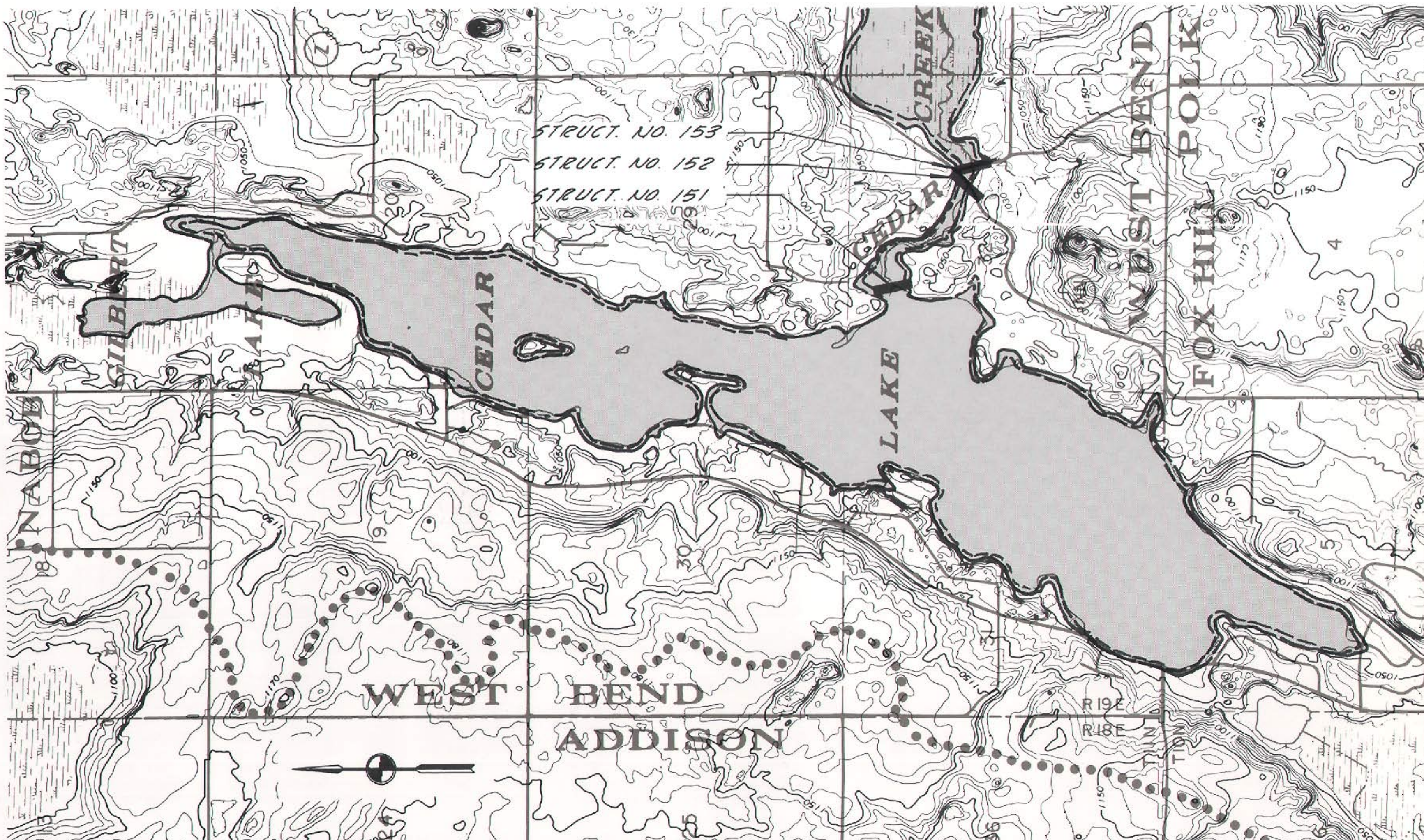
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-3 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

CEDAR CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

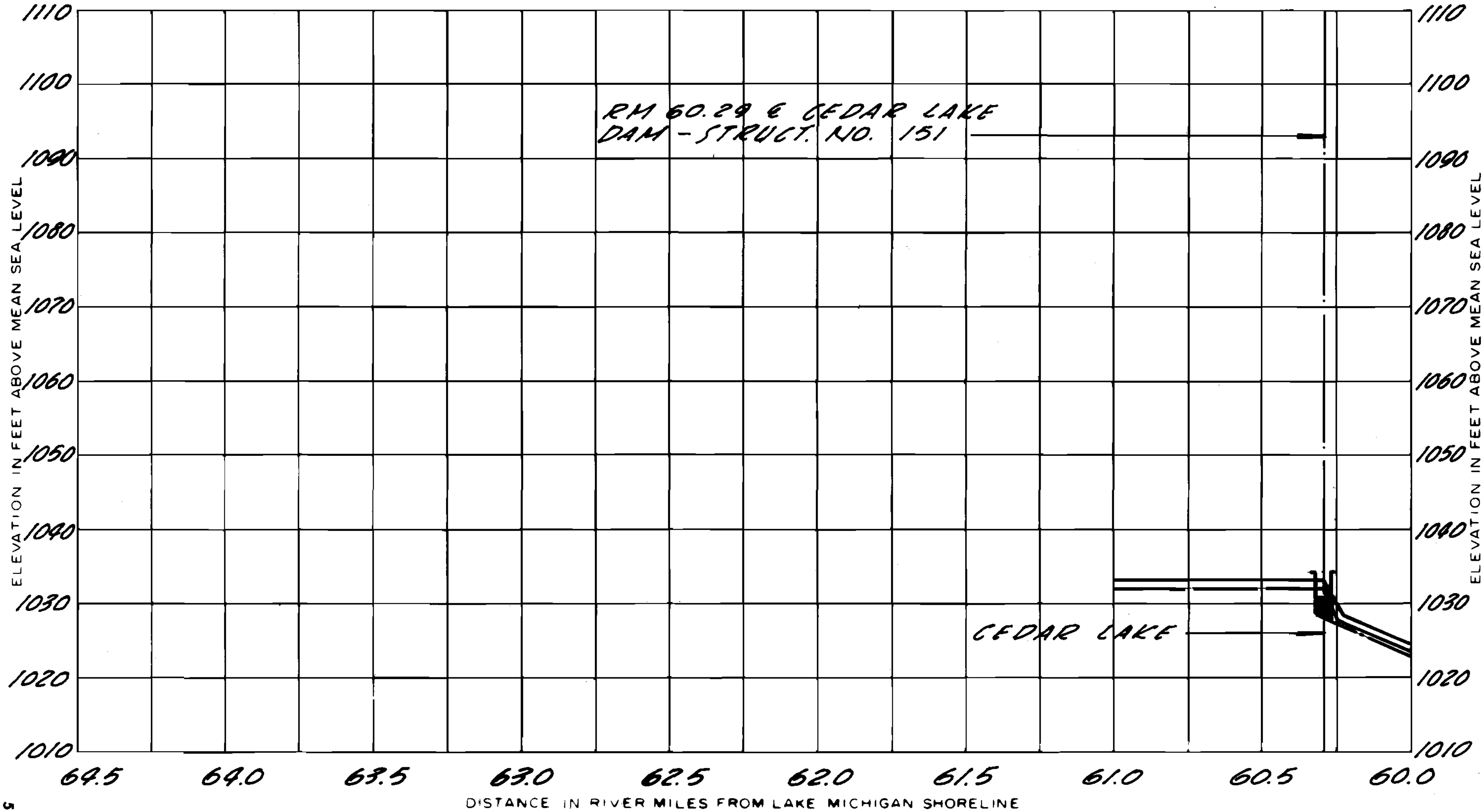
CHECKED BY: S.G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC

Map F-4

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 AND 20 FEET

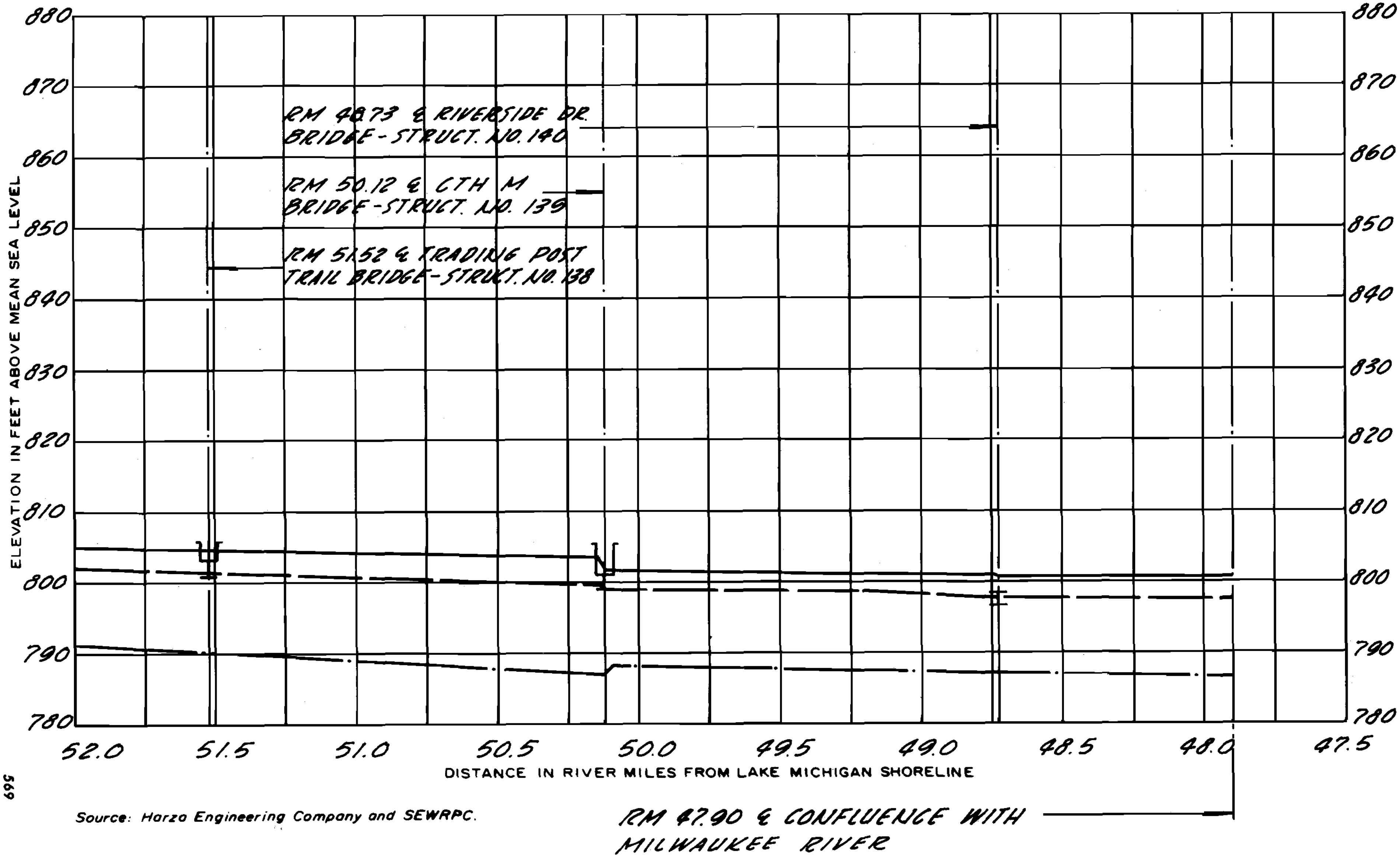
Figure F-4

HIGH WATER AND STREAM BED PROFILES FOR NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-4 (continued)

TOPOGRAPHIC MAP

SHOWING

AREAS SUBJECT TO FLOODING

ALONG

NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

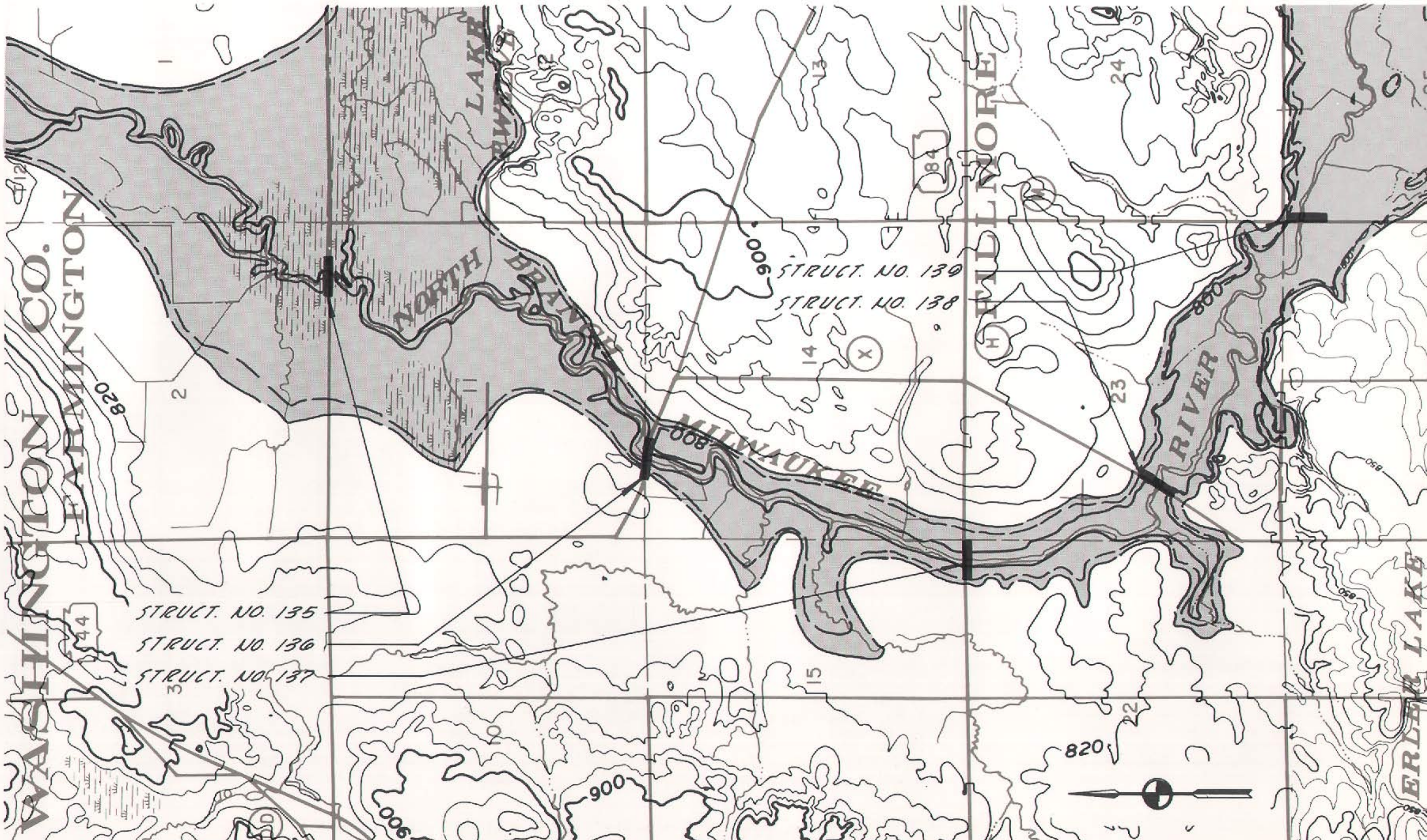
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

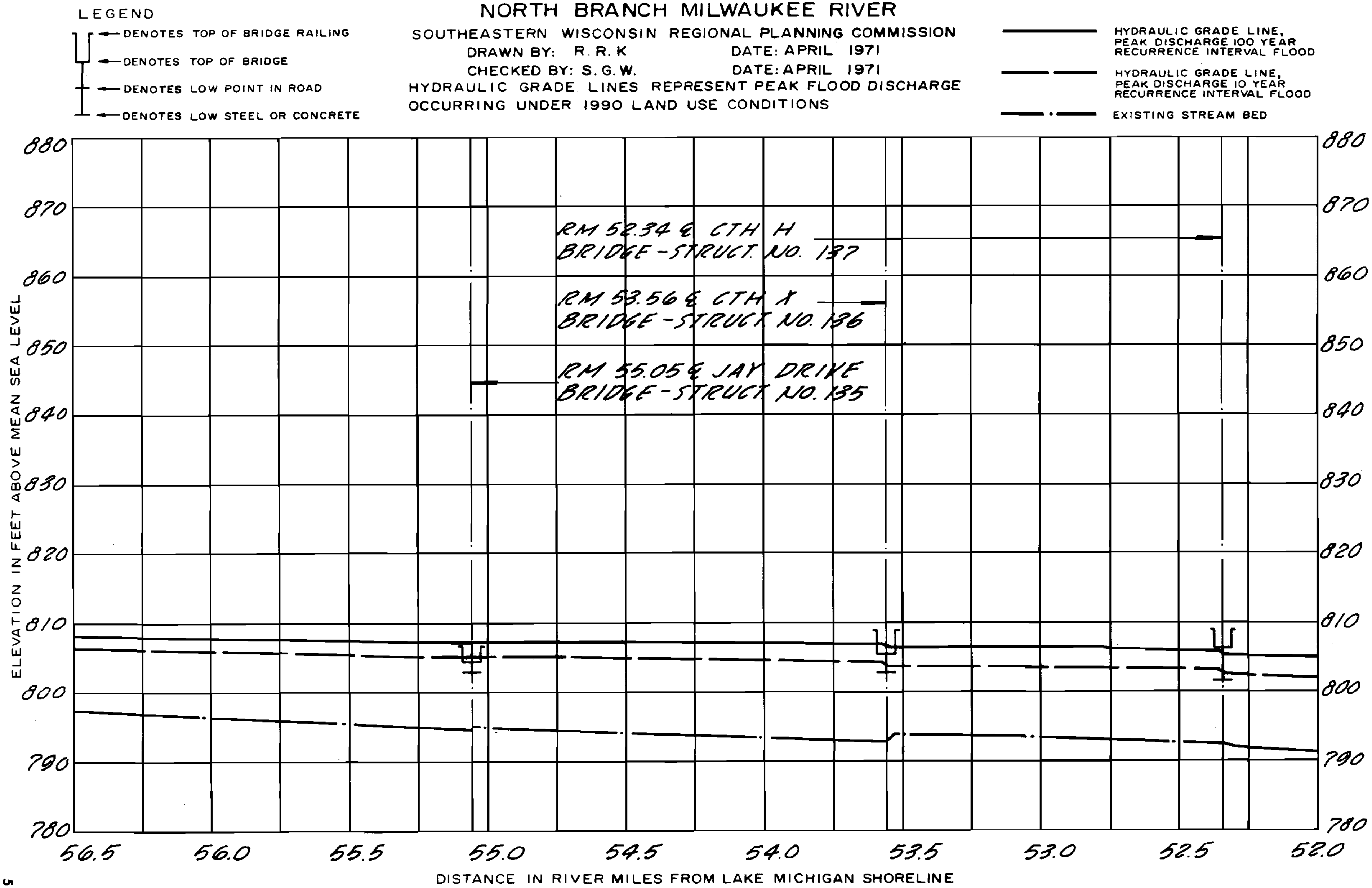
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 AND 20 FEET

Figure F-4 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
NORTH BRANCH MILWAUKEE RIVER



Source: Harza Engineering Company and SEWRPC.

Map F-4 (continued)

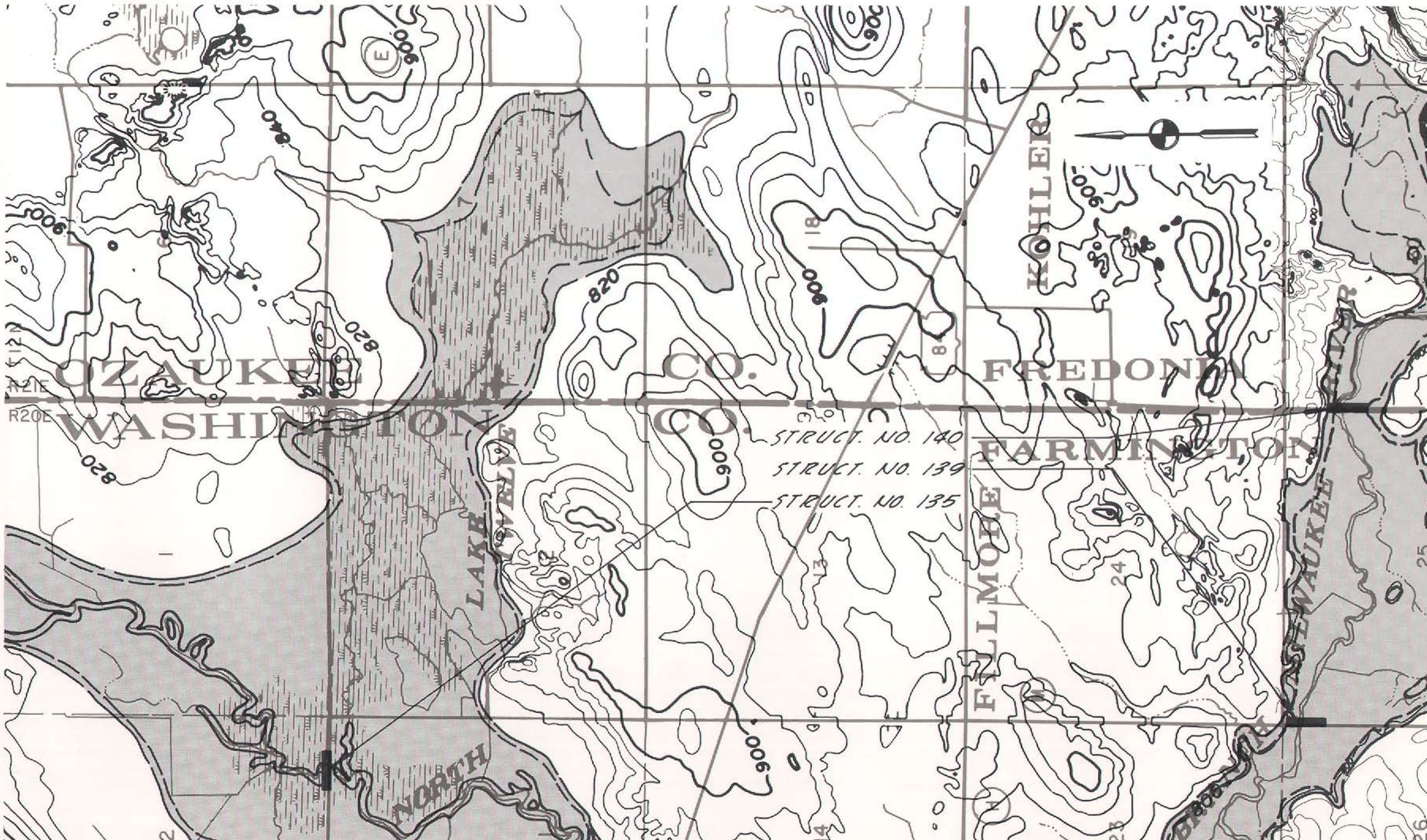
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R.R.K. DATE: APRIL 1971
CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 AND 20 FEET

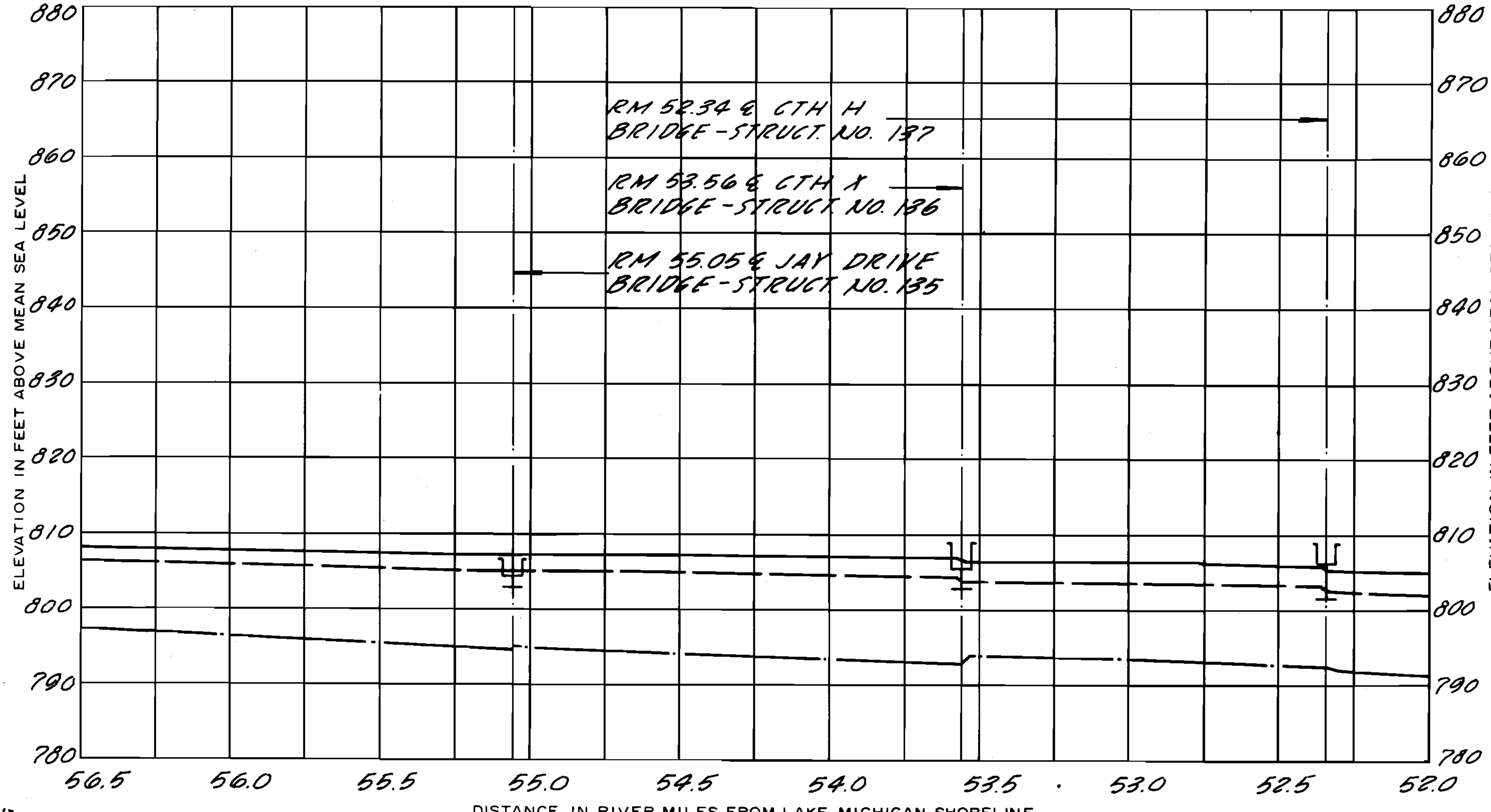
Figure F-4(continued)

HIGH WATER AND STREAM BED PROFILES
FOR
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-4 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

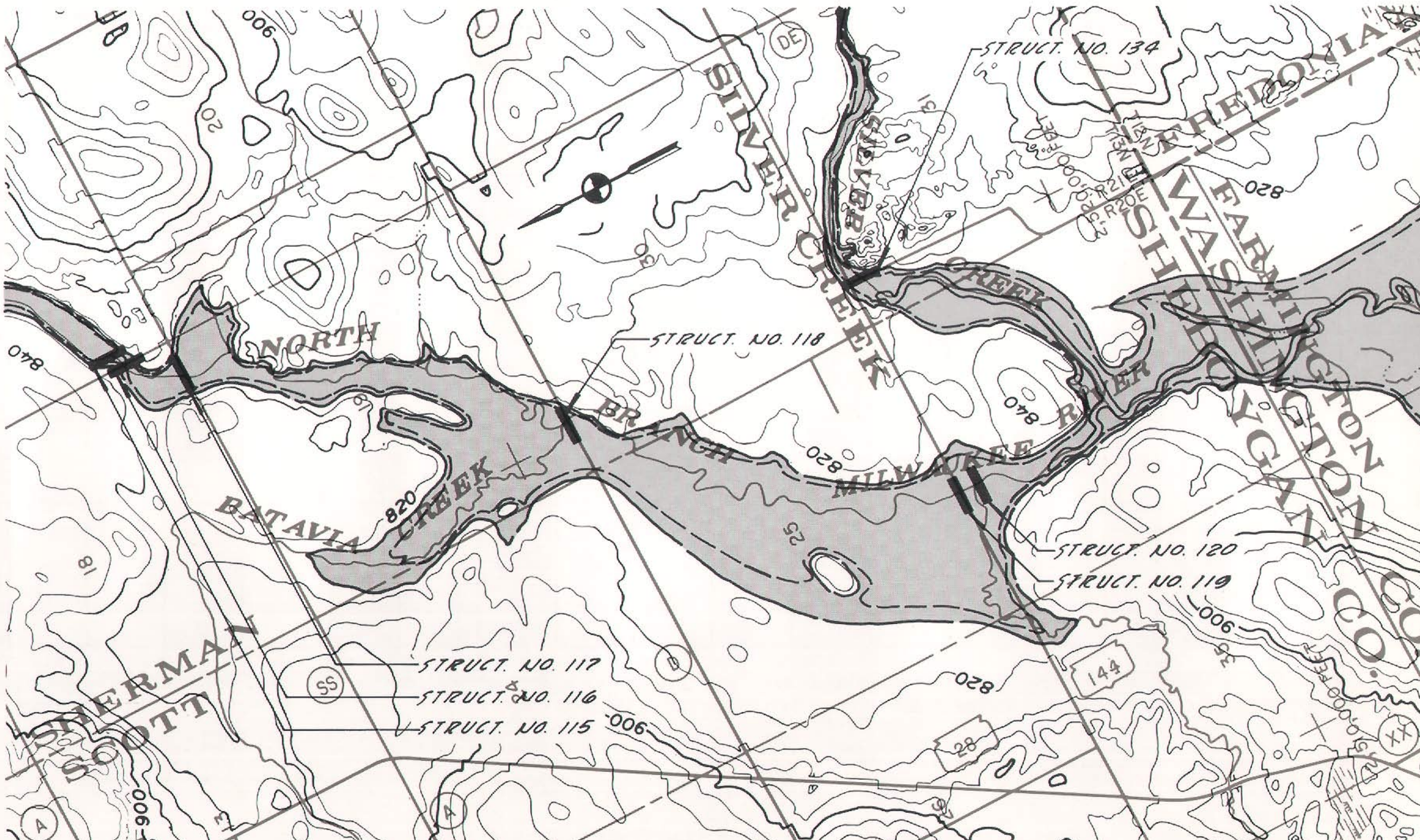
DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

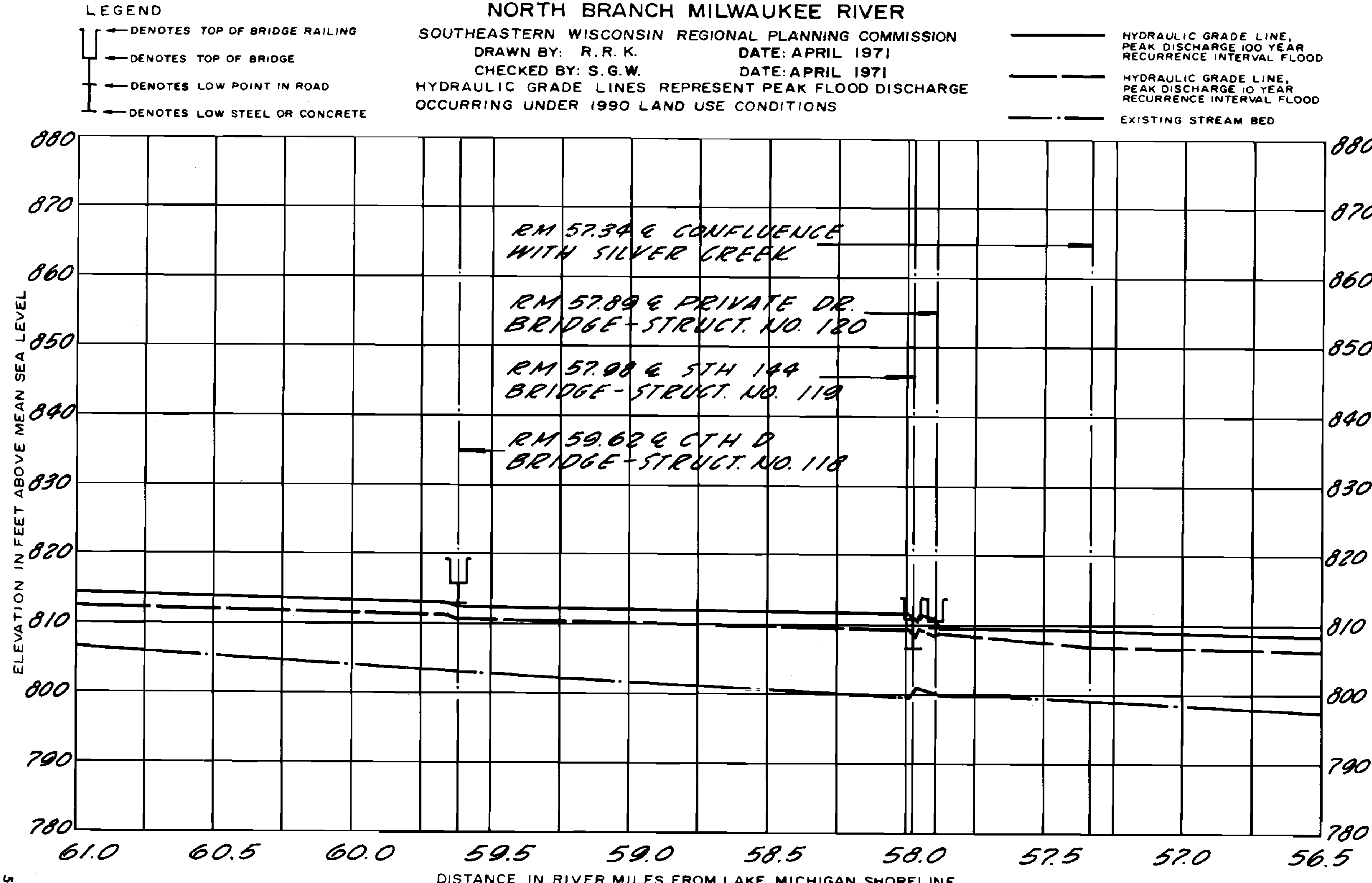
ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-4 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R.R.K. DATE: APRIL 1971
CHECKED BY: S.G.W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



Source: Harza Engineering Company and SEWRPC.

Map F-4 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

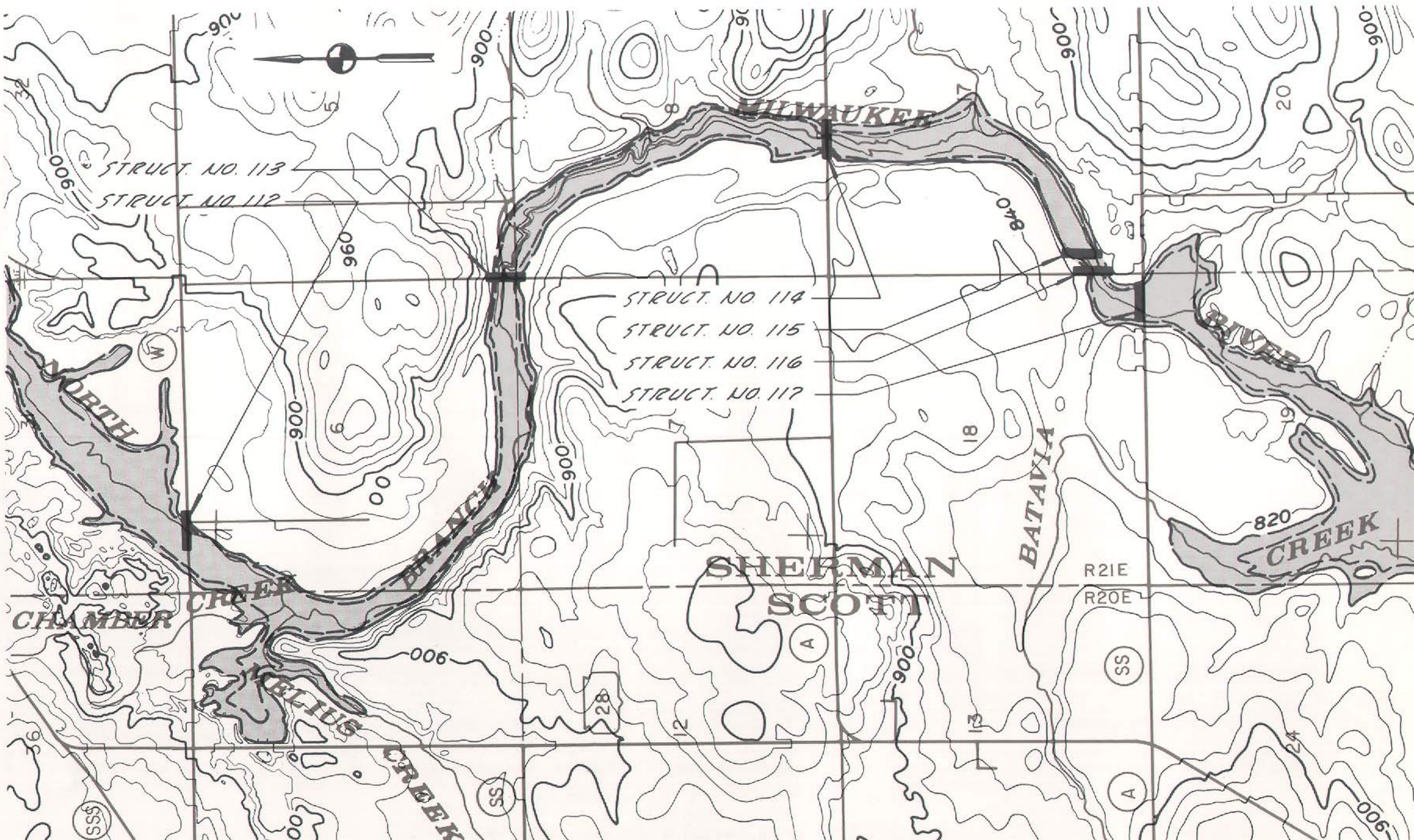
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-4(continued)

HIGH WATER AND STREAM BED PROFILES

FOR

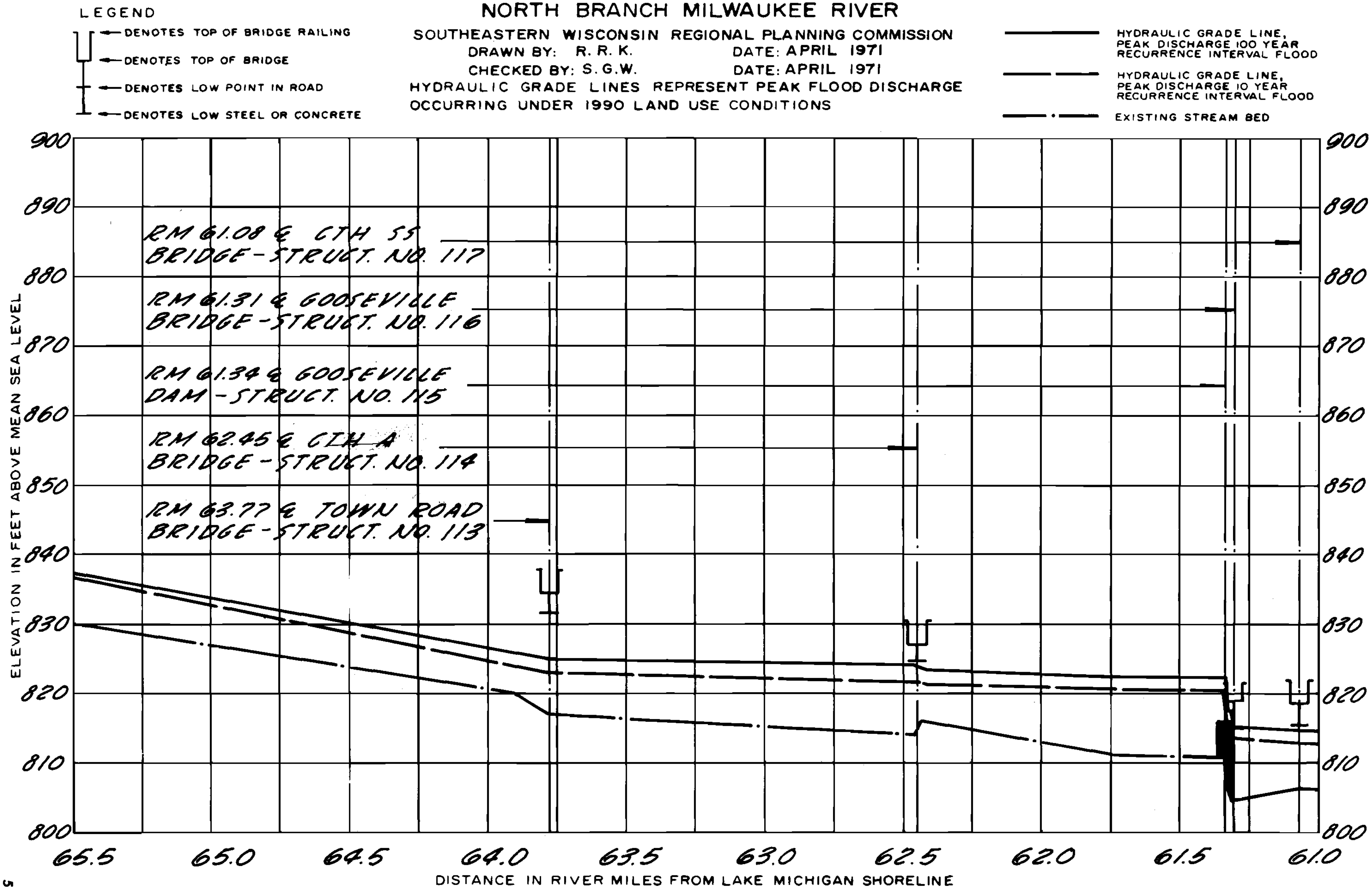
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



Source: Harza Engineering Company and SEWRPC.

Map F-4 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

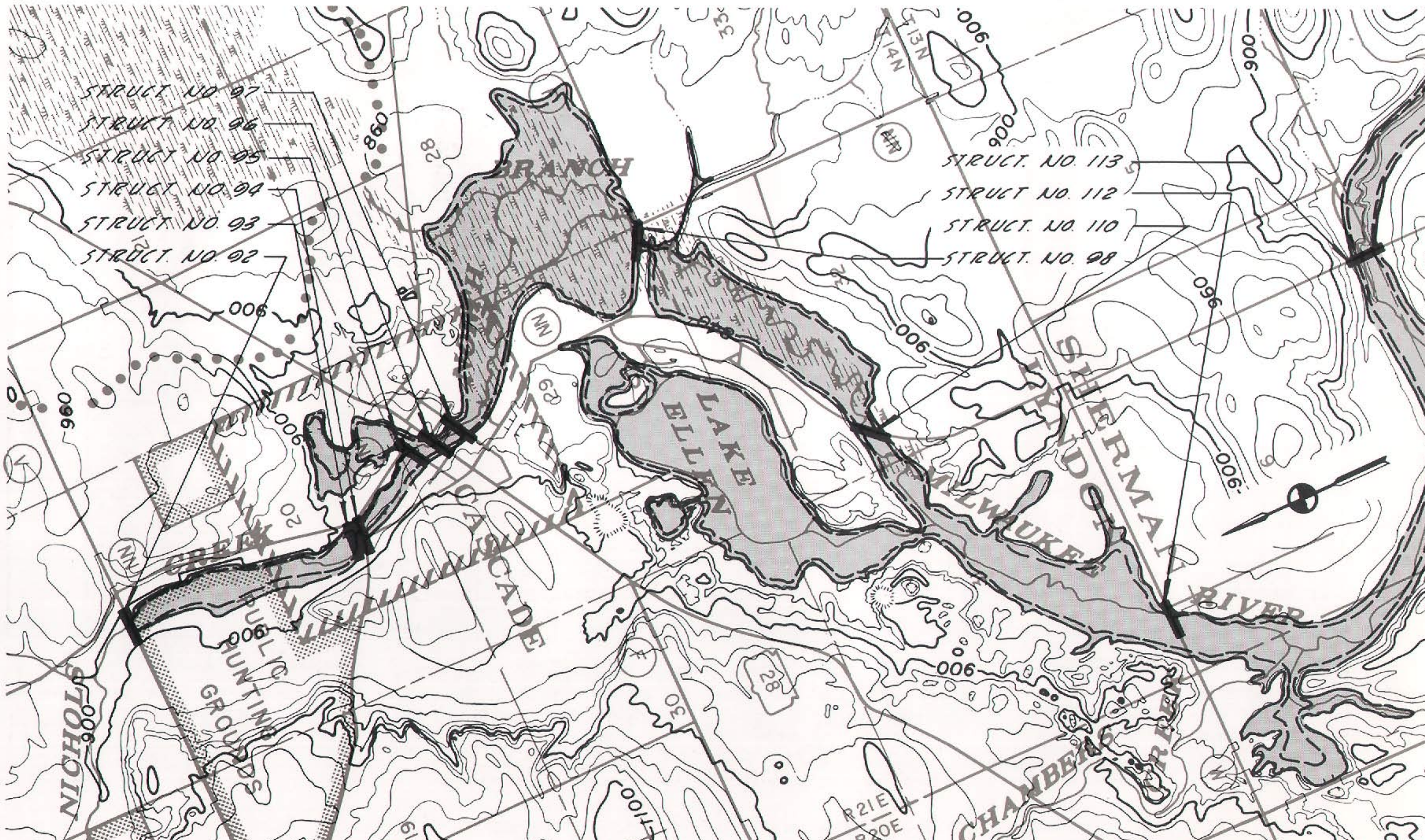
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

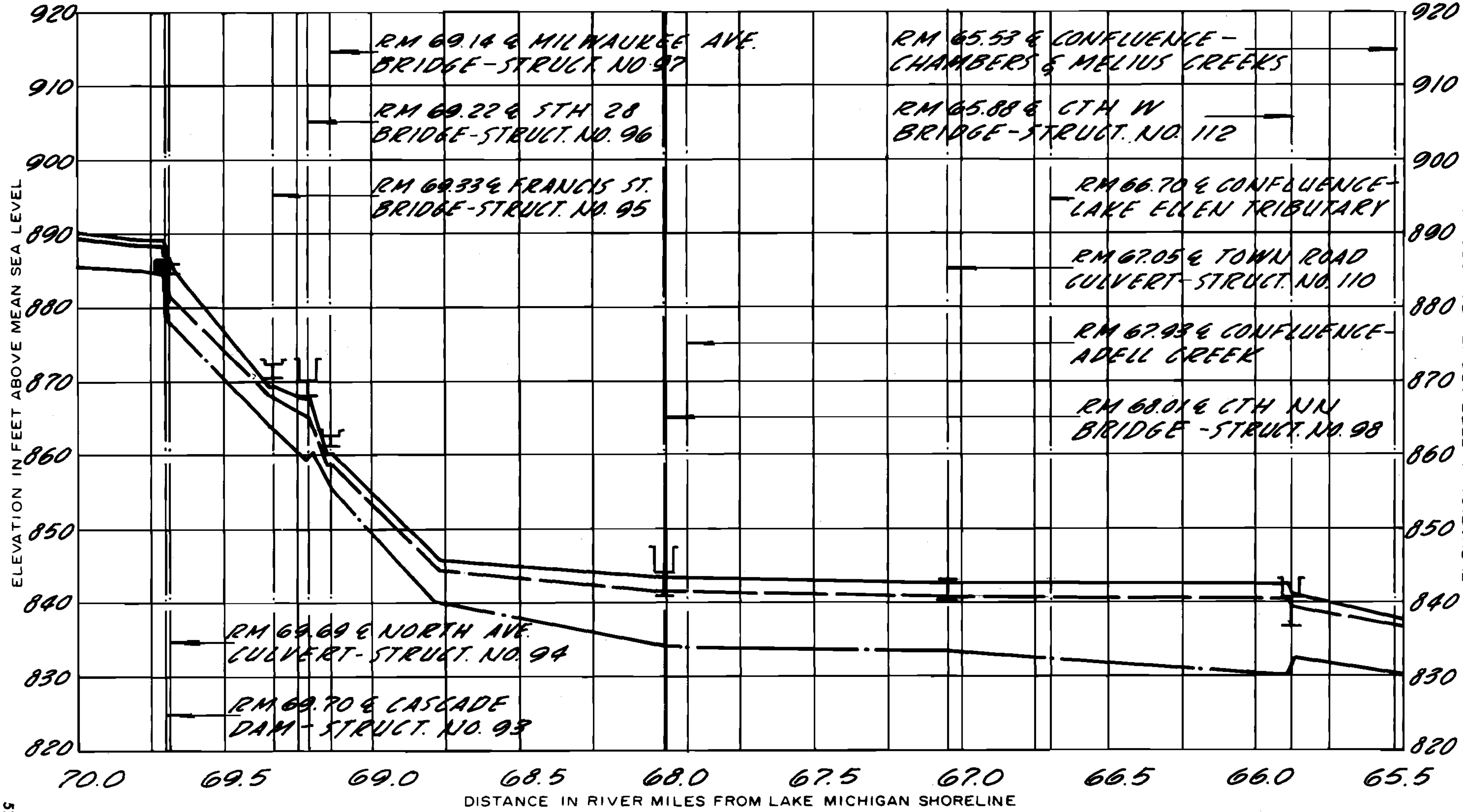
Figure F-4(continued)

HIGH WATER AND STREAM BED PROFILES
FOR
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-4 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

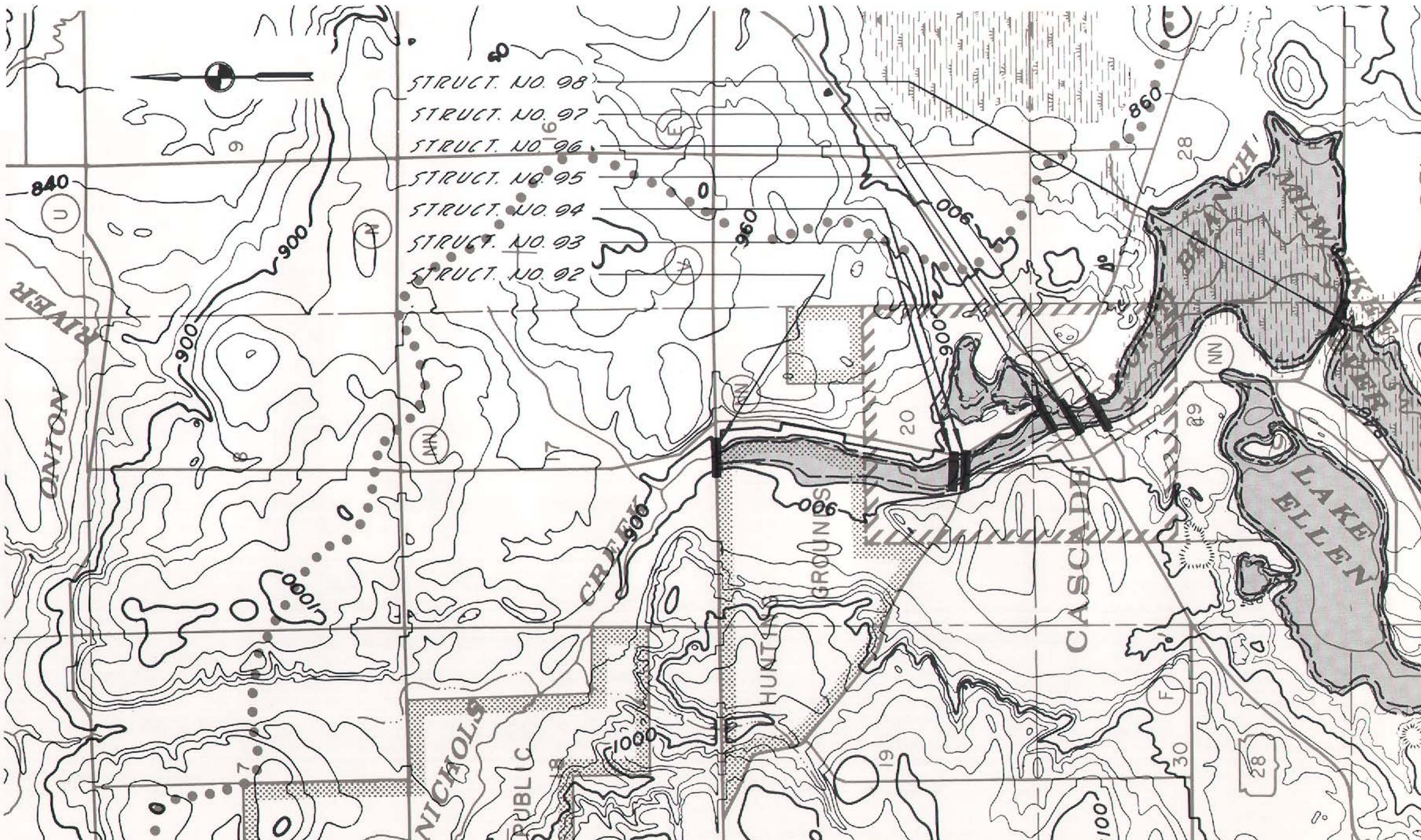
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

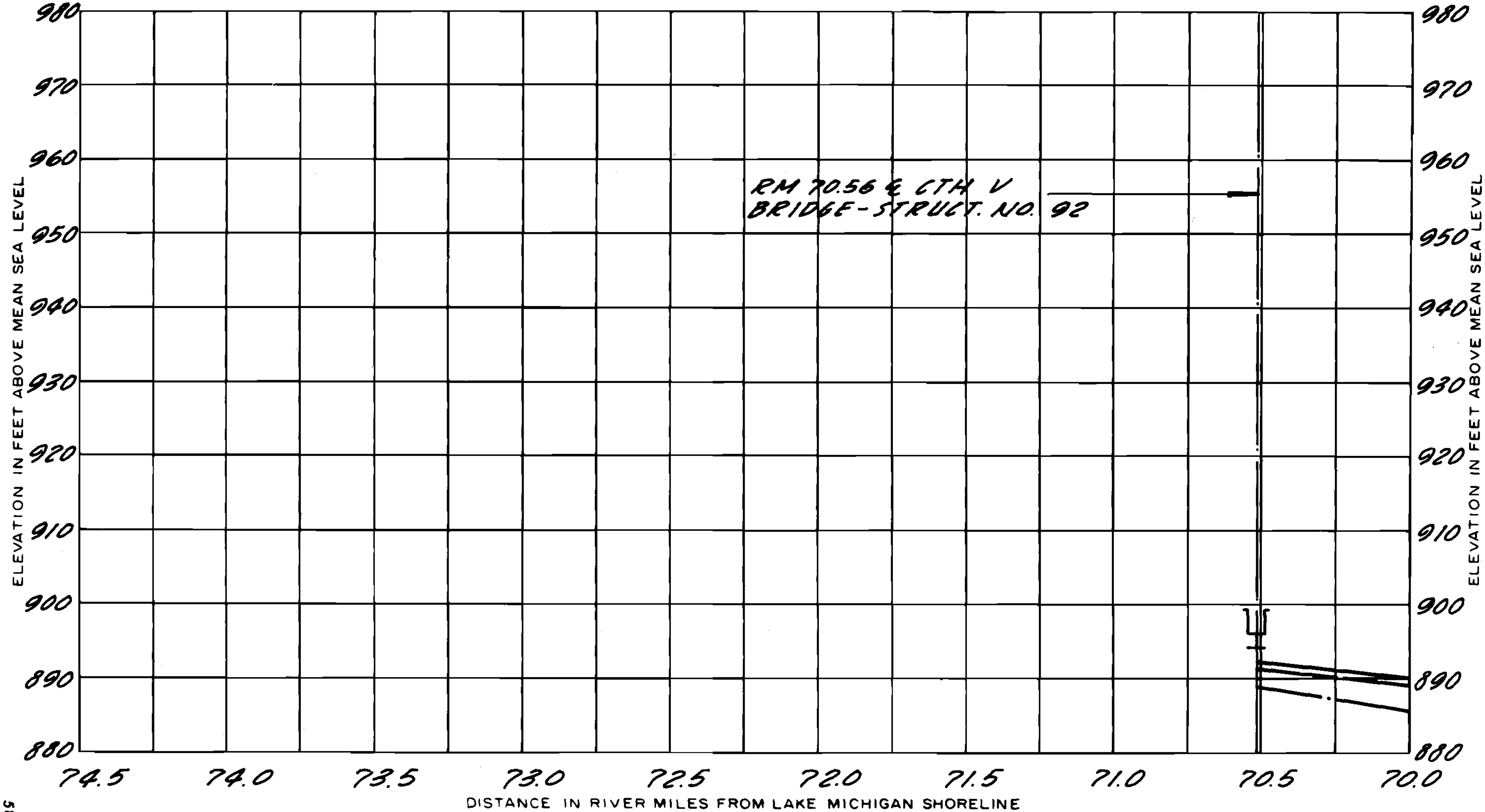
Figure F-4 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
NORTH BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC

Map F-5

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
SILVER CREEK (SHEBOYGAN COUNTY)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

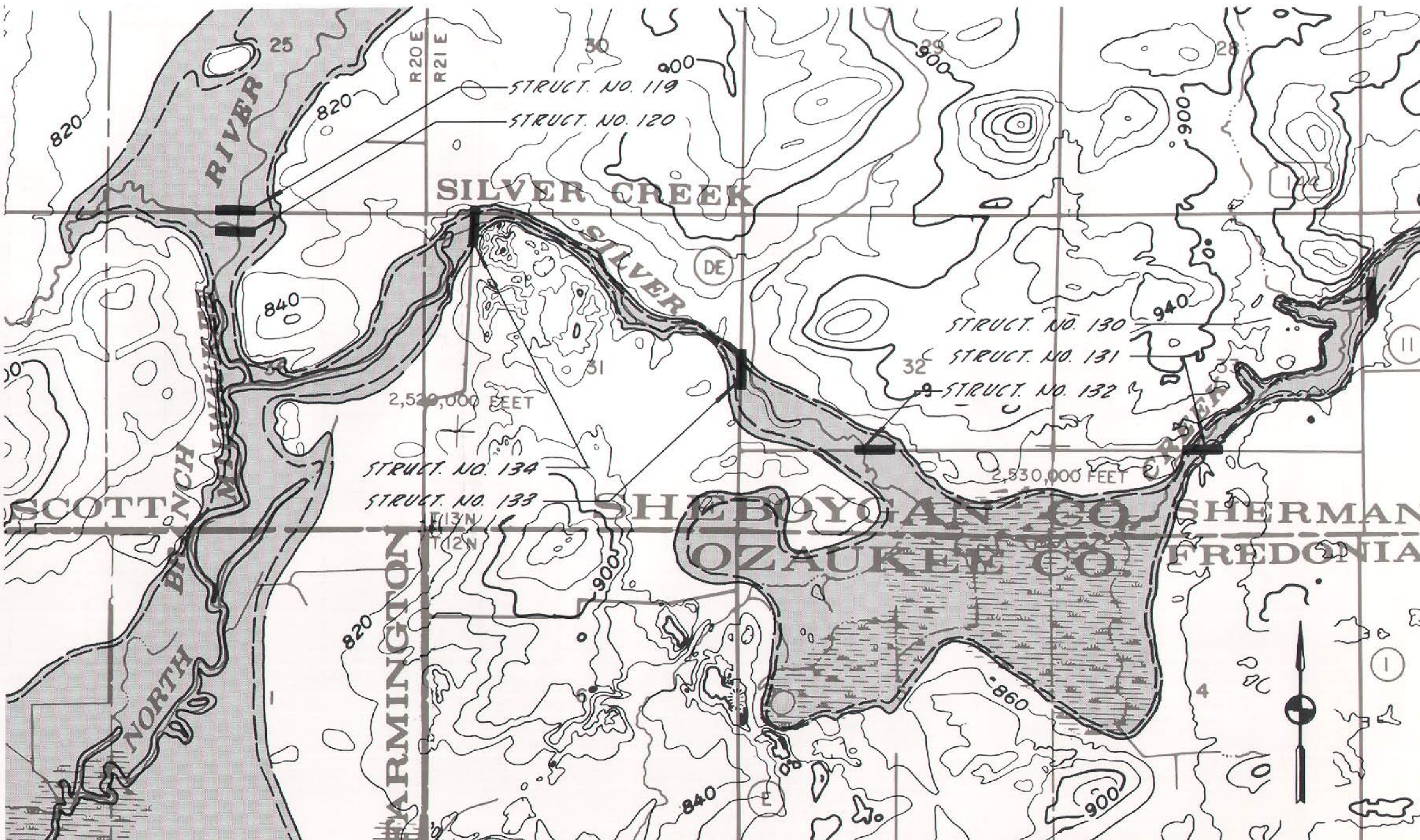
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

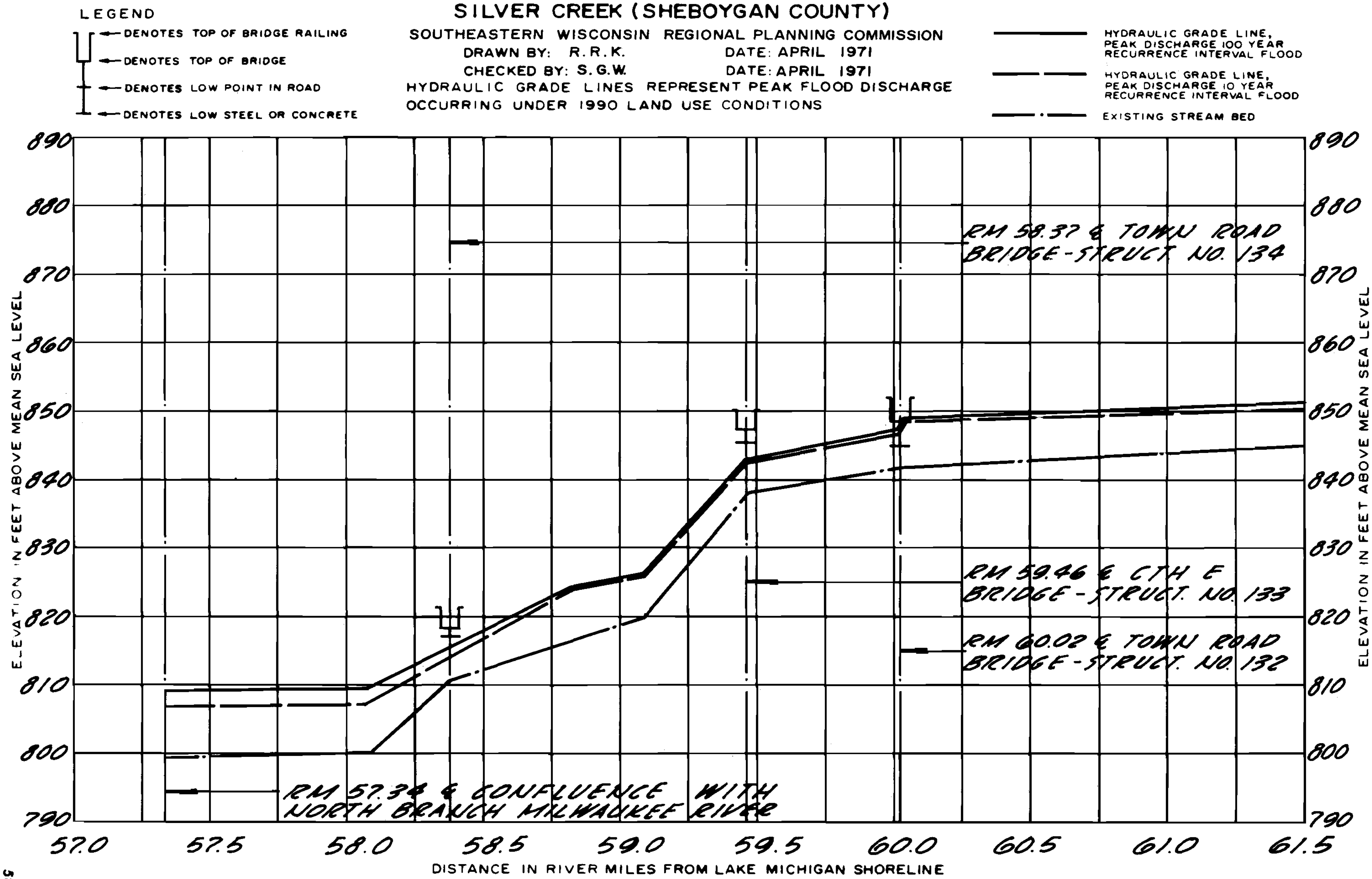
NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-5

HIGH WATER AND STREAM BED PROFILES

FOR

SILVER CREEK (SHEBOYGAN COUNTY)



Source: Harza Engineering Company and SEWRPC.

Map F-5 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
SILVER CREEK (SHEBOYGAN COUNTY)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

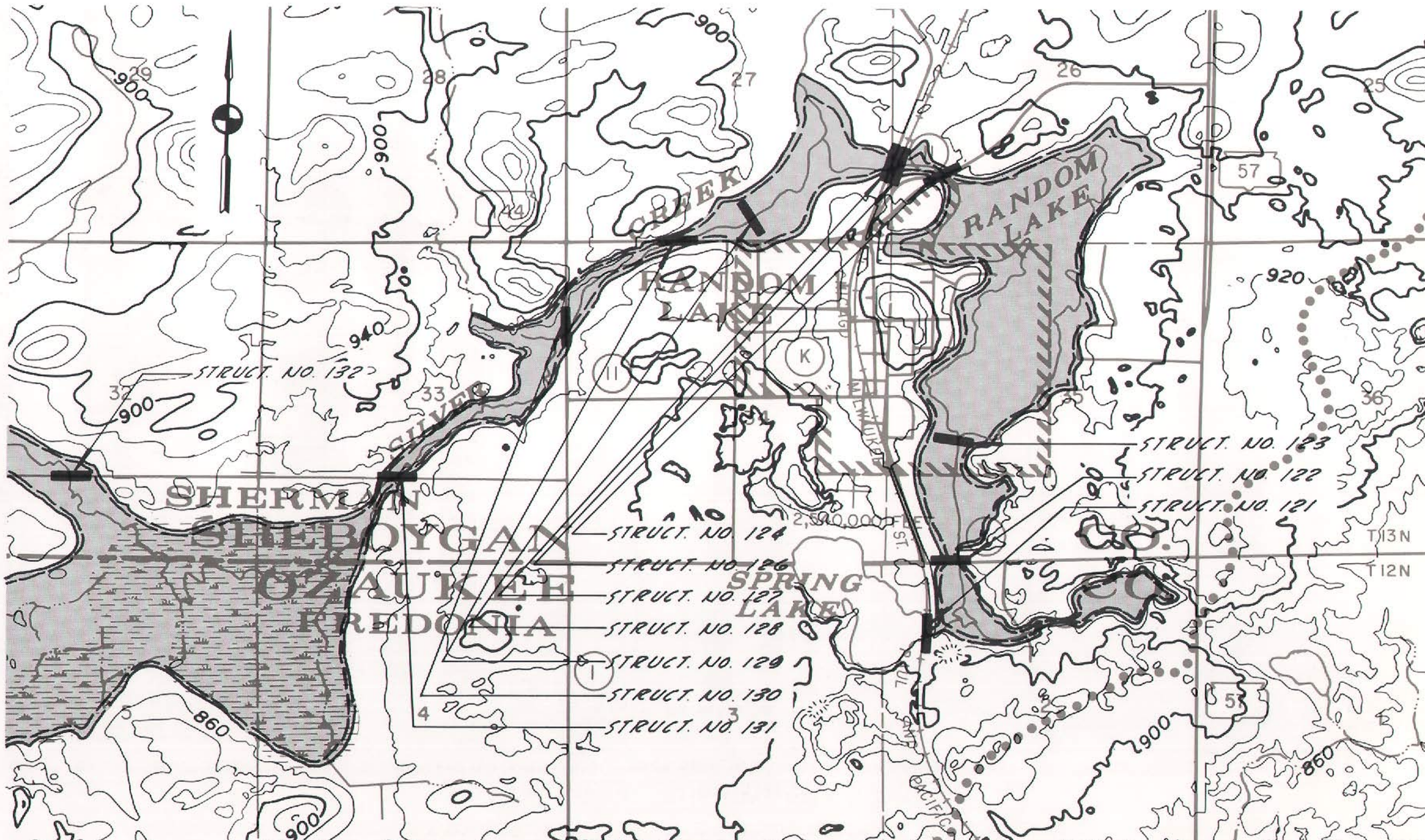
DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

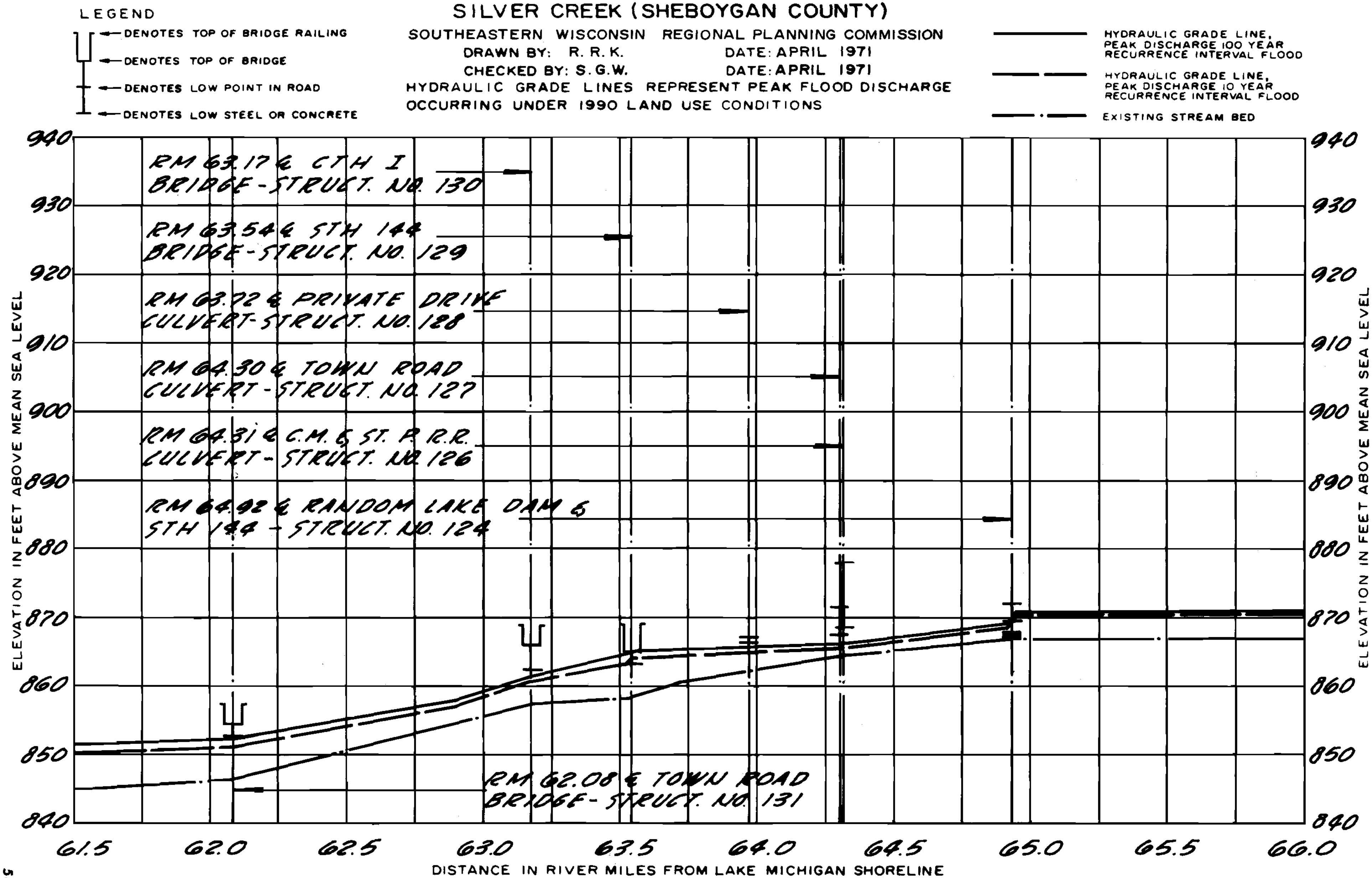
NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-5 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

SILVER CREEK (SHEBOYGAN COUNTY)



NOTE: VILLAGE OF RANDOM LAKE DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 798.12'

Source: Harza Engineering Company and SEWRPC.

Map F-5 (continued)

TOPOGRAPHIC MAP

SHOWING

AREAS SUBJECT TO FLOODING

ALONG

SILVER CREEK (SHEBOYGAN COUNTY)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

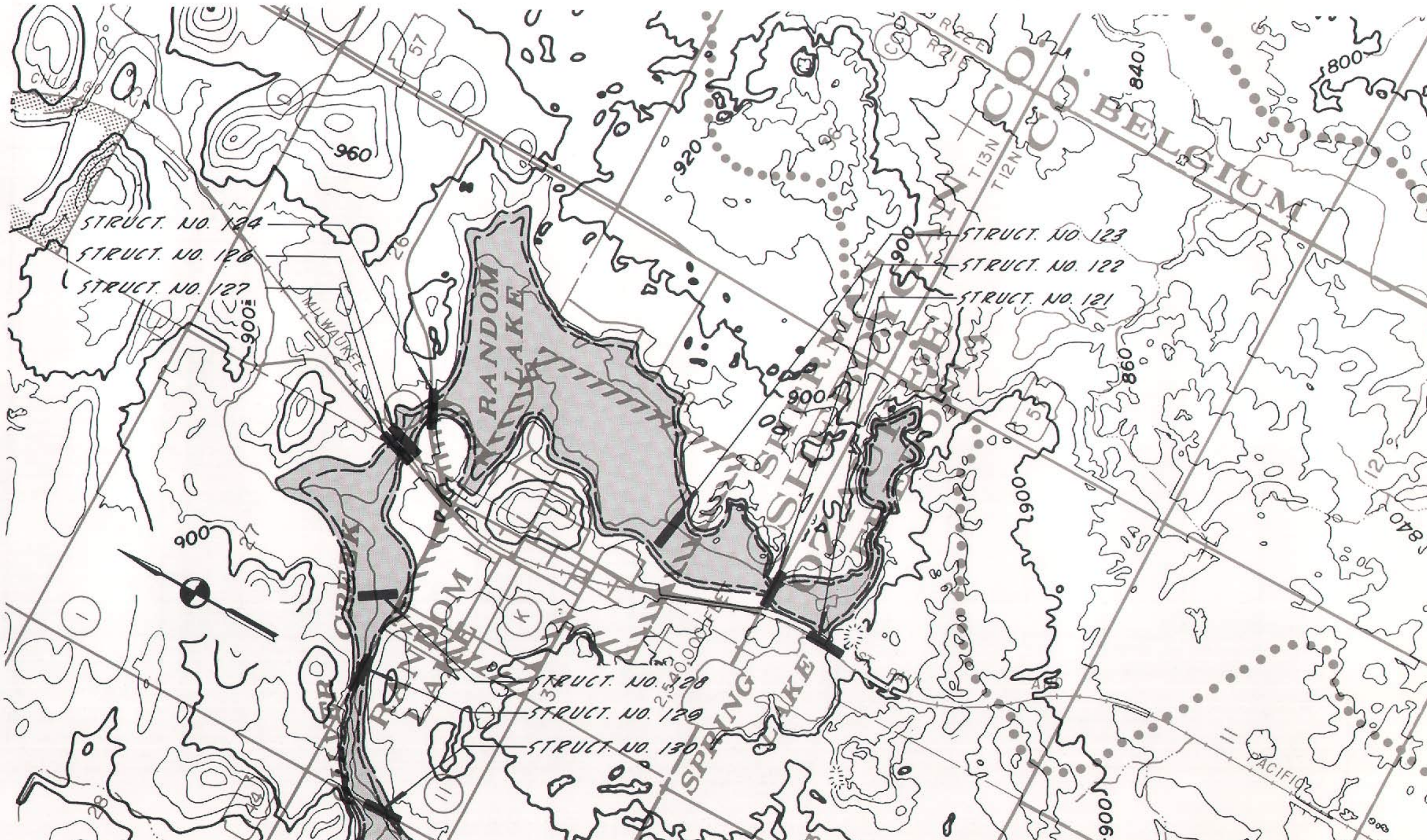
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-5 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

SILVER CREEK (SHEBOYGAN COUNTY)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

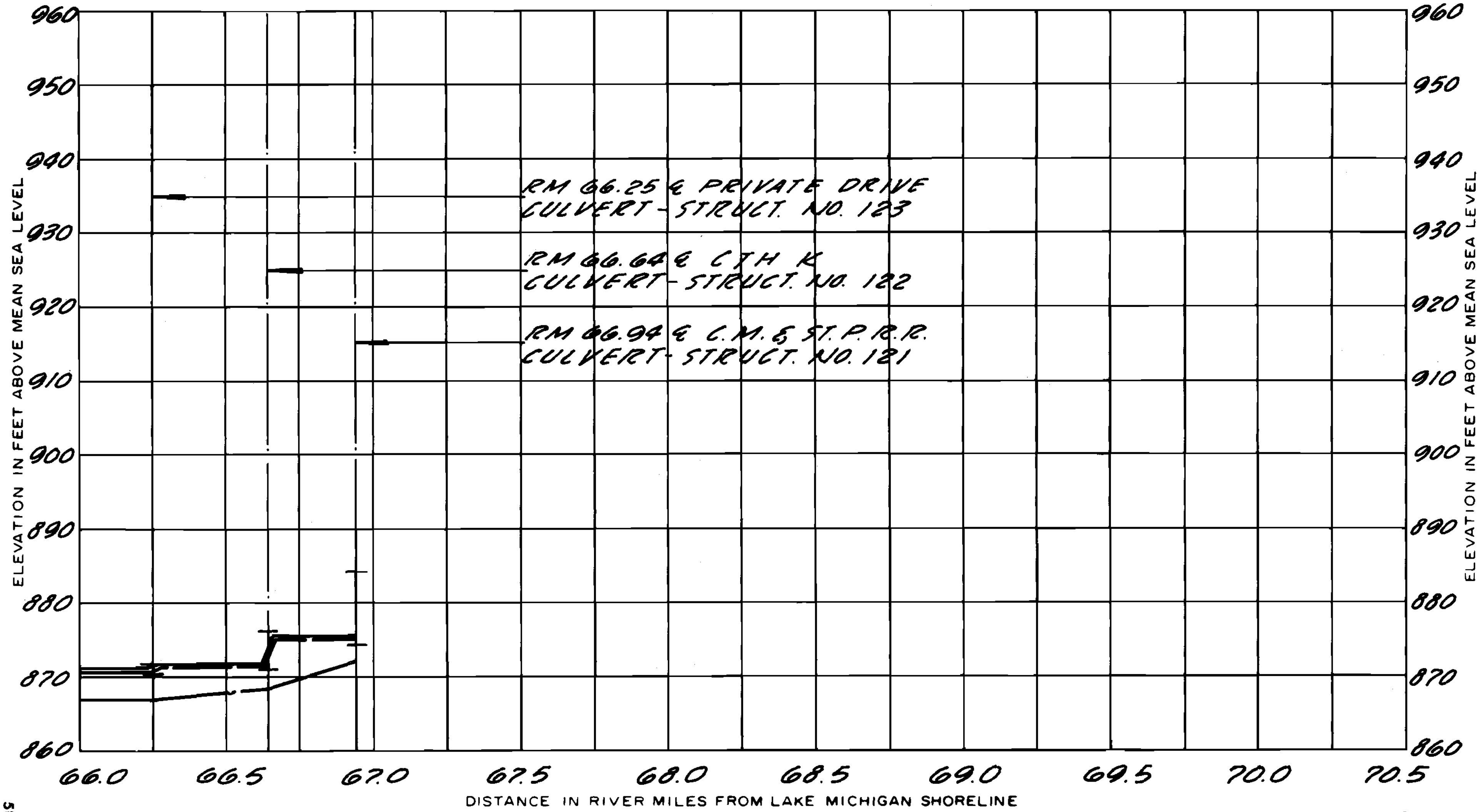
CHECKED BY: S.G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



NOTE: VILLAGE OF RANDOM LAKE DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 798.12'

Source: Harza Engineering Company and SEWRPC.

Map F-6

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
SILVER CREEK (WASHINGTON COUNTY)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

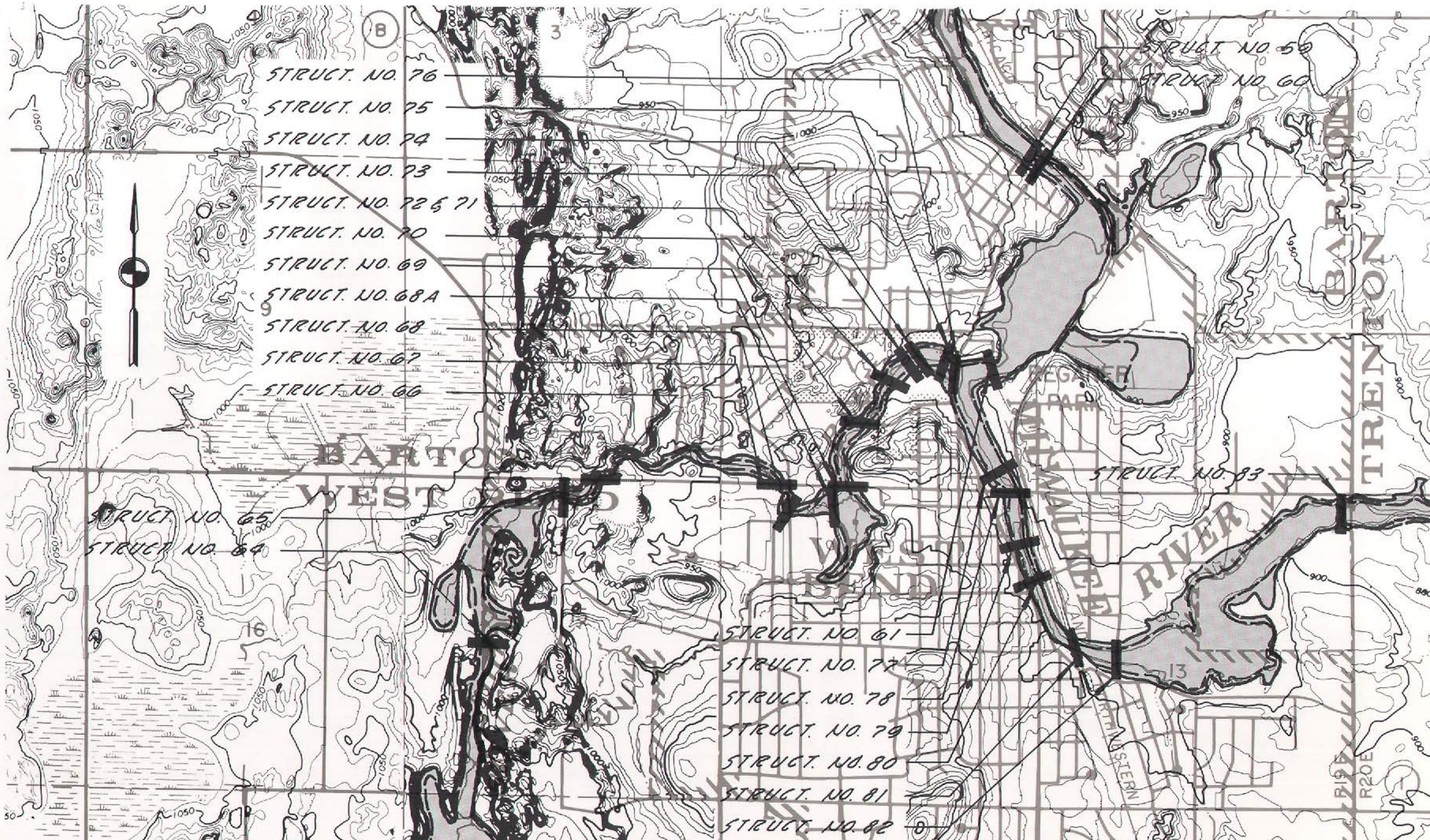
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET

Figure F-6

HIGH WATER AND STREAM BED PROFILES FOR SILVER CREEK (WASHINGTON COUNTY)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

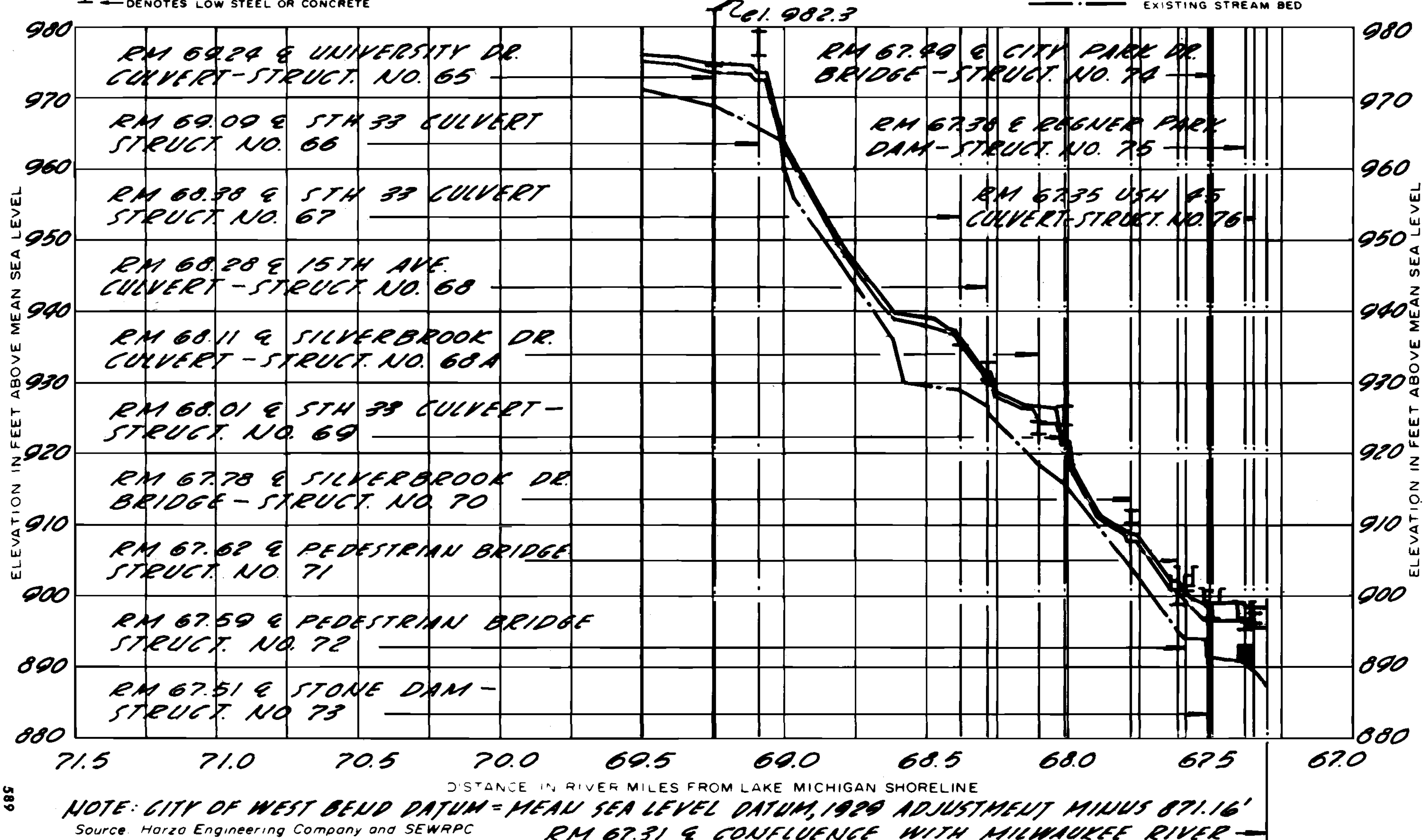
CHECKED BY: S.G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



NOTE: CITY OF WEST BEND DATUM = MEAN SEA LEVEL DATUM, 1929 ADJUSTMENT MINUS 871.16'

Source: Harza Engineering Company and SEWRPC

Map F-6 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
SILVER CREEK (WASHINGTON COUNTY)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

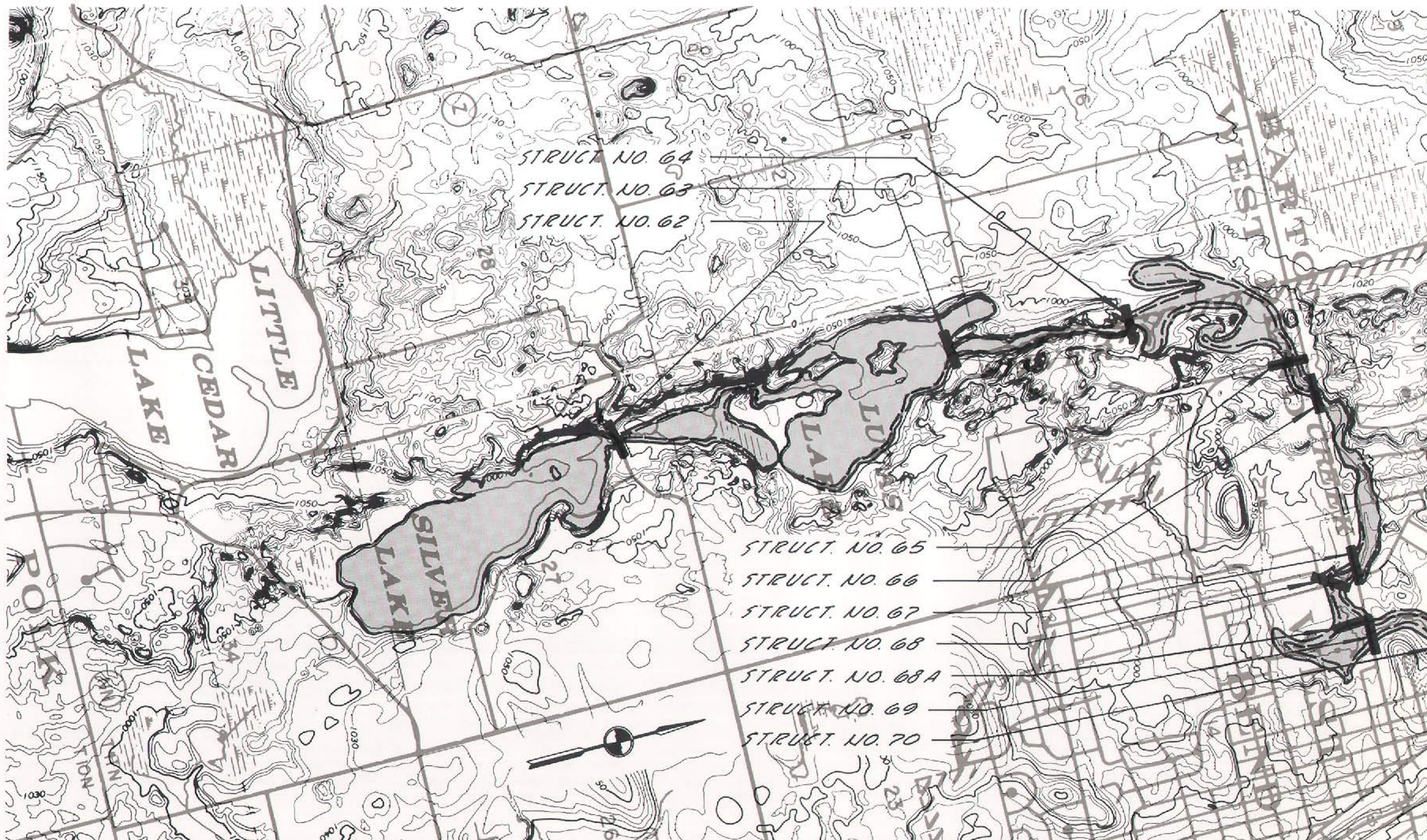
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 10 FEET.

Figure F-6 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

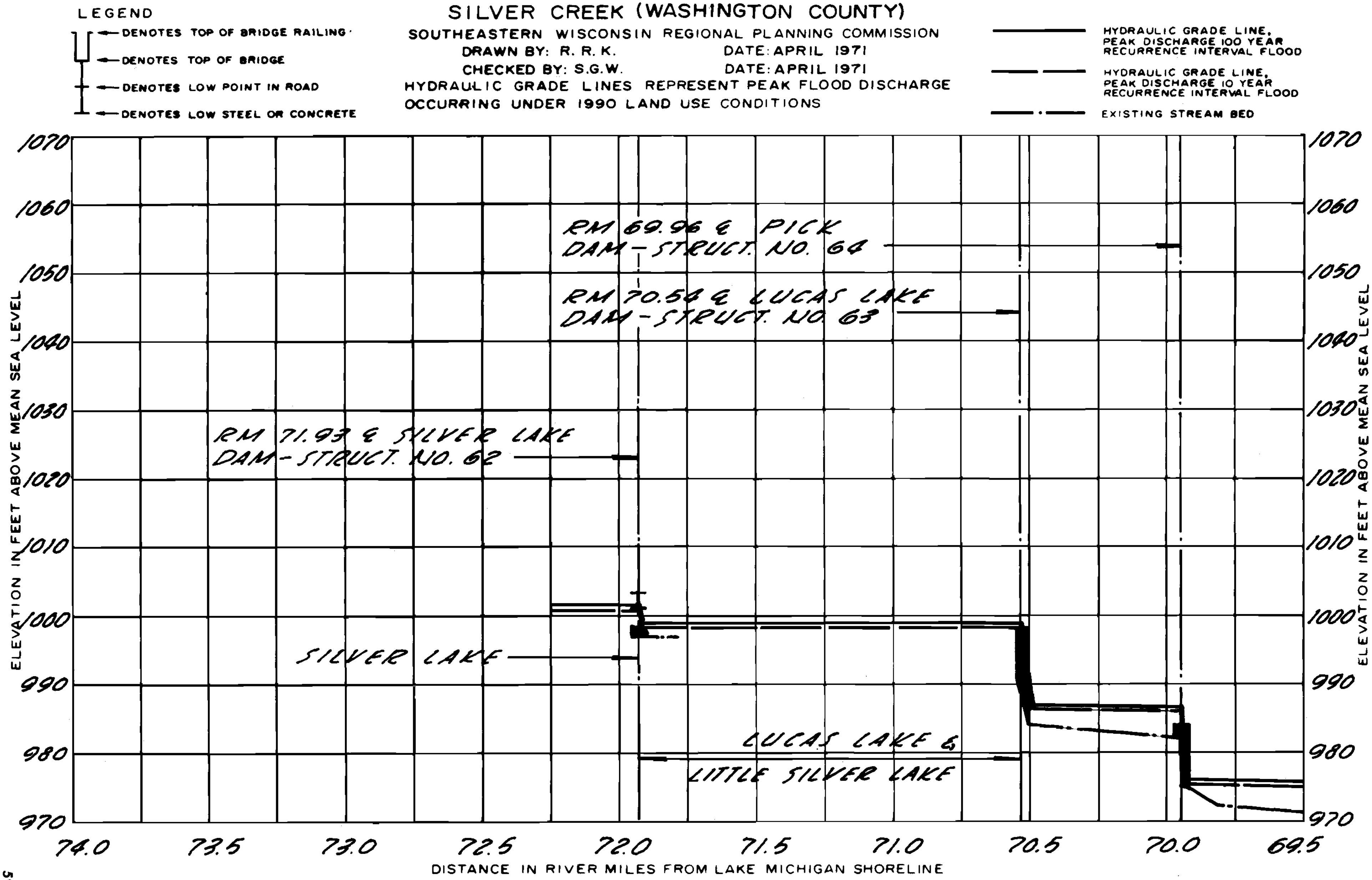
SILVER CREEK (WASHINGTON COUNTY)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS



Source: Harza Engineering Company and SEWRPC.

Map F-7

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
EAST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

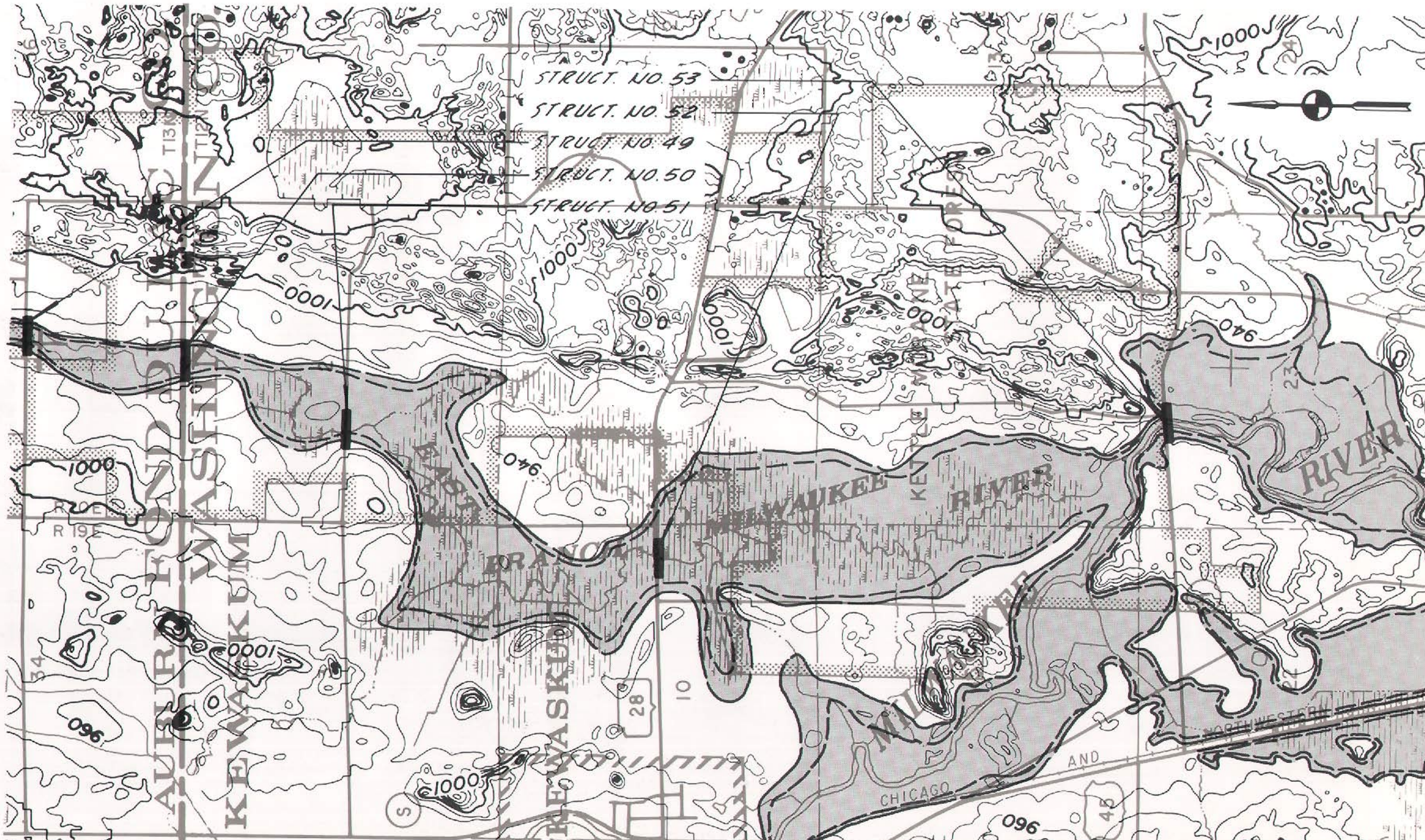
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

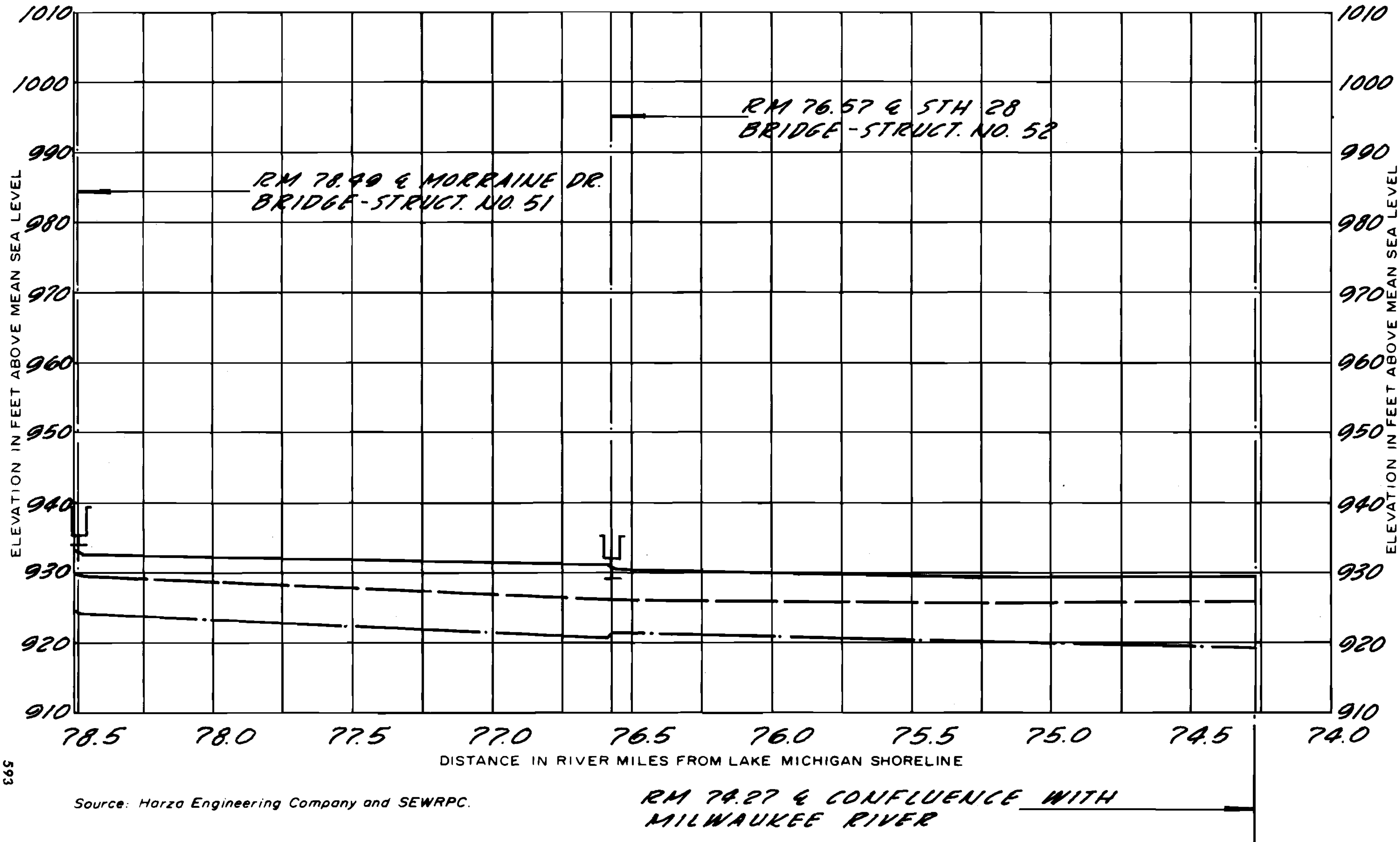
Figure F-7

HIGH WATER AND STREAM BED PROFILES
FOR
EAST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R.R.K. DATE: APRIL 1971
CHECKED BY: S.G.W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-7 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
EAST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

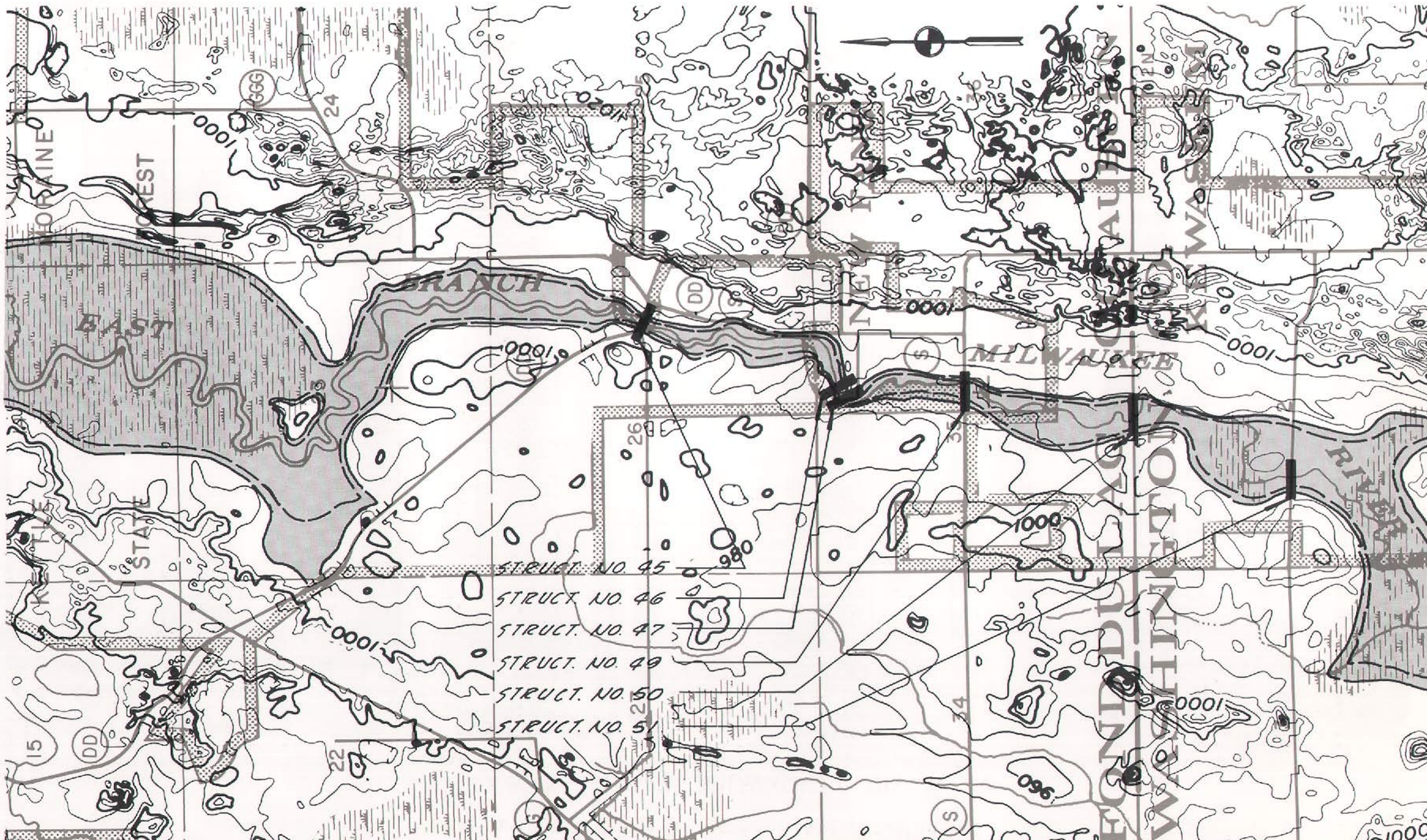
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-7 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

EAST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

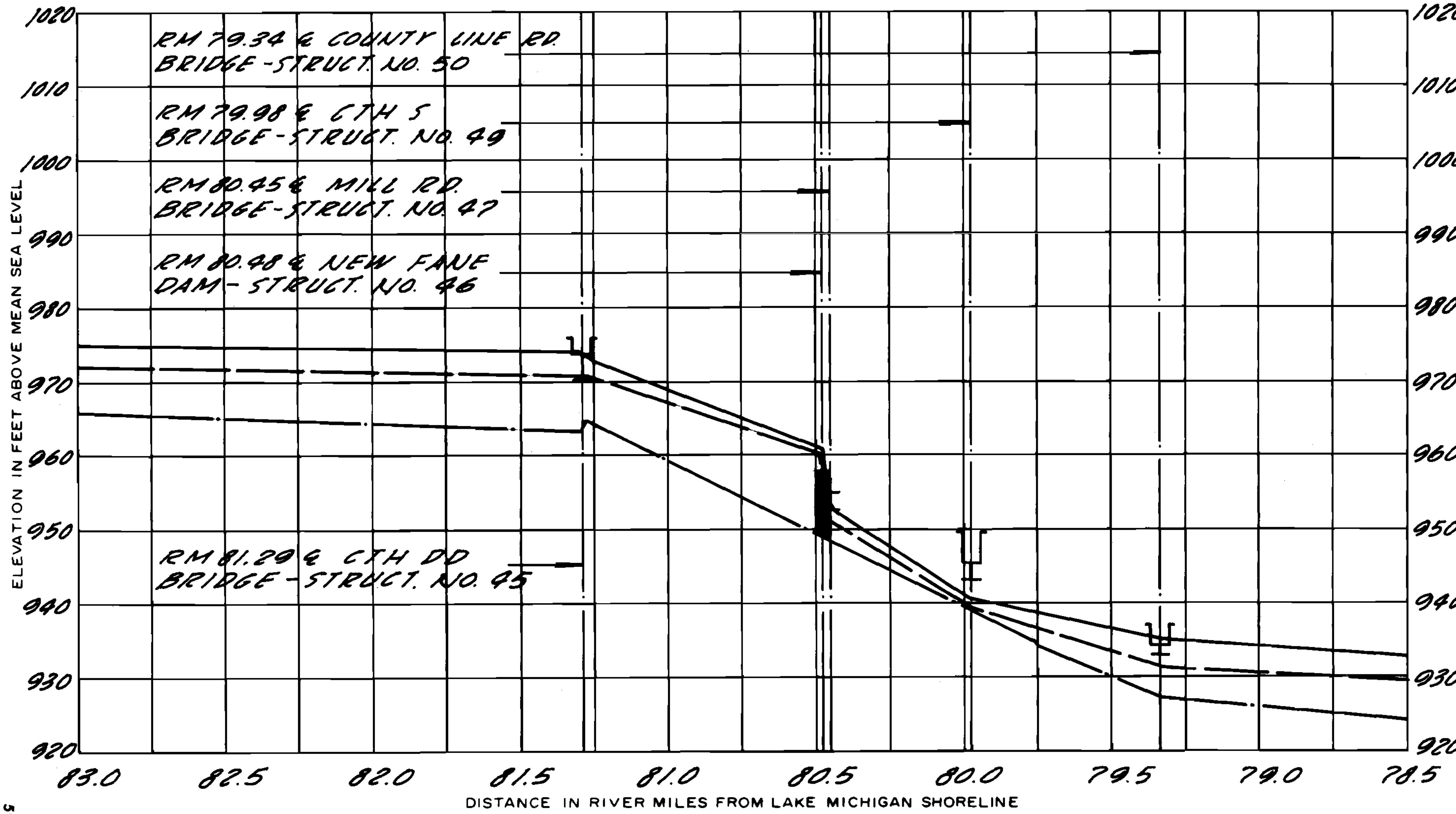
CHECKED BY: S. G. W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-7 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
EAST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

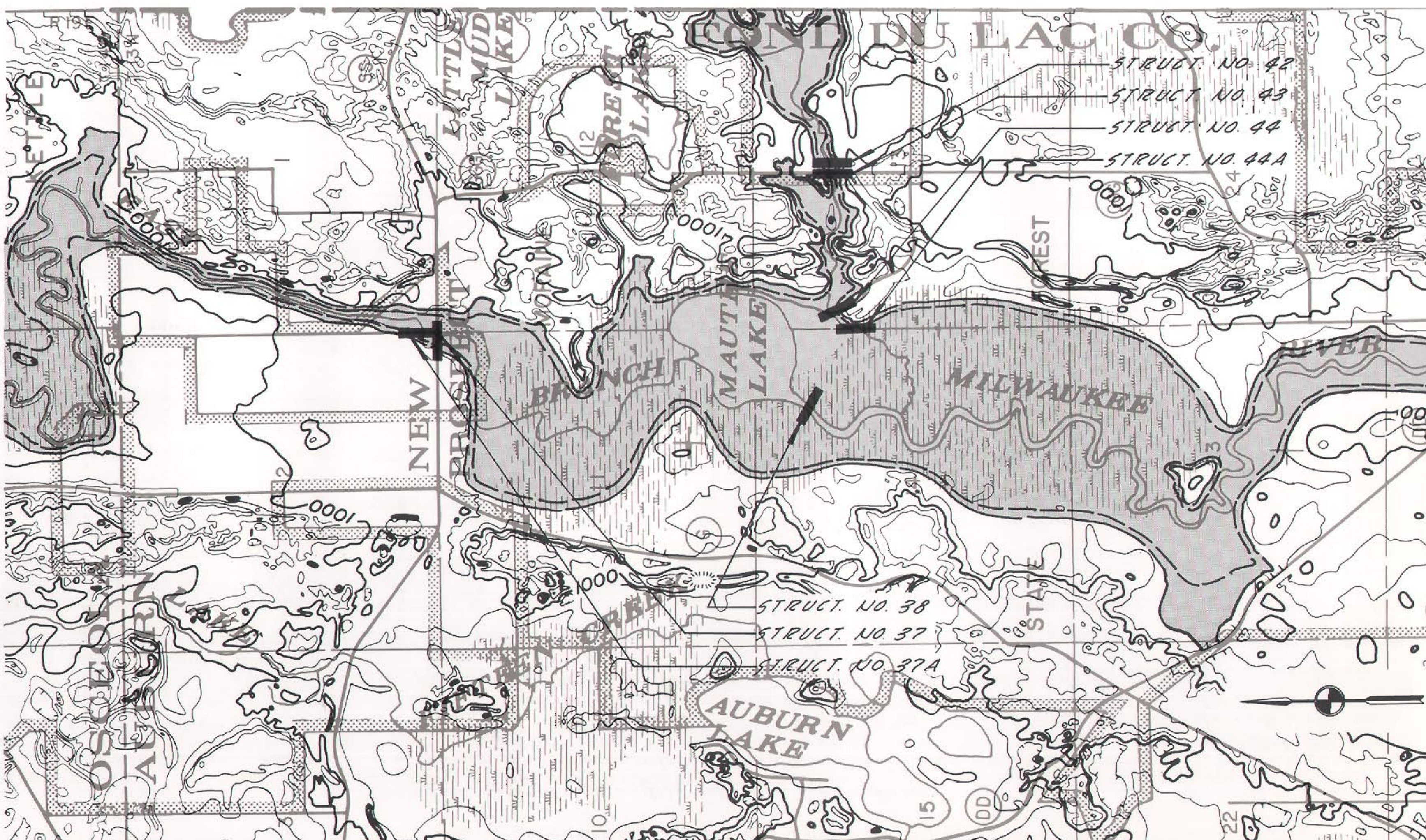
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-7 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
EAST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

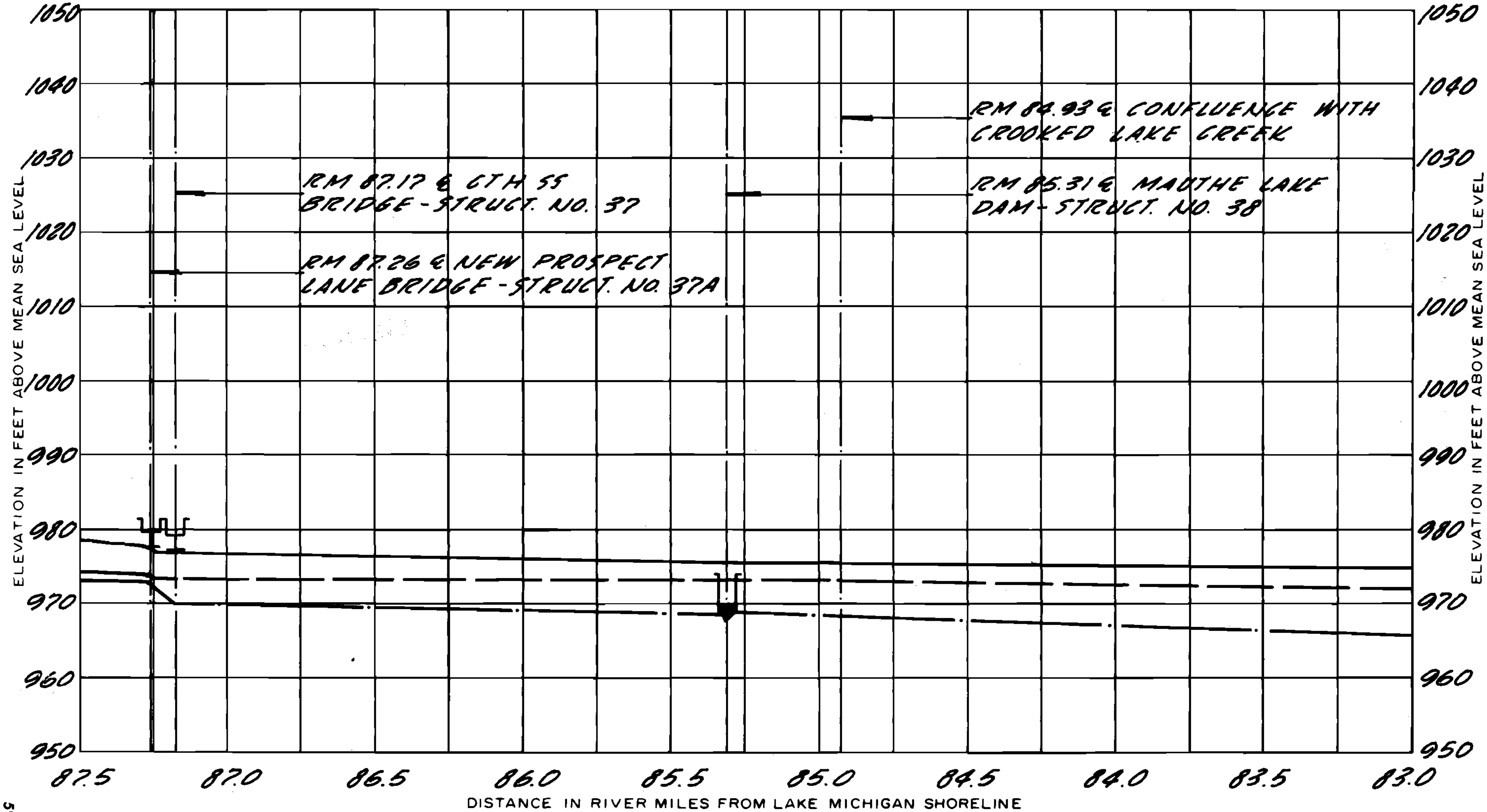
CHECKED BY: S.G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-7 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
EAST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

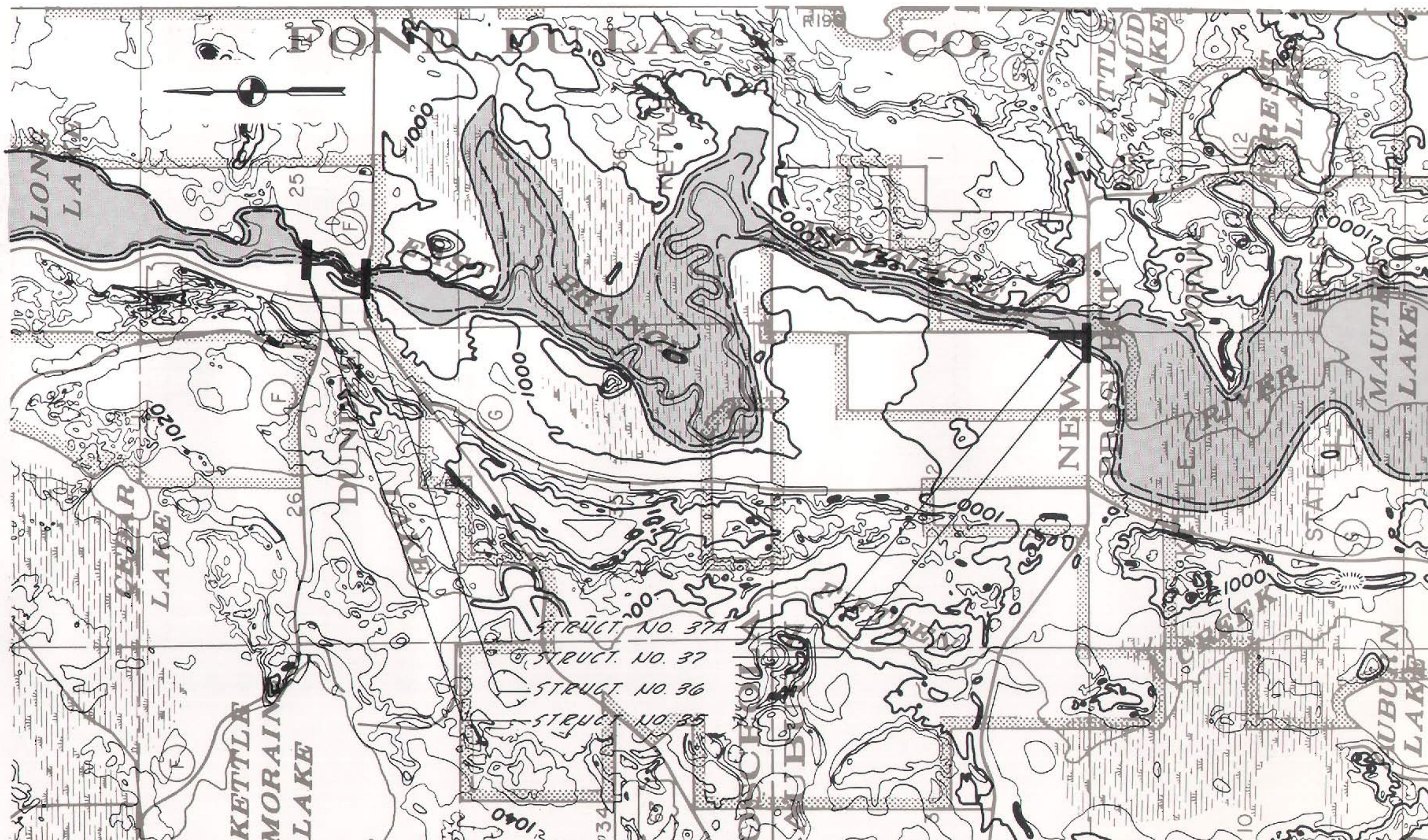
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

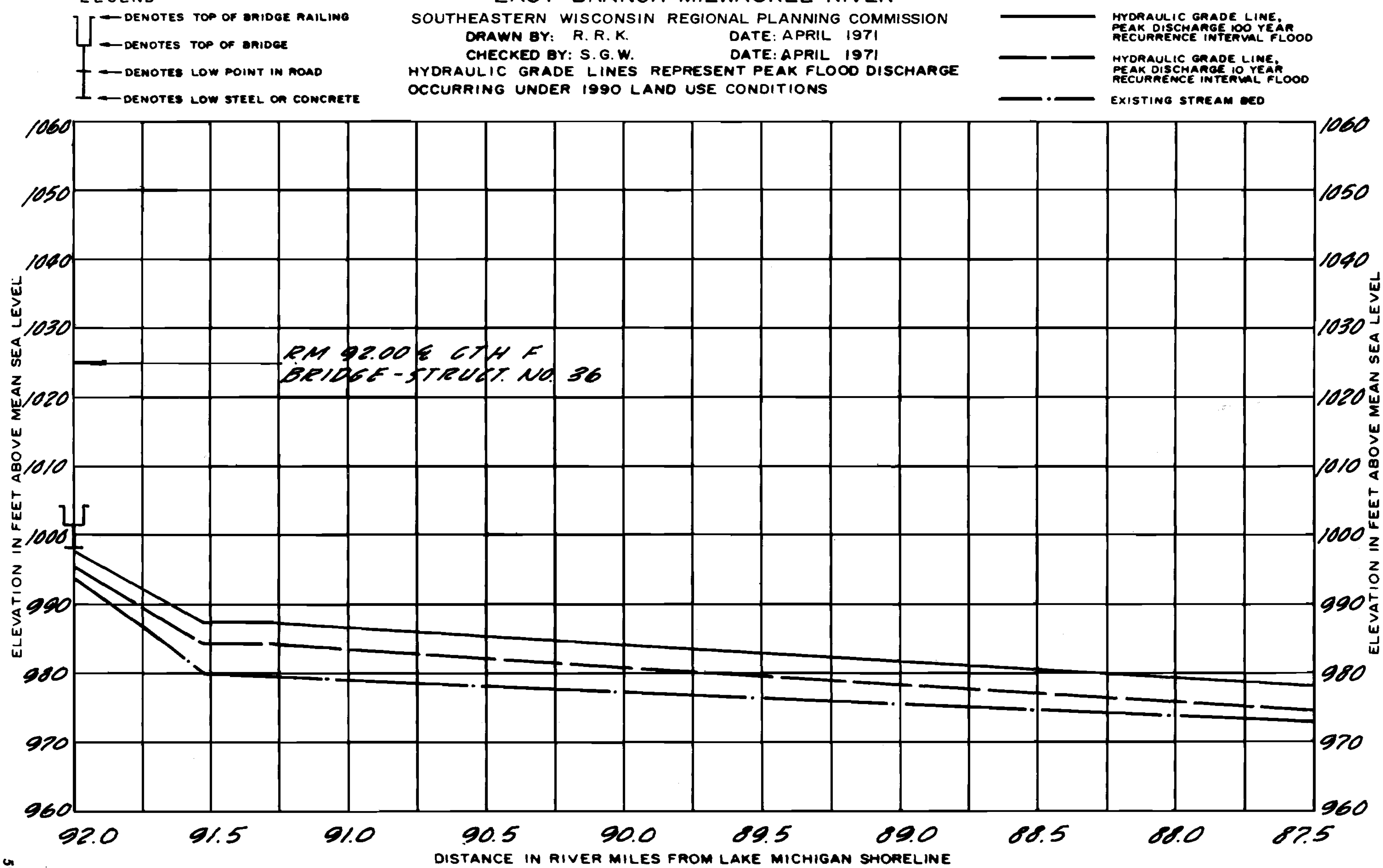
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-7(continued)

HIGH WATER AND STREAM BED PROFILES
FOR
EAST BRANCH MILWAUKEE RIVER



Source: *Harza Engineering Company and SEWRPC.*

Map F-7 (continued)
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
EAST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

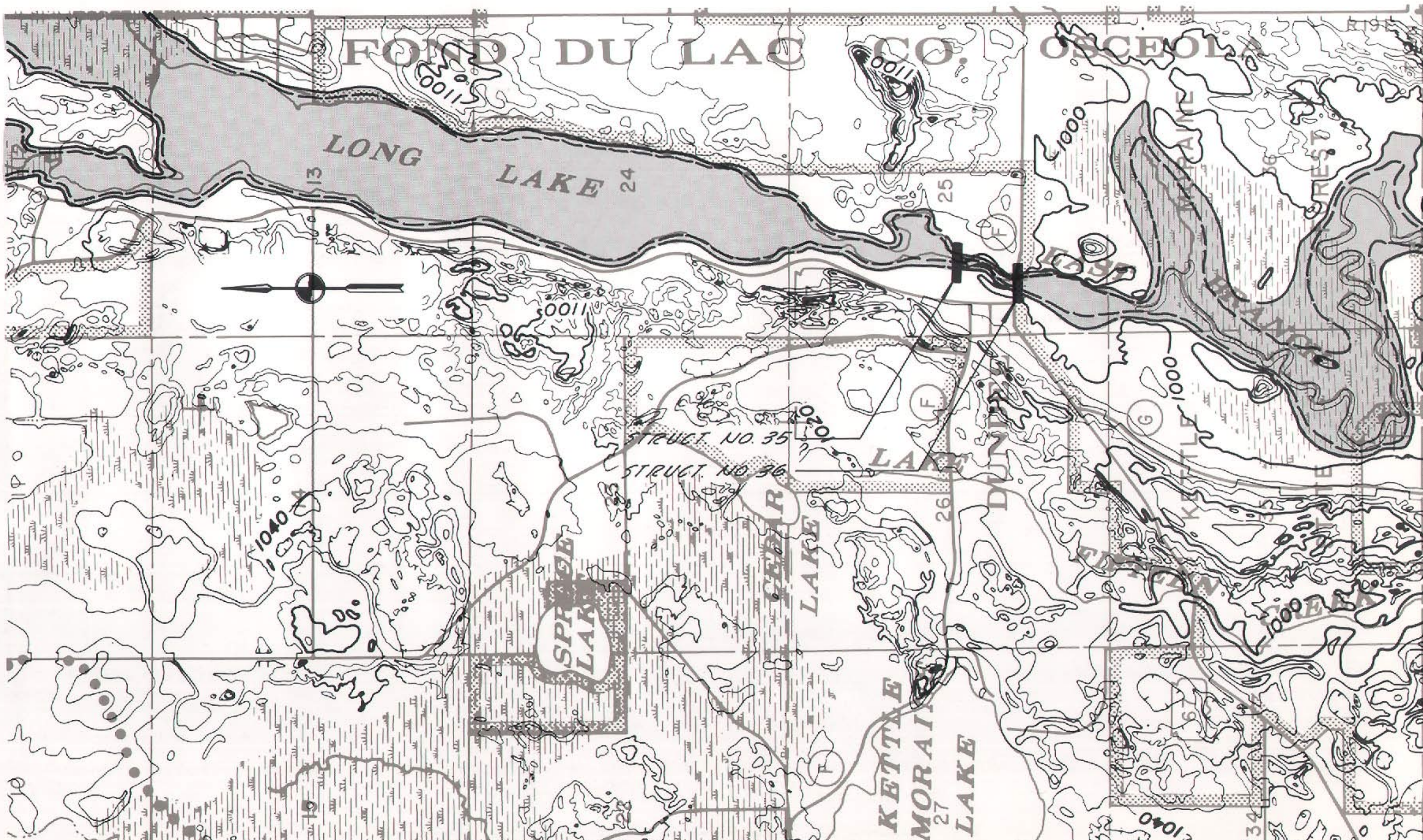
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

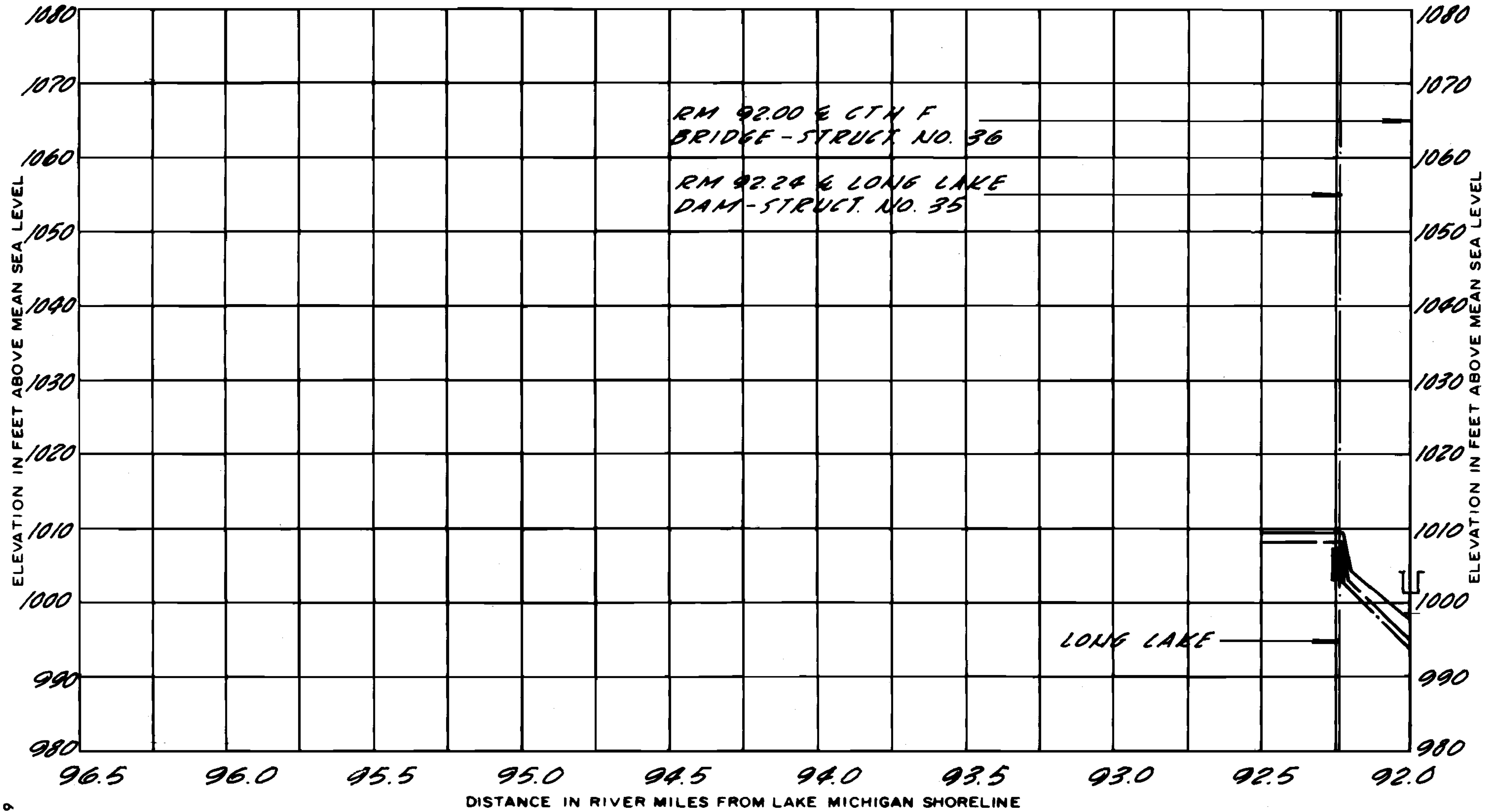
Figure F-7(continued)

HIGH WATER AND STREAM BED PROFILES
FOR
EAST BRANCH MILWAUKEE RIVER

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE
OCCURRING UNDER 1990 LAND USE CONDITIONS

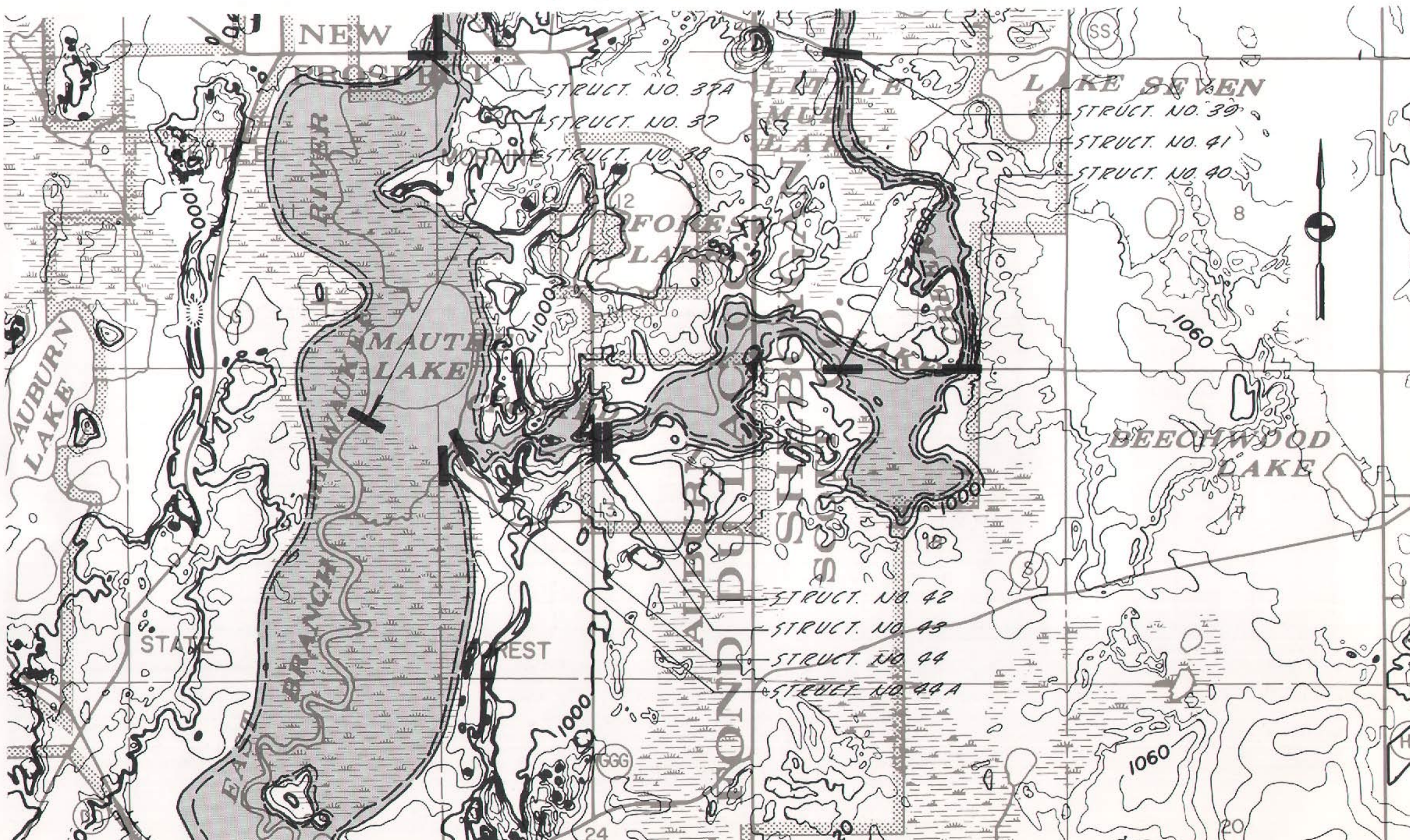
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-8
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CROOKED LAKE CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R.R.K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
SCALE 1" = 2640'
GRAPHIC SCALE
0 1/2 1 MILE



LEGEND
DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

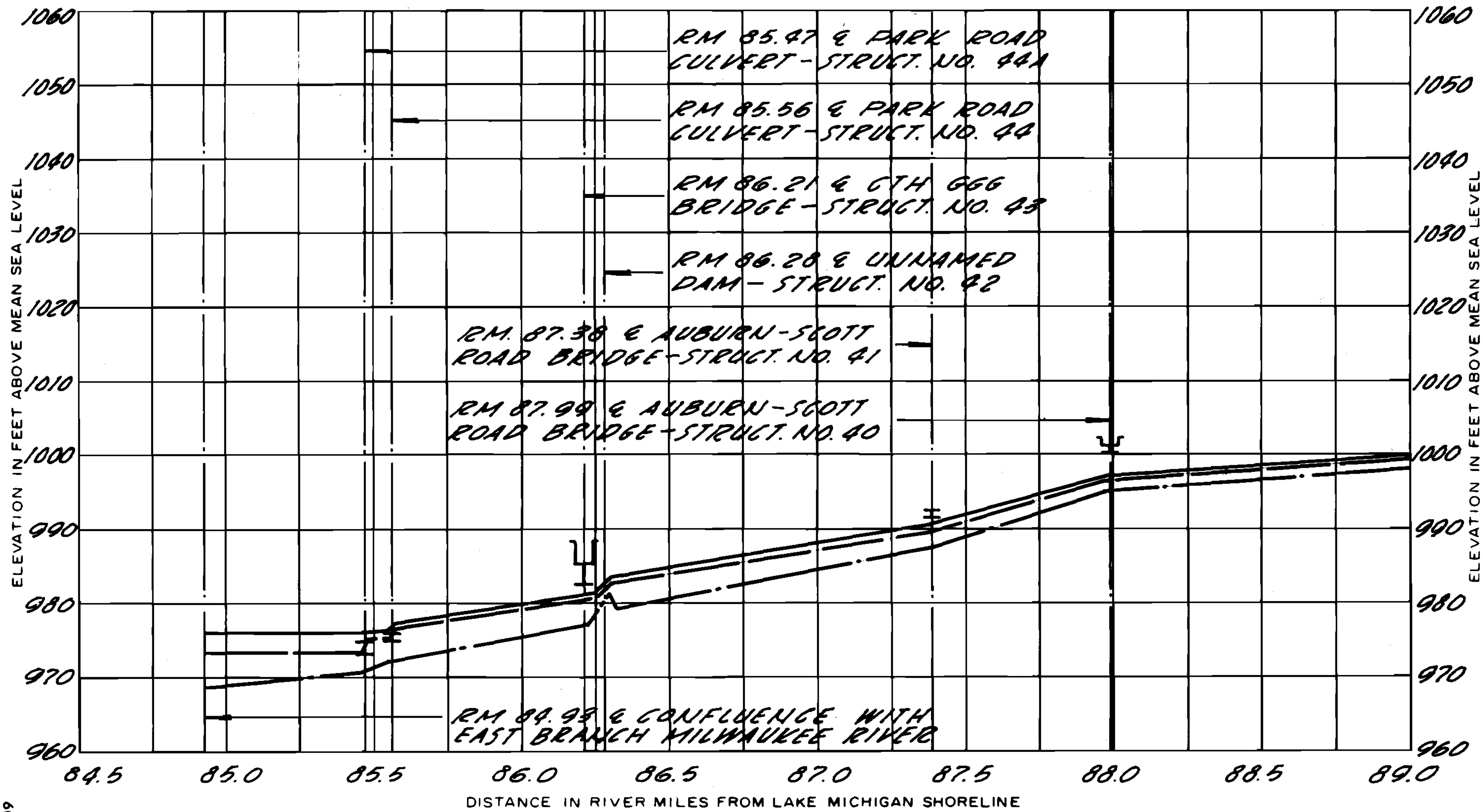
ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT
NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-8
HIGH WATER AND STREAM BED PROFILES
FOR
CROOKED LAKE CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-8 (continued)

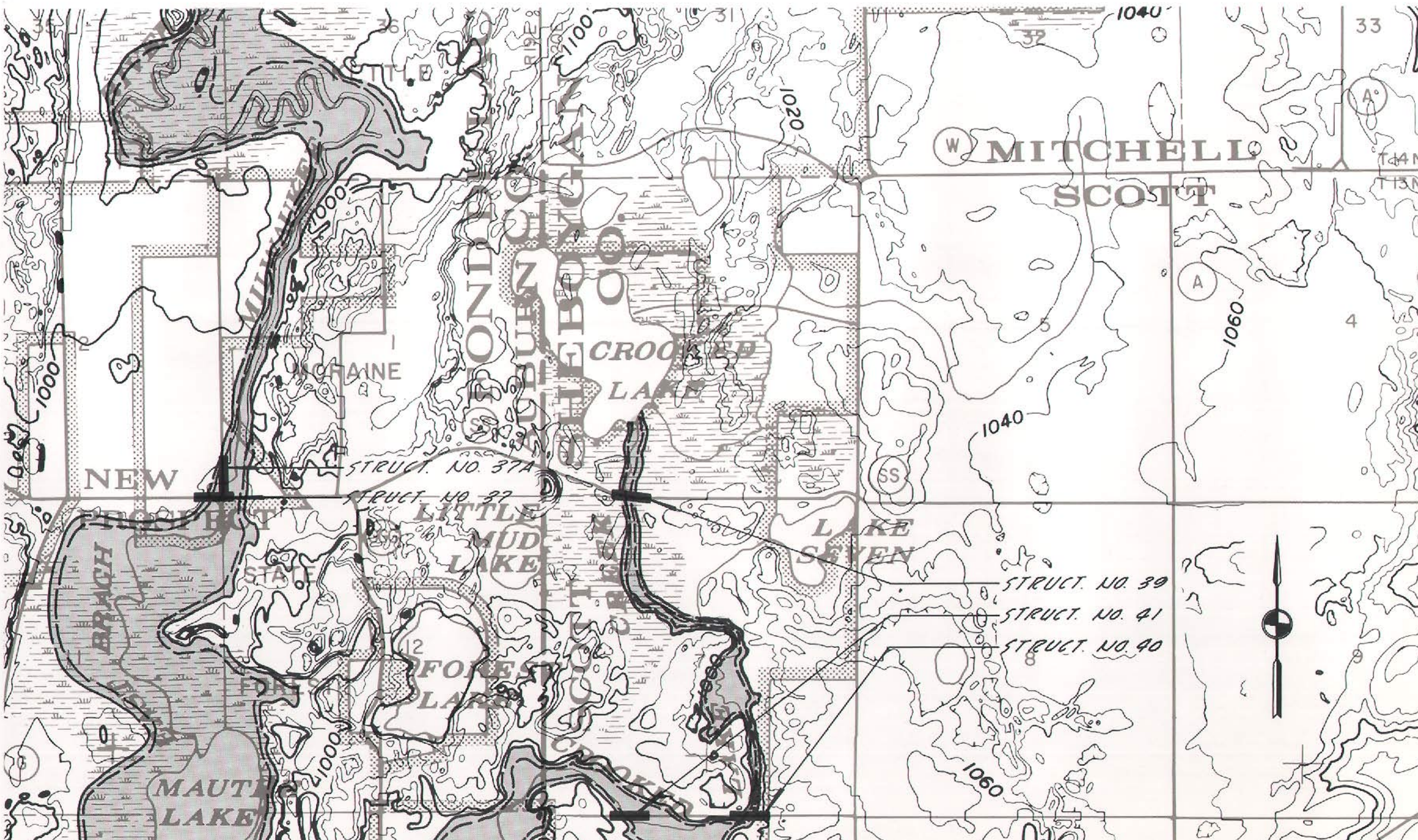
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
CROOKED LAKE CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R.R.K. DATE: APRIL 1971
CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

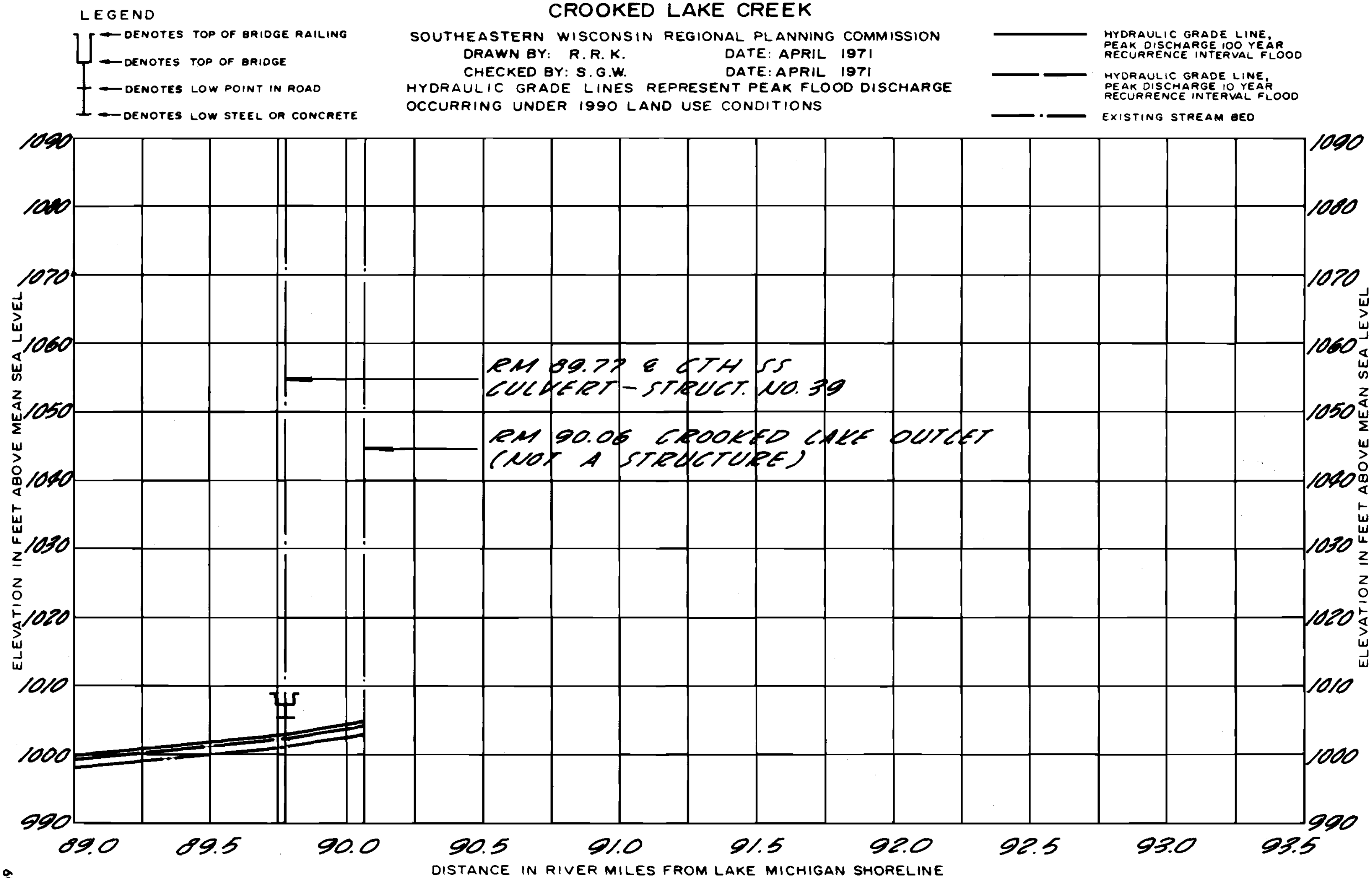
DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-8 (continued)

HIGH WATER AND STREAM BED PROFILES
FOR
CROOKED LAKE CREEK



Source: Harza Engineering Company and SEWRPC.

Map F-9
TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

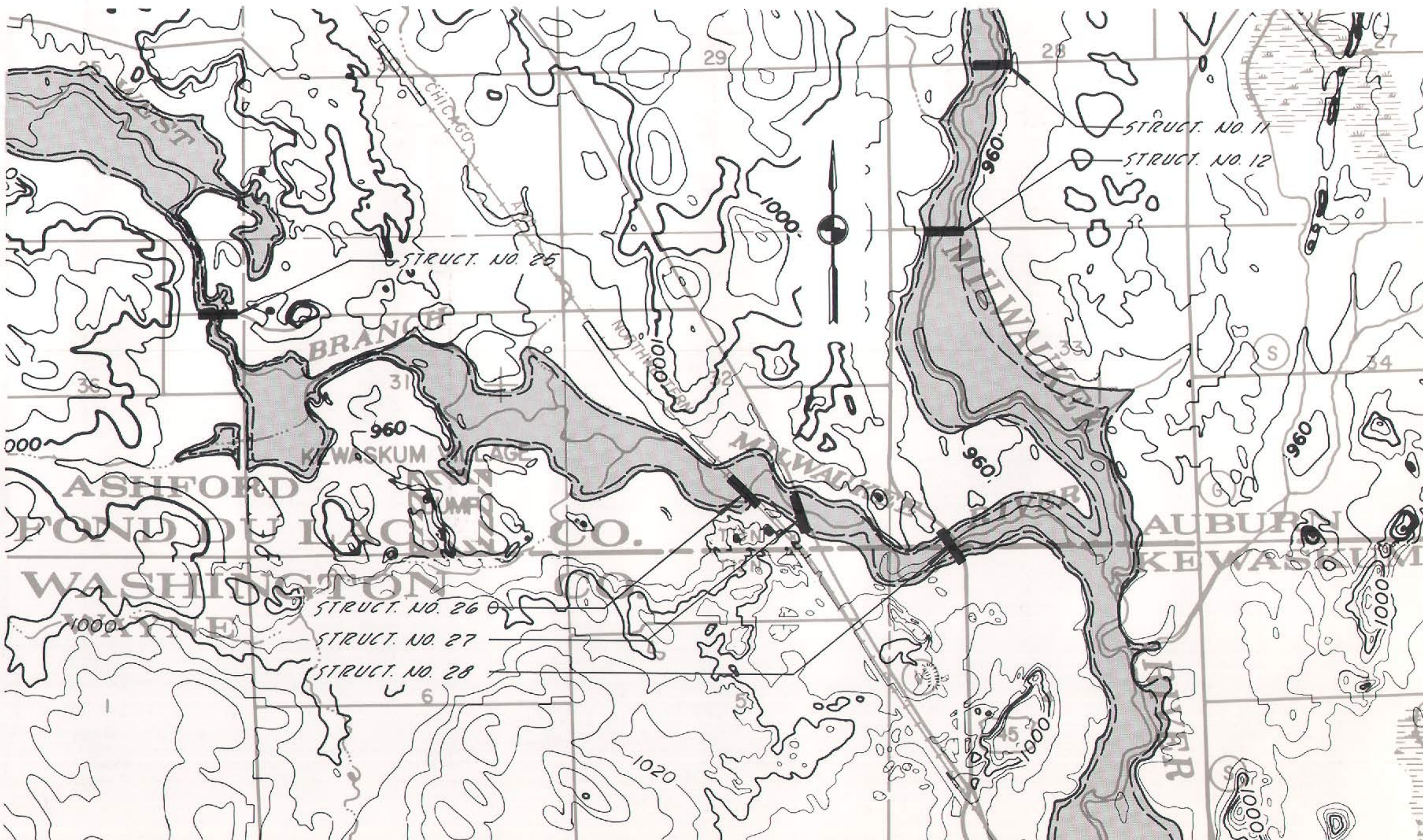
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

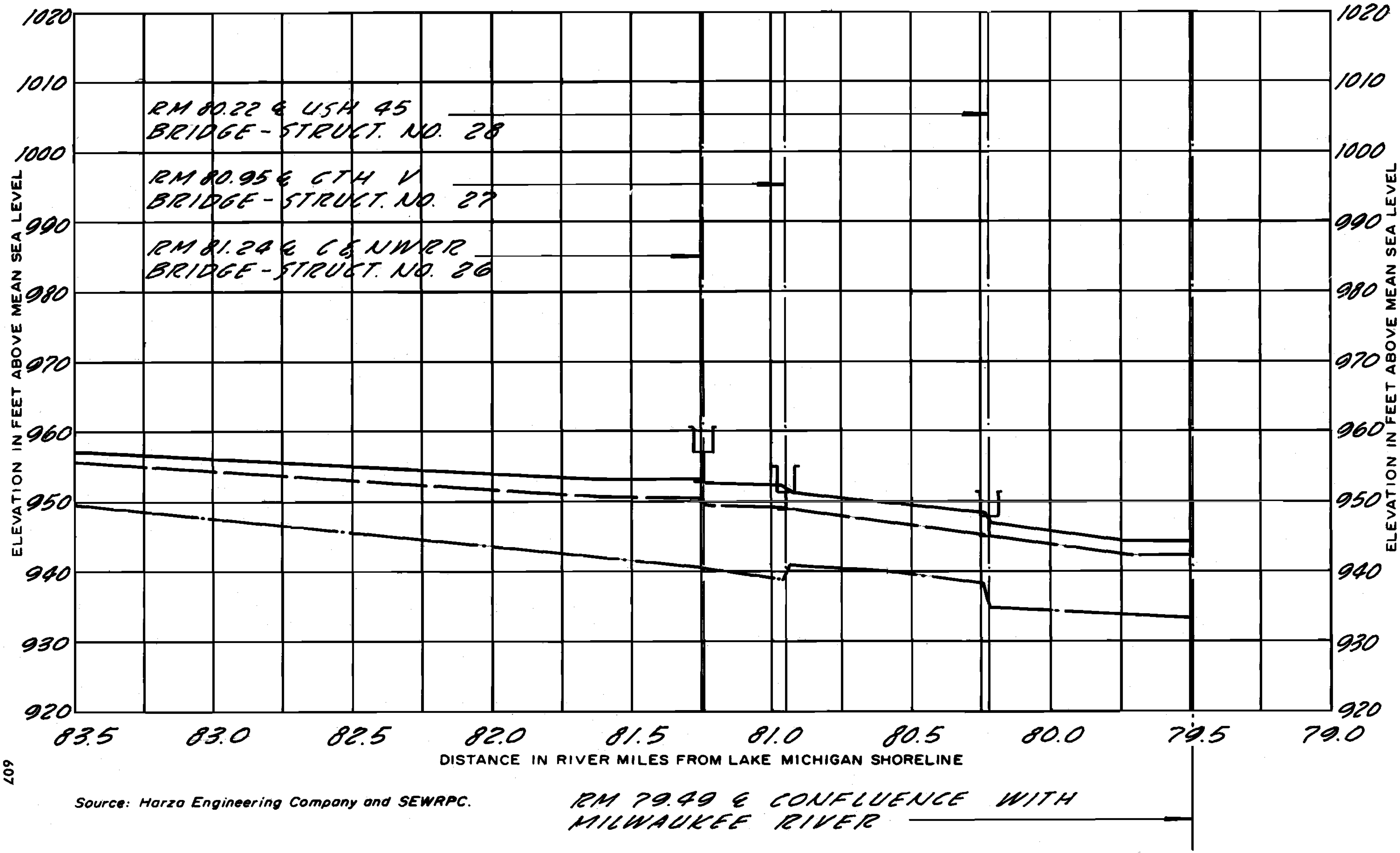
Figure F-9

HIGH WATER AND STREAM BED PROFILES
FOR
WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-9 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

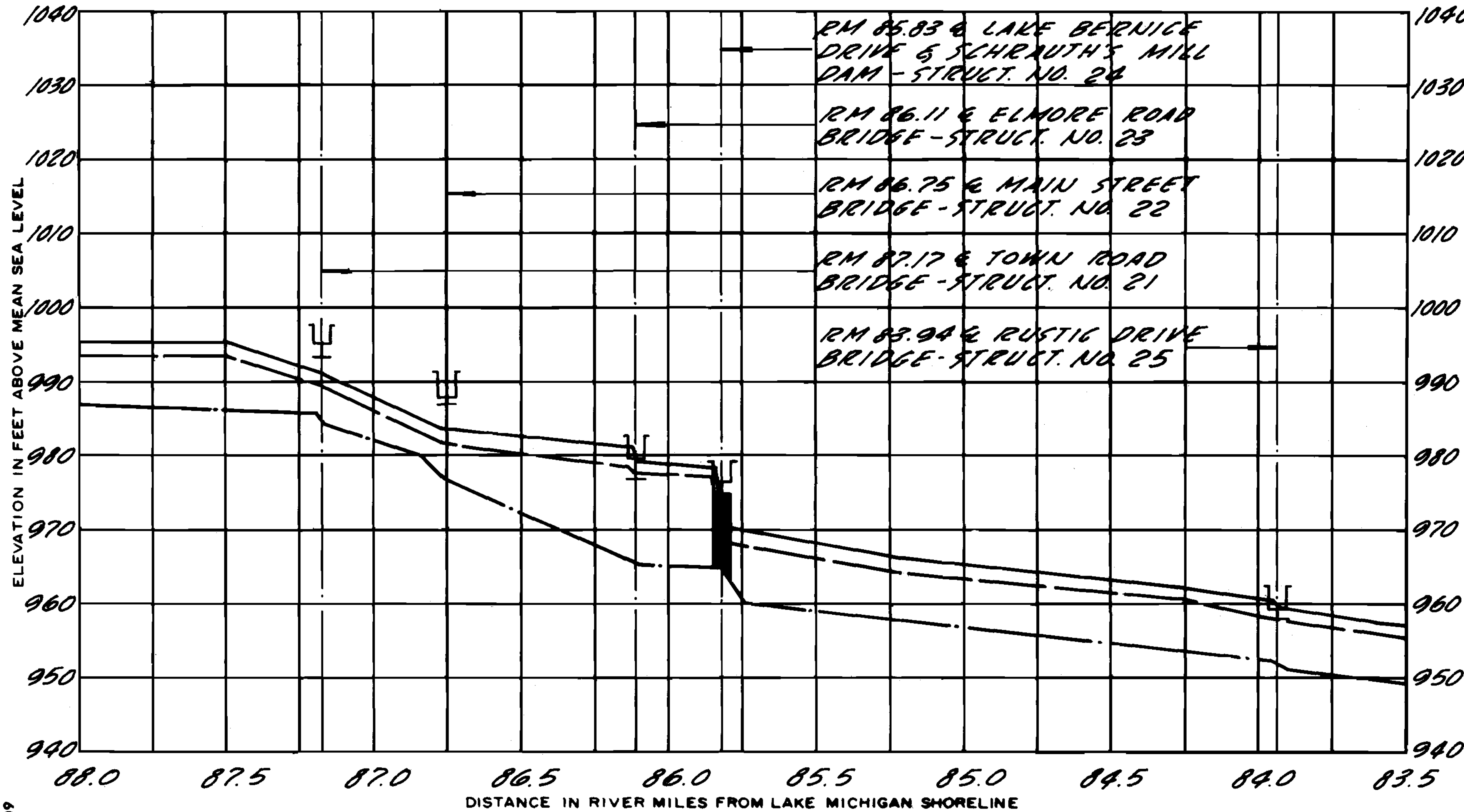
Figure F-9(continued)

HIGH WATER AND STREAM BED PROFILES
FOR
WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC.

Map F-9 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE

LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-9(continued)

HIGH WATER AND STREAM BED PROFILES

FOR

WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R.R.K. DATE: APRIL 1971

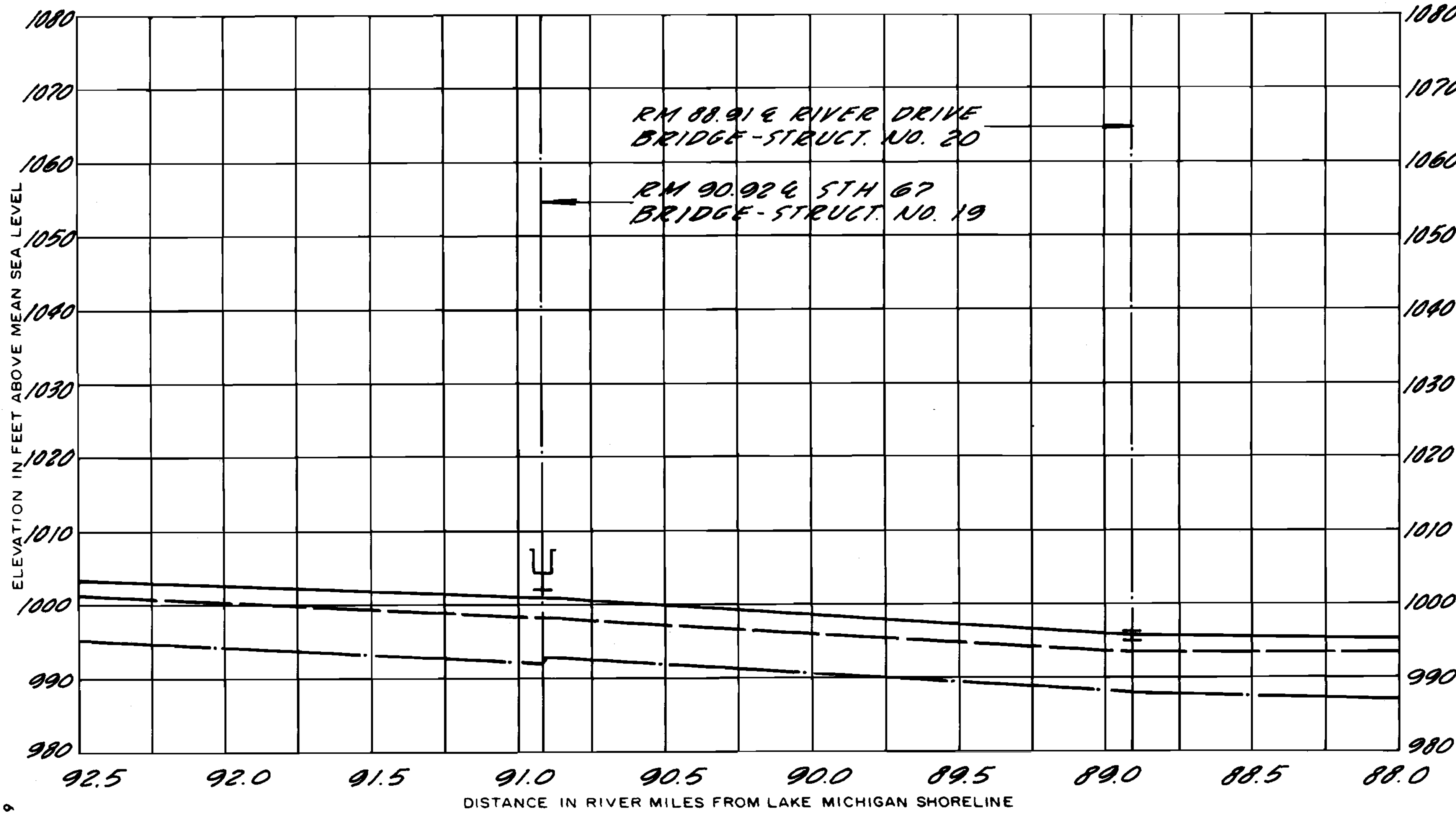
CHECKED BY: S.G.W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED



611

Source: Harza Engineering Company and SEWRPC.

Map F-9 (continued)

TOPOGRAPHIC MAP

SHOWING

AREAS SUBJECT TO FLOODING

ALONG

WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

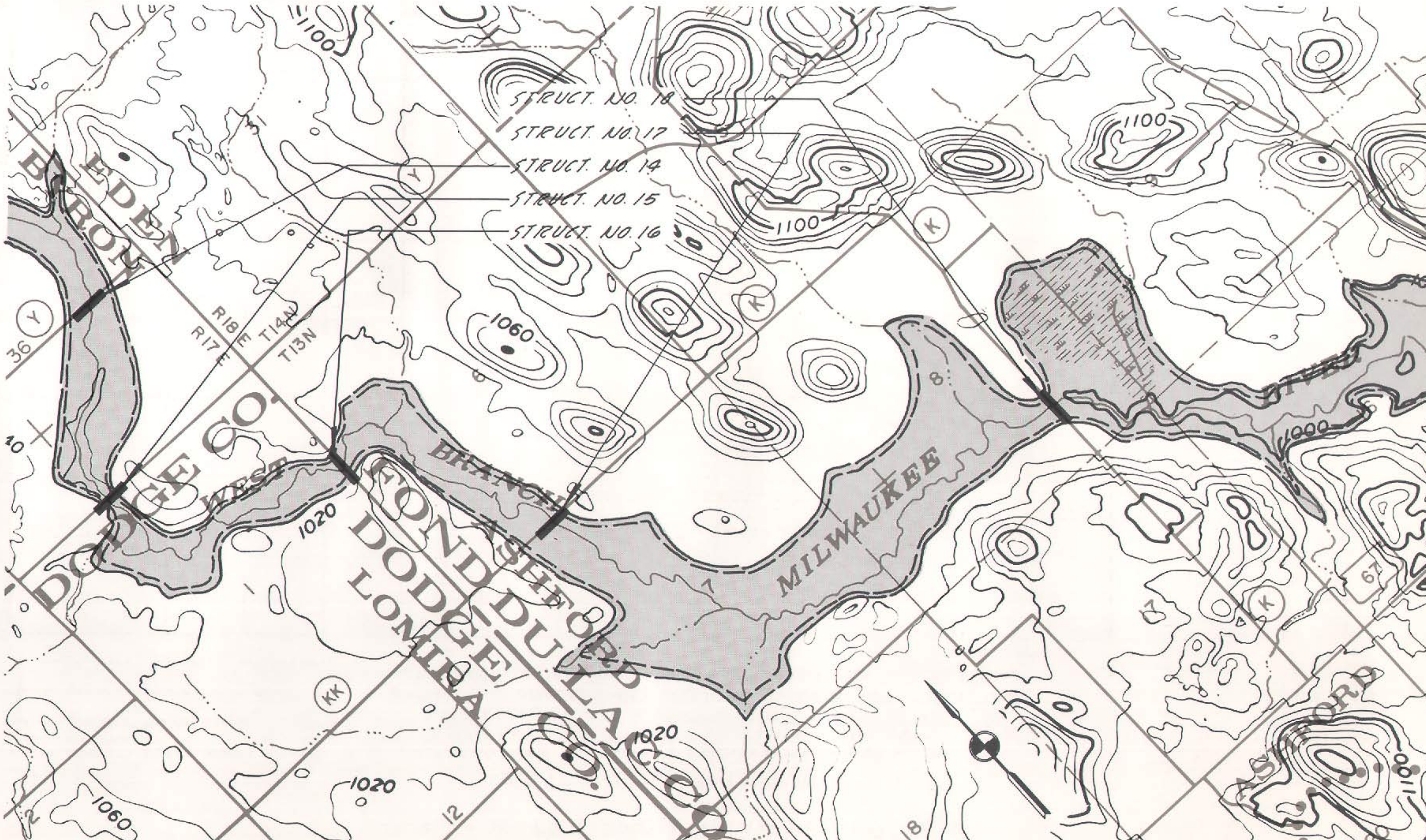
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

Figure F-9 (continued)

HIGH WATER AND STREAM BED PROFILES

FOR

WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

DRAWN BY: R. R. K. DATE: APRIL 1971

CHECKED BY: S. G. W. DATE: APRIL 1971

HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

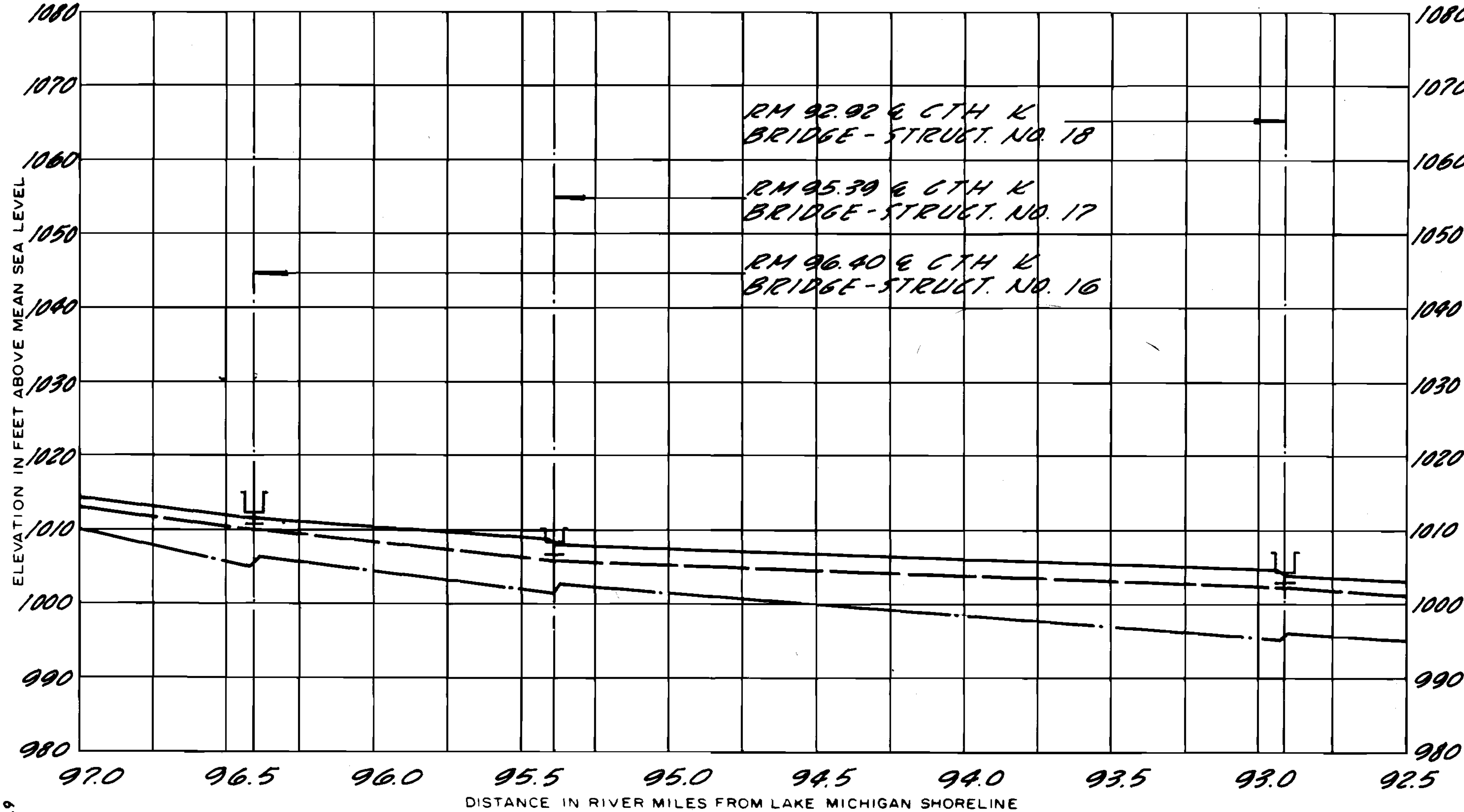
LEGEND

- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD

HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD

EXISTING STREAM BED



Source: Harza Engineering Company and SEWRPC

Map F-9 (continued)

TOPOGRAPHIC MAP
SHOWING
AREAS SUBJECT TO FLOODING
ALONG
WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

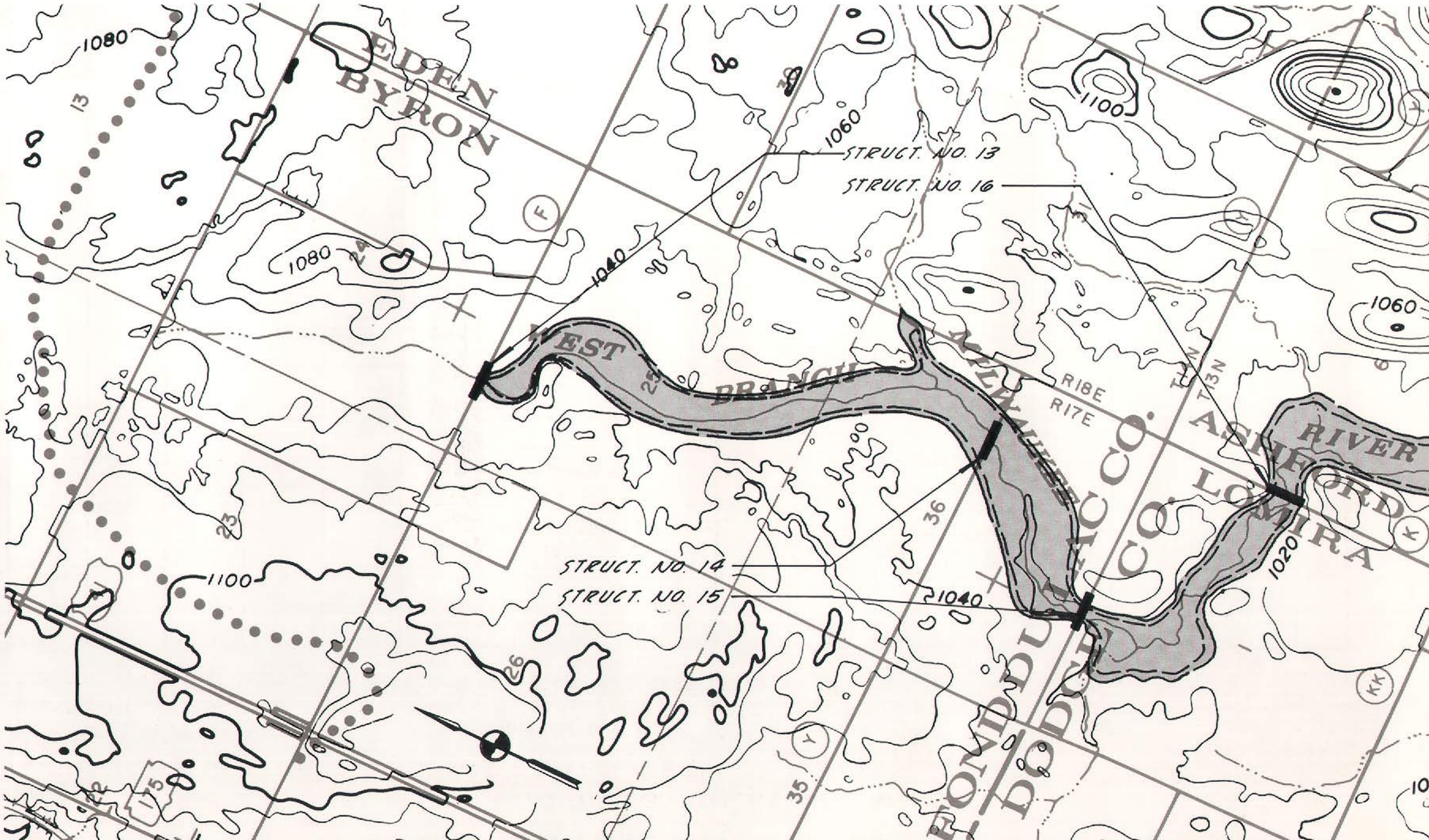
DRAWN BY: R.R.K. DATE: APRIL 1971

CHECKED BY: S.G.W. DATE: APRIL 1971

SCALE 1" = 2640'

GRAPHIC SCALE

0 1/2 1 MILE



LEGEND

DENOTES 10 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

DENOTES 100 YEAR RECURRENCE INTERVAL FLOOD INUNDATION LINE

ALL ELEVATIONS REFERRED TO MEAN SEA LEVEL; 1929 ADJUSTMENT

NOTE: CONTOUR INTERVAL 20 FEET.

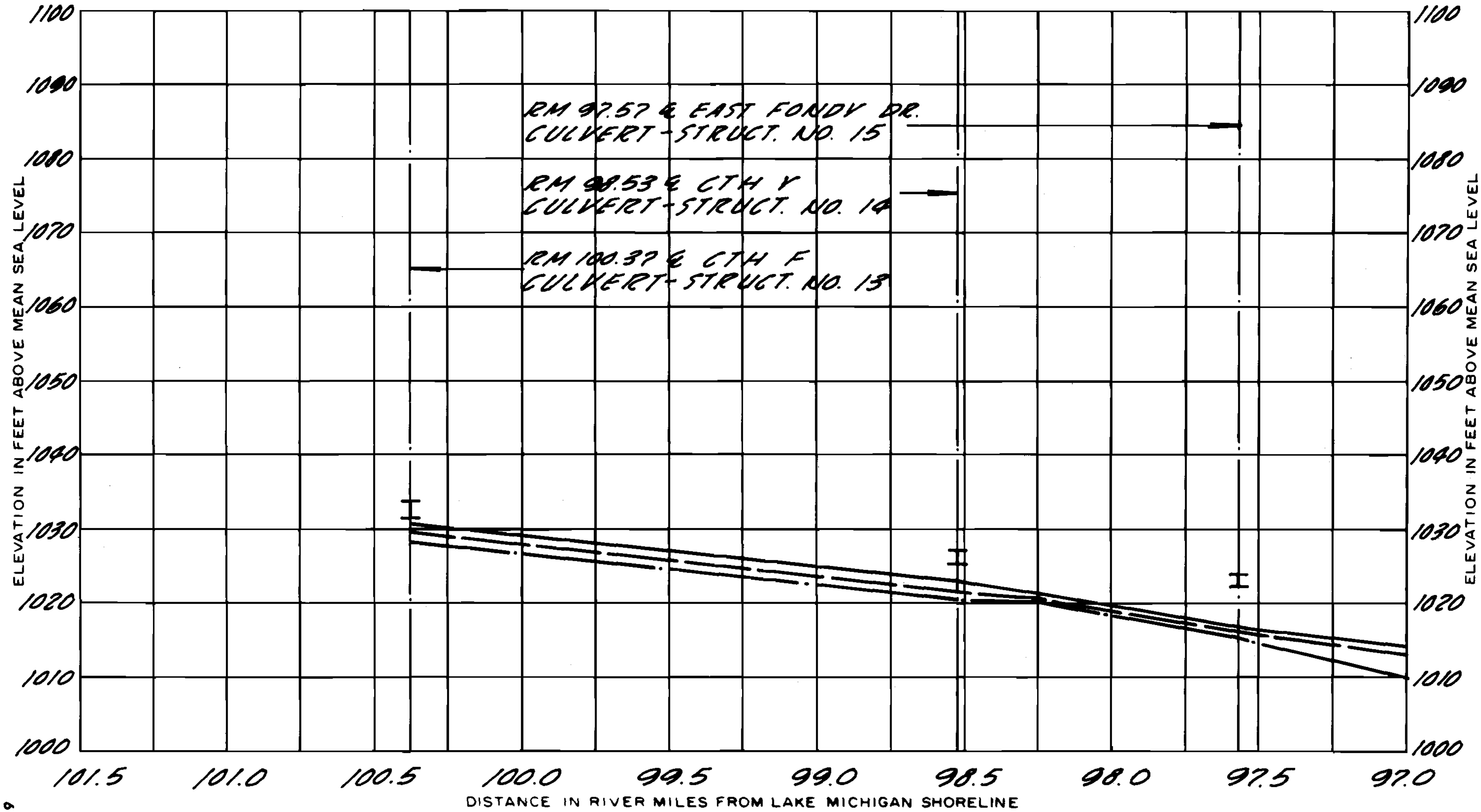
Figure F-9 (continued)

HIGH WATER AND STREAM BED PROFILES FOR WEST BRANCH MILWAUKEE RIVER

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
DRAWN BY: R. R. K. DATE: APRIL 1971
CHECKED BY: S. G. W. DATE: APRIL 1971
HYDRAULIC GRADE LINES REPRESENT PEAK FLOOD DISCHARGE OCCURRING UNDER 1990 LAND USE CONDITIONS

LEGEND
- DENOTES TOP OF BRIDGE RAILING
- DENOTES TOP OF BRIDGE
- DENOTES LOW POINT IN ROAD
- DENOTES LOW STEEL OR CONCRETE

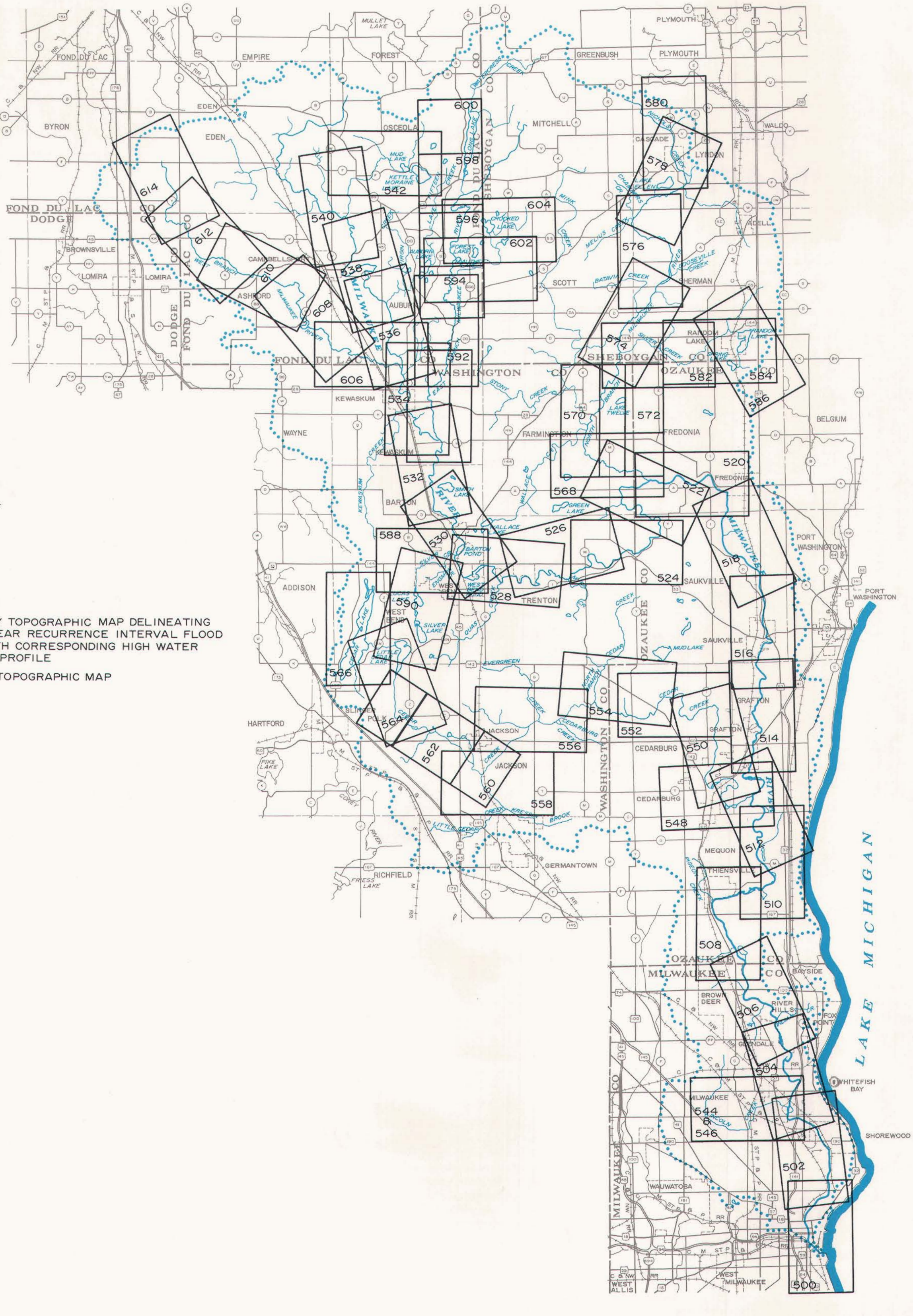
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 100 YEAR RECURRENCE INTERVAL FLOOD
- HYDRAULIC GRADE LINE, PEAK DISCHARGE 10 YEAR RECURRENCE INTERVAL FLOOD
- EXISTING STREAM BED

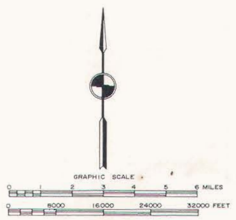


Source: Harza Engineering Company and SEWRPC.

Map F-10

INDEX MAP TO TOPOGRAPHIC MAPS SHOWING AREAS SUBJECT TO FLOODING FOR THE MILWAUKEE RIVER AND SELECTED MAJOR TRIBUTARIES





LEGEND

☐	AREA COVERED BY TOPOGRAPHIC MAP DELINEATING THE 10 AND 100 YEAR RECURRENCE INTERVAL FLOOD HAZARD LINES WITH CORRESPONDING HIGH WATER AND STREAM BED PROFILE
500	PAGE NUMBER OF TOPOGRAPHIC MAP

Appendix G

HYDRAULIC DATA SUMMARY FOR BRIDGES OVER THE MILWAUKEE RIVER AND SELECTED MAJOR TRIBUTARIES

Table G-1

HYDRAULIC ANALYSIS SUMMARY LOWER MILWAUKEE RIVER

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
237	C & N W R R	1953	100	YES	13,100	583.0	0.0	-24.4	-24.4	19,400	583.0	0.0	-24.4	-24.4	26,700	583.0	0.0	-24.4	-24.4
236	BROADWAY ST	1903	50	YES	13,100	583.0	0.0	-12.6	-12.6	19,400	583.0	0.0	-12.6	-12.6	26,700	583.0	0.0	-12.6	-12.6
235	WATER ST	1910	50	YES	13,100	583.0	0.0	-12.6	-12.6	19,400	583.0	0.0	-12.6	-12.6	26,700	583.0	0.0	-12.6	-12.6
234	BUFFALO ST	1914	10	YES	10,300	583.0	0.0	-11.1	-11.1	14,800	583.1	0.0	-11.0	-11.0	16,700	583.2	0.0	-10.9	-10.9
233	ST PAUL ST	1966	50	YES	10,300	583.0	0.0	-14.3	-14.3	14,800	583.1	0.0	-14.2	-14.2	16,700	583.2	0.0	-14.1	-14.1
231	CLYBOURN ST	1968	50	YES	10,300	583.0	0.0	-14.0	-14.0	14,800	583.1	0.0	-13.9	-13.9	16,700	583.3	0.1	-13.7	-13.7
230	MICHIGAN ST	1910	50	YES	10,300	583.1	0.1	-13.0	-13.0	14,800	583.3	0.2	-12.8	-12.8	16,700	583.4	0.1	-12.7	-12.7
229	WISCONSIN AV	1902	50	YES	10,300	583.2	0.1	-10.9	-10.9	14,800	583.4	0.1	-10.7	-10.7	16,700	583.7	0.3	-10.4	-10.4
228	WELLS ST	1912	50	YES	10,300	583.3	0.1	-10.1	-10.1	14,800	583.6	0.1	- 9.8	- 9.8	16,700	583.9	0.1	- 9.5	- 9.5
227	KILBOURN AV	1929	50	YES	10,300	583.4	0.1	-14.7	-14.7	14,800	583.9	0.1	-14.2	-14.2	16,700	584.2	0.1	-13.9	-13.9
226	STATE ST	1924	50	YES	10,300	583.4	0.0	-13.7	-13.7	14,800	583.9	0.0	-13.2	-13.2	16,700	584.2	0.0	-12.9	-12.9
225	JUNEAU ST	1954	50	YES	10,300	583.4	0.0	-15.2	-15.2	14,800	583.9	0.0	-14.7	-14.7	16,700	584.3	0.1	-14.3	-14.3
224	CHERRY ST	1940	50	YES	10,300	583.5	0.0	-15.1	-15.1	14,800	584.1	0.0	-14.5	-14.5	16,700	584.5	0.0	-14.1	-14.1
223	PLEASANT ST	1887	50	YES	10,300	583.6	0.1	-13.1	-13.1	14,800	584.2	0.0	-12.5	-12.5	16,700	584.6	0.0	-12.1	-12.1
222	HOLTON ST	1926	50	YES	10,300	583.6	0.0	-63.2	-63.2	14,800	584.3	0.0	-62.5	-62.5	16,700	584.8	0.0	-62.0	-62.0
221	HUMBOLDT AV	1958	50	YES	10,300	583.7	0.0	-22.4	-22.4	14,800	584.5	0.0	-21.6	-21.6	16,700	584.9	0.0	-21.2	-21.2
219	NORTH AV	1921	50	YES	10,320	599.3	0.0	-34.2	-42.4	14,800	600.5	0.0	-33.0	-41.2	16,680	601.1	0.1	-32.4	-40.6
218	LOCUST ST	1894	50	YES	10,320	600.3	0.1	-47.5	-49.7	14,800	601.7	0.0	-46.1	-48.3	16,680	602.3	0.0	-45.5	-47.7
217	CAPITOL DR	1927	50	YES	10,320	603.6	0.1	-30.9	-32.5	14,800	605.5	0.2	-29.0	-30.6	16,680	606.2	0.1	-28.3	-29.9
216	C & NWRR	1922	100	YES	10,320	614.9	0.1	-24.5	-25.7	14,600	615.5	0.1	-23.9	-25.1	16,680	615.7	0.0	-23.7	-24.9
212	PORT WASHINGTON RD	1913	50	YES	10,127	617.4	0.0	-11.6	-13.7	14,600	618.5	0.1	-10.5	-12.6	16,444	618.8	0.1	-10.2	-12.3
211	USH 141	1959	100	YES	10,127	617.6	0.1	-28.0	-35.4	14,600	618.6	0.1	-27.0	-34.4	16,444	619.0	0.1	-26.6	-34.0
210	USH 141 RAMP	1959	100	YES	10,127	617.9	0.1	-20.4	-21.7	14,600	619.1	0.1	-19.2	-20.5	16,444	619.5	0.1	-18.8	-20.1
209A	NEW HAMPTON AV	1969	50	YES	10,127	619.0	0.0	-12.6	-13.6	14,600	620.5	0.0	-11.1	-12.1	16,444	621.1	0.0	-10.5	-11.5
208	C & NWRR	1911	100	YES	9,894	619.6	0.1	-13.5	-13.6	14,500	621.4	0.2	-11.7	-11.8	16,136	622.0	0.2	-11.1	-11.2
207	SILVER SPRING DR	1956	50	YES	9,894	622.2	0.0	- 7.4	- 8.9	14,500	624.4	0.1	- 5.2	- 6.7	16,136	625.1	0.1	- 4.5	- 6.0
206	BENDER RD	1929	50	NO[a]	9,894	628.1	0.0	3.1	- 9.1	14,500	629.7	0.0	4.7	- 7.5	16,136	630.1	0.0	5.1	- 7.1
205	C & NWRR	1938	100	YES	9,894	628.9	0.1	-37.9	-37.9	14,500	630.8	0.2	-36.0	-36.0	16,136	631.2	0.3	-35.6	-35.6
203	GREEN TREE RD	1918	50	YES	9,894	633.5	1.1	- 8.6	-12.9	14,500	635.3	1.9	- 6.8	-11.1	16,136	636.0	2.2	- 6.1	-10.4
202A	GOOD HOPE RD	1966	50	YES	9,894	636.3	0.0	- 5.1	- 6.6	14,500	638.5	0.0	- 2.9	- 4.4	16,136	639.3	0.0	- 2.1	- 3.6
202	GOOD HOPE RD	1966	50	YES	9,894	636.3	0.0	- 5.1	-18.1	14,500	638.5	0.0	- 2.9	-15.9	16,136	639.3	0.0	- 2.1	-15.1
201A	GOOD HOPE RD	1966	50	YES	9,894	636.4	0.0	- 5.0	- 6.5	14,500	638.6	0.0	- 2.8	- 4.3	16,136	639.4	0.0	- 2.0	- 3.5
201	GOOD HOPE RD	1966	50	YES	9,894	636.4	0.0	- 5.0	-18.0	14,500	638.6	0.0	- 2.8	-15.8	16,136	639.4	0.0	- 2.0	-15.0
200	GOLF COURSE PEDESTRIAN BRIDGE	(C)1968	--	--	9,653	643.1	0.0	- 4.2	- 7.4	14,000	644.8	0.0	- 2.5	- 5.7	15,830	645.5	0.1	- 1.8	- 5.0
199	GOLF COURSE PEDESTRIAN BRIDGE	(C)1965	--	--	9,653	645.7	0.0	- 1.6	- 5.4	14,000	647.5	0.2	0.2	- 3.6	15,830	648.0	0.1	0.7	- 3.1
198	RANGE LINE RD	UNKNOWN	50	YES	9,653	647.0	0.1	- 3.2	-11.0	14,000	648.8	0.0	- 1.4	- 9.2	15,830	649.4	0.0	- 0.8	- 8.6
197	BROWN DEER RD	1933	50	YES	9,653	647.4	0.1	- 3.7	- 9.2	14,000	649.2	0.3	- 1.9	- 7.4	15,830	649.8	0.4	- 1.3	- 6.8
196	STH 167	1927	50	YES	9,530	655.3	0.0	- 2.4	- 7.3	13,700	657.3	0.0	- 0.4	- 5.3	15,669	658.1	0.0	0.4	- 4.5
194	CTH M	1949	50	NO	9,530	661.9	0.0	- 1.2	- 6.4	13,700	663.8	0.3	0.7	- 4.5	15,669	664.6	0.3	1.5	- 3.7
193	CTH C	1953	50	YES	9,530	667.8	0.0	- 2.8	- 5.8	13,700	669.6	0.0	- 1.0	- 4.0	15,669	670.3	0.0	- 0.3	- 3.3
150A	CTH T	1964	10	YES	7,129	680.0	0.0	- 3.3	-12.1	10,400	681.1	0.0	- 2.2	-11.0	11,892	681.5	0.0	- 1.8	-10.6
148	BRIDGE ST	1889	10	YES	7,129	726.5	0.0	-15.9	-15.9	10,400	728.1	0.0	-14.3	-14.3	11,892	728.8	0.0	-13.6	-13.6
146	STH 57	1928	50	YES	7,129	739.2	0.0	- 4.6	- 5.1	10,400	740.4	0.0	- 3.4	- 3.9	11,892	740.9	0.0	- 2.9	- 3.4
145	ABANDONED INTERURBAN R R	--	--	--	7,129	743.2	0.4	--	--	10,400	744.9	0.5	--	--	11,892	745.6	0.6	--	--
144	STH 33	1928	50	NO[a]	6,926	753.6	0.0	- 1.3	- 5.4	10,400	756.3	0.3	1.4	- 2.7	12,286	757.1	0.1	2.2	- 1.9
143	CM ST P & P RR	1902	100	YES	6,926	761.5	0.0	-11.9	-11.9	10,400	763.3	0.0	- 9.9	- 9.9	12,286	764.1	0.0	- 9.3	- 9.3
142A	CTH A	1968	50	YES	6,752	781.3	0.0	- 3.0	- 7.3	10,400	782.7	0.0	- 1.6	- 5.9	12,293	783.3	0.0	- 1.0	- 5.3
142	CTH I	(C)1950	50	YES	6,591	783.7	0.1	- 2.7	- 5.7	10,300	785.8	0.3	- 0.6	- 3.6	12,294	786.7	0.4	0.3	- 2.7

[a]STANDARD COULD BE MET BY ELEVATION OF APPROACH ROAD.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table G-2

HYDRAULIC ANALYSIS SUMMARY MIDDLE MILWAUKEE RIVER

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
89	CTH A	1952	50	NO[a]	5,478	800.4	0.2	- 0.2	- 4.4	8,400	802.1	0.2	1.5	- 2.7	9,766	802.8	0.2	2.2	- 2.0
87	CTH MY	1929	50	NO[a]	5,318	847.1	5.5[b]	2.5	- 4.9	8,200	848.1	4.7[b]	3.5	- 3.9	9,476	848.6	4.6[b]	4.0	- 3.4
85	STH 33	1930	50	YES	5,207	856.7	0.0	- 3.8	- 4.9	8,000	859.3	0.4	- 1.2	- 2.3	9,270	860.7	0.7	0.2	- 0.9
84	CTH M	1952	50	YES	5,207	856.6	0.0	- 4.4	- 4.7	8,000	859.8	0.5	- 1.2	- 1.5	9,270	861.2	0.6	0.2	- 0.1
82	INDIANA AV	1956	50	YES	4,970	880.3	0.0	- 6.7	-10.1	7,600	883.1	0.0	- 3.9	- 7.3	8,800	884.4	0.0	- 2.6	- 6.0
81	C & N W R R	1900	100	YES	4,970	881.3	0.0	-17.3	-17.3	7,600	884.2	0.0	-14.4	-14.4	8,800	885.5	0.0	-13.1	-13.1
80	WATER ST	1937	10	YES	4,970	885.9	0.0	- 6.1	- 6.1	7,600	887.3	0.0	- 4.7	- 4.7	8,800	888.3	0.0	- 3.7	- 3.7
79	PEDESTRIAN BRIDGE	(C)1910	--	--	4,970	889.7	1.3	1.1	1.1	7,600	892.0	1.3	3.4	3.4	8,800	892.9	1.3	4.3	4.3
78	STH 33	1917	50	YES	4,970	891.7	0.1	- 7.5	- 8.4	7,600	895.8	2.2	- 3.4	- 4.3	8,800	897.4	3.0	- 1.8	- 2.7
61	PEDESTRIAN BRIDGE	(C)1965	--	--	4,840	895.0	0.1	- 1.5	- 6.0	7,400	898.1	0.1	1.6	- 2.9	8,580	899.4	0.1	2.9	1.6
60	STH 144	1925	50	YES	4,840	900.7	0.0	-10.5	-11.4	7,400	902.5	0.0	- 8.7	- 9.6	8,580	903.2	0.0	- 8.0	- 8.9
58	C & N W R R	1900	100	YES	4,840	911.5	0.1	-21.5	-21.5	7,400	913.3	0.0	-19.7	-19.7	8,580	914.1	0.0	-18.9	-18.9
57	WOOD FORD DR	(C)1900	10	YES	4,840	913.0	0.0	- 4.0	- 4.0	7,400	914.7	0.0	- 2.3	- 2.3	8,580	915.4	0.0	- 1.6	- 1.6
55	LIGHTHOUSE LN	(C)1930	10	YES	4,640	921.5	0.0	- 0.7	- 3.1	7,000	924.9	2.1	2.7	0.3	8,220	925.6	2.2	3.4	1.0
53	CTH H	1950	50	NO	4,613	929.2	0.4	- 1.2	- 1.7	7,000	931.0	0.6	0.6	0.1	8,120	931.4	0.4	1.0	0.5

[a]STANDARD COULD BE MET BY ELEVATION OF APPROACH ROAD.

[b]THIS LARGE HEAD LOSS IS CAUSED PRIMARILY BY THE NEWBURG WEIR WHICH IS LOCATED BENEATH STRUCTURE NUMBER 87.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table G-3

HYDRAULIC ANALYSIS SUMMARY UPPER MILWAUKEE RIVER

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
29	STH 28	1928	50	YES	3,421	933.4	0.0	- 4.4	- 5.3	5,200	935.3	0.0	- 2.5	- 3.4	6,075	935.6	0.0	- 2.2	- 3.1
12	OLD BRIDGE RD	UNKNOWN	10	YES	1,661	947.4	0.0	- 3.5	- 4.9	2,500	948.8	0.0	- 2.1	- 3.5	2,928	949.2	0.0	- 1.7	- 3.1
11	AUBURN-ASHFORD RD	UNKNOWN	10	YES	1,661	952.7	0.1	- 6.4	- 8.1	2,500	953.7	0.1	- 5.4	- 7.1	2,929	954.3	0.4	- 4.8	- 6.5
10	USH 45	1922	50	YES	1,619	966.2	0.3	- 3.3	- 3.4	2,900	968.8	1.4	- 0.7	- 0.8	3,563	969.5	1.9	0	- 0.1
9	CTH Y	1927	10	YES	1,621	972.6	0.3	- 3.5	- 3.5	2,900	974.1	0.5	- 2.0	- 2.0	3,569	974.8	0.7	- 1.3	- 1.3
8	CTH Y	1927	10	YES	1,863	984.1	0.0	- 7.1	- 7.1	3,200	985.4	0.0	- 5.8	- 5.8	3,922	986.2	0.0	- 5.0	- 5.0
7	STH 67	(C)1925[a]	10	YES	1,864	987.2	0.2	- 2.4	- 2.5	3,200	989.4	1.4	- 0.2	- 0.3	3,924	991.0	2.0	1.4	1.3
5	PRIVATE DR	UNKNOWN	--	--	1,654	998.7	0.6	0.5	0.5	2,850	999.9	0.6	1.7	1.7	3,473	1,000.2	0.2	2.0	2.0
4	USH 45	1958	50	YES	821	1,015.4	0.1	-10.3	-10.3	1,400	1,016.0	0.1	- 9.7	- 9.7	1,720	1,016.3	0.0	- 9.4	- 9.4
3	CTH F	1929	50	YES	822	1,021.1	0.1	- 2.3	- 4.4	1,400	1,022.0	0.1	- 1.4	- 3.5	1,722	1,022.5	0.0	- 0.9	- 3.0
2	TOWN RD	CULVERT	10	YES	380	1,023.6	0.3	- 0.6	- 1.8	650	1,025.0	0.3	0.8	- 0.4	789	1,025.7	0.3	1.5	0.3

[a]THIS BRIDGE WAS REPLACED IN 1970 SUBSEQUENT TO THE WATERSHED FLOOD-FLOW SIMULATION. THE FLOOD STAGE DATA IN THE TABLE, THEREFORE, DO NOT REFLECT THE NEW BRIDGE.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table G-4

HYDRAULIC ANALYSIS SUMMARY LINCOLN CREEK

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Flood Interval--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
238	N GREEN BAY AV	1951	50	YES	2,800	620.0	0.0	- 4.3	- 4.3	3,410	621.5	0.0	- 2.8	- 2.8	3,700	622.2	0.0	- 2.1	- 2.1
239	VILLARD AV	1956	10	YES	2,520	620.3	0.1	- 4.7	- 4.7	3,070	621.8	0.1	- 3.2	- 3.2	3,270	622.3	0.1	- 2.7	- 2.7
240	TUETONIA AV	1936	10	YES	2,450	620.9	0.0	- 8.3	- 9.1	2,950	622.2	0.0	- 7.0	- 7.8	3,150	622.7	0.1	- 6.5	- 7.3
241	CAMERON AV	1961	10	YES	2,450	621.7	0.0	-11.4	-11.4	2,950	622.7	0.0	-10.4	-10.4	3,150	623.1	0.0	-10.0	-10.0
242	C M ST P & P R R	1965	100	YES	2,450	622.8	0.3	-24.3	-24.3	2,950	623.6	0.3	-23.5	-23.5	3,150	624.0	0.3	-23.1	-23.1
243	HAMPTON AV	1961	50	YES	2,450	623.3	0.3	-11.4	-11.4	2,950	624.1	0.3	-10.6	-10.6	3,150	624.4	0.3	-10.3	-10.3
244	32ND	1926	10	YES	2,450	630.1	6.0[a]	- 8.5	- 8.5	2,950	631.0	6.1[a]	- 7.6	- 7.6	3,150	631.4	6.2[a]	- 7.2	- 7.2
245	C M ST P & P R R	1954	100	YES	2,450	634.4	0.3	-15.3	-15.3	2,950	635.3	0.3	-14.4	-14.4	3,150	635.6	0.3	-14.1	-14.1
246	GLENDALE AV	1926	10	YES	2,170	636.0	0.0	- 6.0	- 6.0	2,680	636.8	0.0	- 5.2	- 5.2	2,870	637.1	0.0	- 4.9	- 4.9
248	35TH ST	1936	50	YES	2,170	639.4	0.3	- 7.7	- 7.7	2,680	640.7	1.9	- 6.4	- 6.4	2,870	641.2	1.9	- 5.9	- 5.9
249	37TH ST	1936	10	YES	1,900	640.7	0.1	-16.6	-16.6	2,390	641.9	0.1	-15.4	-15.4	2,590	642.3	0.1	-15.0	-15.0
250	SHERMAN BL	1936	50	YES	1,900	643.2	0.0	- 4.4	- 4.4	2,390	644.3	0.0	- 3.3	- 3.3	2,590	645.5	0.8	- 2.1	- 2.1
251	PEDESTRIAN BRIDGE	1961	--	--	1,360	643.8	0.0	- 3.2	- 3.2	1,780	644.7	0.0	- 2.3	- 2.3	1,940	645.7	0.0	- 1.3	- 1.3
252	51ST ST	1959	10	YES	1,210	645.6	0.1	- 7.3	- 7.3	1,590	646.4	0.1	- 6.5	- 6.5	1,750	646.4	0.1	- 6.5	- 6.5
253	PEDESTRIAN BRIDGE	1961	--	--	1,210	646.4	0.0	-16.0	-16.0	1,590	647.1	0.0	-15.3	-15.3	1,750	647.2	0.0	-15.2	-15.2
254	60TH ST	1959	50	YES	1,060	656.3	0.0	- 2.5	- 3.2	1,400	657.5	0.0	- 1.3	- 2.0	1,540	657.9	0.0	- 0.9	- 1.6
255	HAMPTON AV	1960	50	YES	850	656.5	0.0	-15.4	-15.4	1,130	657.7	0.0	-14.2	-14.2	1,250	658.1	0.0	-13.8	-13.8
256	PEDESTRIAN BRIDGE	1961	--	--	850	656.7	0.0	-11.1	-11.1	1,130	657.9	0.0	- 9.9	- 9.9	1,250	658.3	0.0	- 9.5	- 9.5
257	VILLARD AV	1956	10	YES	570	657.1	0.0	-11.4	-11.4	785	658.3	0.0	-10.2	-10.2	870	658.7	0.0	- 9.8	- 9.8
258	60TH ST	1955	50	YES	320	658.7	0.0	- 5.0	- 5.0	445	659.8	0.0	- 3.9	- 3.9	500	660.2	0.0	- 3.5	- 3.5
259	PEDESTRIAN BRIDGE	1959	--	--	320	659.1	0.0	-12.9	-12.9	445	660.1	0.0	-11.9	-11.9	500	660.5	0.0	-11.5	-11.5
260	SILVER SPRING DR	1957	50	YES	320	660.2	0.0	-11.8	-11.8	445	661.0	0.0	-11.0	-11.0	500	661.2	0.0	-10.8	-10.8

[a]THIS LARGE HEAD LOSS IS CAUSED PRIMARILY BY AN ABRUPT 5.5 FOOT DROP IN THE CHANNEL BOTTOM AT STRUCTURE NUMBER 244.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table G-5

HYDRAULIC ANALYSIS SUMMARY CEDAR CREEK

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
152	GREEN BAY RD	1927	50	NO[a]	3,454	697.4	0.0	- 3.0	- 8.2	5,600	701.1	0.0	0.7	- 4.5	6,313	701.2	0.0	0.8	- 4.4
190	CTH T	1964	50	YES	3,454	710.2	0.0	- 2.3	- 6.3	5,600	711.7	0.0	- 0.8	- 4.8	6,313	712.2	0.0	- 0.3	- 4.3
189	CM ST P & P RR	1906	100	YES	3,454	722.5	0.0	- 0.6	-37.4	5,600	731.3	0.0	-34.9	-34.9	6,313	731.8	0.2	-34.5	-34.5
188	DRIVEWAY	(C)1930	--	--	3,454	732.5	0.2	- 9.1	- 9.1	5,600	735.1	0.2	- 6.9	- 6.9	6,313	735.3	0.4	- 6.7	- 6.7
185	N HIGHLAND DR	1939	10	YES	3,454	769.2	0.0	-10.7	-12.5	5,600	771.3	0.0	- 8.6	-10.4	6,313	772.0	0.0	- 7.9	- 9.7
184	STH 57	1949	10	YES	3,454	777.1	0.0	- 5.8	-13.2	5,600	778.9	0.0	- 9.6	-11.4	6,313	779.4	0.0	- 7.5	-10.9
182	PEDESTRIAN BRIDGE	(C)1900	--	--	3,454	780.2	0.0	- 4.4	- 4.4	5,600	791.6	1.3	- 1.1	- 1.1	6,313	792.5	1.6	- 0.2	- 0.2
181	BRIDGE ST	(C)1885	50	YES	3,454	791.8	0.0	- 5.0	- 6.5	5,600	794.7	0.0	- 2.1	- 3.6	6,313	796.7	1.1	- 0.1	- 1.6
179	STH 60	1928	50	YES	3,454	800.5	0.0	- 6.8	- 6.8	5,600	808.1	0.1	- 5.2	- 5.2	6,313	808.7	0.3	- 4.6	- 4.6
178	CEDAR CREEK RD	1915	10	NO[a]	3,455	813.9	0.3	1.2	- 0.9	5,600	814.8	0.3	1.5	1.4	6,314	816.9	0.3	4.2	2.1
177	CTH I	(C)1885	10	YES	3,457	814.8	0.0	- 7.7	- 8.2	5,600	816.8	0.0	- 5.7	- 6.2	6,319	817.7	0.1	- 4.8	- 5.3
176	CEDAR CREEK RD	1917	50	YES	3,459	816.0	0.0	- 1.7	- 4.7	5,600	819.0	0.2	0.7	- 2.3	6,320	819.7	0.1	1.4	- 1.6
175	COVERED BRIDGE	1961	10	YES	3,460	818.3	0.0	- 2.7	- 2.7	5,600	820.5	0.2	- 0.5	- 0.1	6,321	821.5	0.3	0.5	0.5
174	CTH N	1961	10	YES	3,461	818.4	0.0	- 1.3	- 3.7	5,600	820.7	0.0	1.0	- 1.4	6,322	821.8	0.2	2.1	- 0.3
173	HORNS CORNERS RD	1888	10	NO[a]	3,198	823.6	0.0	3.7	- 2.0	5,600	825.5	0.0	5.6	- 0.1	5,842	826.2	0.2	6.3	0.6
172	STH 143	1928	10	YES	3,202	827.3	0.0	- 5.0	-11.7	5,000	829.4	0.0	- 2.9	- 5.6	5,848	829.8	0.0	- 2.5	- 5.2
171	CTH Y	1956	50	YES	3,203	831.2	0.0	-11.8	-13.8	5,000	832.9	0.0	-10.1	-12.1	5,849	833.6	0.1	- 9.4	-11.4
170	CTH M	1930	50	NO	2,563	837.6	0.0	- 0.5	- 2.8	4,050	840.6	0.0	2.1	0.2	4,768	842.0	0.0	3.5	1.6
169	CTH G	1956	50	NO[a]	2,551	838.3	0.1	- 0.9	- 2.8	4,100	841.0	0.0	1.8	- 0.1	4,893	842.0	0.0	2.8	0.9
168	STH 60	1924	10	YES	1,817	839.3	0.0	- 4.1	- 4.6	3,100	842.3	0.0	- 1.1	- 1.6	3,794	843.6	0.0	0.2	- 0.3
167	SHERMAN RD	1928	10	YES	1,822	843.1	0.0	- 1.4	- 4.0	3,100	844.3	0.0	- 0.2	- 2.8	3,802	844.8	0.0	0.3	- 2.3
166	C & NWRR	1900	100	YES	1,823	843.6	0.0	-15.2	-15.2	3,100	845.2	0.0	-13.6	-13.6	3,803	845.8	0.0	-13.0	-13.0
165	SHERMAN RD	(C)1930	10	YES	930	845.4	0.0	- 3.6	- 5.4	1,670	847.1	0.0	- 1.9	- 3.7	2,038	848.0	0.0	- 1.0	- 2.8
164	USH 45	1920	50	YES	931	873.7	0.0	- 3.8	- 4.4	1,670	874.1	0.0	- 3.4	- 4.0	2,038	874.6	0.0	- 2.9	- 3.5
163A	MILL RD	UNKNOWN	10	YES	931	886.6	0.0	- 1.3	- 3.1	1,670	889.5	1.0	1.6	- 0.2	2,039	890.1	1.5	2.2	0.4
163	STH 60	CULVERT	50	YES	932	890.4	0.0	- 7.8	- 4.5	1,070	891.3	0.0	- 6.9	- 8.6	2,042	891.5	0.0	- 6.7	- 8.4
162	MAYFIELD RD	(C)1950	10	YES	209	914.0	0.4	- 3.5	- 4.4	450	915.3	0.4	- 2.2	- 3.1	571	915.7	0.8	- 1.8	- 2.7
161A	PEDESTRIAN BRIDGE	UNKNOWN	--	--	212	--	--	--	--	450	--	--	--	--	584	--	--	--	--
160	CTH Z	(C)1950	10	YES	212	955.1	4.7[b]	- 3.2	- 3.2	450	955.4	3.4[b]	- 2.9	- 2.9	584	955.6	3.4[b]	- 2.7	- 2.7
158	SCENIC DR	1961	10	YES	212	977.1	1.0	- 2.8	- 3.1	450	979.0	1.1	- 1.5	- 1.8	584	979.3	1.2	- 1.2	- 1.5
157	LILLY RD	CULVERT	50	YES	212	991.2	11.3[b]	-18.9	-18.9	450	992.0	11.0[b]	-18.2	-18.2	585	992.3	10.9[b]	-17.9	-17.9
156	CTH C	(C)1950	50	YES	212	1,005.1	0.6	- 8.2	- 8.4	450	1,010.2	0.4	- 7.1	- 7.3	586	1,010.6	0.4	- 6.7	- 6.9
155	PLEASANT VALLEY	(C)1950	10	YES	213	1,012.6	0.2	- 2.6	- 4.7	450	1,014.0	0.3	- 1.2	- 3.3	[illegible]	1,014.5	0.3	- 0.7	- 2.8
153	HILLCREST RD	CULVERT	50	YES	203	1,017.6	0.0	- 1.8	- 1.8	450	1,018.0	0.0	- 1.4	- 1.4	577	1,018.1	0.0	- 1.3	- 1.3
152	CTH NN	CULVERT	50	YES	203	[illegible]	0.0	- 4.1	- 4.1	450	1,018.0	0.0	- 3.7	- 3.7	577	1,018.1	0.0	- 3.6	- 3.6

[a]STANDARD COULD BE MET BY ELEVATION OF APPROACH ROAD.

[b]THIS LARGE HEAD LOSS IS PRIMARILY DUE TO A STEEP CHANNEL SLOPE.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table G-6

HYDRAULIC ANALYSIS SUMMARY NORTH BRANCH MILWAUKEE RIVER

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
140	RIVERSIDE DR	1890	10	NO[a]	4,755	797.8	0.1	3.1	- 0.3	7,800	799.9	0.1	5.2	1.8	9,102	800.8	0.3	6.1	2.7
139	CTH M	1927	10	NO[a]	4,807	799.4	0.6	0.7	- 1.6	7,800	802.6	1.4	3.9	1.6	9,162	803.8	2.2	5.1	2.8
138	TRADING POST TR	1966	50	NO	4,634	801.5	0.3	- 0.6	- 1.5	7,400	803.3	0.3	1.2	0.3	8,846	804.6	0.2	2.5	1.6
137	CTH H	(C)1960	50	NO[a]	4,636	802.8	0.2	1.4	- 3.2	7,400	804.9	0.4	3.5	- 1.1	8,851	805.8	0.4	4.4	- 0.2
136	CTH X	1927	50	NO	3,760	804.3	0.3	3.3	- 1.1	6,000	806.1	0.3	5.1	0.7	7,191	807.0	0.3	6.0	1.6
135	JAY DR	1909	10	NO	3,314	805.2	0.0	3.0	0.8	5,300	806.8	0.0	4.6	2.4	6,347	807.4	0.0	5.2	3.0
120	PRIVATE DR	(C)1920	--	--	3,028	808.5	0.0	0.8	- 2.2	4,850	810.2	0.9	2.5	- 0.5	5,789	811.0	1.3	3.3	0.3
119	STH 144	(C)1930	50	NO	2,231	809.2	1.0	- 1.0	- 1.5	3,550	811.2	1.3	1.0	0.5	4,235	812.0	1.4	1.8	1.3
118	CTH O	1961	10	YES	2,290	810.3	0.0	- 3.3	- 5.7	3,800	812.0	0.0	- 1.6	- 4.0	4,497	812.7	0.0	- 0.9	- 3.3
117	CTH SS	1929	50	YES	1,943	812.8	0.0	- 3.4	- 5.7	3,200	814.1	0.0	- 2.1	- 4.4	3,816	814.7	0.0	- 1.5	- 3.8
116	GOOSEVILLE	1921	10	YES	1,943	813.6	0.0	- 4.6	- 4.9	3,200	816.4	1.6	- 1.8	- 2.1	3,817	817.7	2.4	- 0.5	- 0.8
114	CTH A	1951	50	YES	1,943	821.5	0.0	- 5.2	- 5.2	3,200	823.3	0.0	- 3.8	- 3.8	3,817	824.1	0.0	- 3.0	- 3.0
113	TOWN RD	1934	10	YES	1,566	823.3	0.0	- 9.2	-11.2	2,550	824.5	0.0	- 8.0	-10.0	3,046	825.1	0.0	- 7.4	- 9.4
112	CTH W	(C)1930	50	NO	1,150	840.2	0.6	1.8	- 0.1	1,900	841.4	1.3	3.0	1.1	2,231	842.5	1.6	4.1	2.2
110	TOWN RD	1961	10	NO[a]	873	840.6	0.0	1.0	- 2.3	1,400	841.8	0.0	2.2	- 1.1	1,689	842.8	0.0	3.2	- 0.1
98	CTH NN	1932	50	NO[a]	468	841.7	0.0	- 0.2	- 2.1	760	843.1	0.0	1.2	- 0.7	890	843.8	0.0	1.9	0.0
97	MILWAUKEE AV	(C)1940	10	YES	504	858.6	0.2	- 1.4	- 4.0	840	859.7	0.1	- 0.3	- 2.9	1,001	860.0	0.0	0.0	- 2.6
96	STH 28	(C)1930	50	YES	504	865.9	0.3	- 2.3	- 4.1	840	867.3	0.2	- 0.9	- 2.7	1,001	867.8	0.0	- 0.4	- 2.2
95	FRANCIS ST	(C)1940	10	YES	504	868.0	0.2	- 2.8	- 4.4	840	868.9	0.1	- 1.9	- 3.5	1,002	869.2	0.0	- 1.6	- 3.2
94	NORTH AV	CULVERT	10	YES	504	881.5	0.2	- 2.8	- 4.4	840	884.3	0.6	0.0	- 1.6	1,002	886.1	0.8	1.8	0.2
92	CTH V	(C)1930	50	YES	499	891.5	0.0	- 5.0	- 5.1	840	892.1	0.0	- 4.4	- 4.5	997	892.3	0.0	- 4.2	- 4.3

[a]STANDARD COULD BE MET BY ELEVATION OF APPROACH ROAD.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table G-7

HYDRAULIC ANALYSIS SUMMARY SILVER CREEK (SHEBOYGAN COUNTY)

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood--1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year: Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year: Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year: Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
134	TOWN RD	1967	10	YES	1,570	814.4	0.0	- 3.0	- 4.0	2,190	815.0	0.0	- 2.4	- 3.4	2,430	815.2	0.0	- 2.2	- 3.2
133	CTH E	1947	50	YES	1,210	842.6	0.0	- 4.6	- 4.6	1,710	843.0	0.0	- 4.2	- 4.2	1,910	843.1	0.0	- 4.1	- 4.1
132	TOWN RD	1919	10	NO	1,210	848.8	1.8	0.7	0.2	1,710	849.0	1.4	0.9	0.4	1,910	849.1	1.4	1.0	0.5
131	TOWN RD	1940	10	YES	780	851.4	0.0	- 3.0	- 3.0	1,070	852.0	0.0	- 2.4	- 2.4	1,200	852.2	0.0	- 2.2	- 2.2
130	CTH I	(C)1930	50	YES	650	860.7	0.0	- 2.1	- 5.1	910	861.1	0.0	- 1.7	- 4.7	1,010	861.3	0.0	- 1.5	- 4.5
129	STH 144	1920	50	NO	570	864.3	0.6	- 0.7	- 0.7	760	865.3	0.8	0.3	0.3	835	865.4	0.7	0.4	0.4
128	PRIVATE DR	CULVERT	--	--	570	864.6	0.0	- 2.3	- 2.3	760	865.5	0.0	- 1.4	- 1.4	835	865.7	0.0	- 1.2	- 1.2
127	TOWN RD	CULVERT	10	YES	150	866.1	0.0	- 5.1	- 5.4	180	866.4	0.0	- 4.8	- 5.1	190	866.5	0.0	- 4.7	- 5.0
126	C M ST P & P R R	1915	100	YES	150	866.1	0.0	-11.9	-11.9	180	866.4	0.0	-11.6	-11.6	190	866.5	0.0	-11.5	-11.5
123	PRIVATE DR	CULVERT	--	--	175	871.6	1.0	0.3	0.2	230	871.7	1.3	0.4	0.3	253	871.8	0.8	0.5	0.4
122	CTH K	CULVERT	50	NO	175	875.3	3.6	0.2	0.2	230	875.4	3.5	0.3	0.3	253	875.5	3.6	0.4	0.4
121	C M ST P & P R R	1909	100	YES	24	--	--	--	--	35	--	--	--	--	41	--	--	--	--

SOURCE- HARZA ENGINEERING COMPANY & SEWRPC.

Table G-8

HYDRAULIC ANALYSIS SUMMARY SILVER CREEK (WASHINGTON COUNTY)

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
76	USH 45	(C)1965	50	NO*	740	895.5	0.0	- 0.1	- 1.8	1,000	897.9	0.0	2.3	0.6	1,135	899.0	0.0	3.0	1.7
74	CITY PARK DR	1933	10	NO	740	896.6	0.0	0.6	- 1.6	1,000	897.7	0.0	1.7	- 0.5	1,135	899.0	0.0	3.0	0.8
72	PEDESTRIAN BRIDGE	UNKNOWN	--	--	740	898.7	0.0	- 2.6	- 2.6	1,000	899.4	0.0	- 1.9	- 1.9	1,135	899.8	0.0	- 1.5	- 1.5
71	PEDESTRIAN BRIDGE	UNKNOWN	--	--	740	900.6	0.1	2.1	1.2	1,000	901.6	0.1	3.1	2.2	1,135	902.0	0.0	3.5	2.6
70	SILVER BROOK DR	1964	10	YES	740	907.8	0.0	- 5.0	- 5.0	1,000	908.4	0.0	- 4.4	- 4.4	1,135	908.4	0.0	- 4.4	- 4.4
69	STH 33	1958	50	YES	680	921.2	0.0	- 4.8	- 5.4	930	921.8	0.0	- 4.2	- 4.8	1,030	922.1	0.0	- 3.9	- 4.5
68A	SILVER BROOK DR	(C)1965	10	NO	680	924.9	0.7	0.3	0.3	930	925.6	0.0	1.0	1.0	1,030	926.1	0.0	1.5	1.5
68	N 25TH AV	1957	10	YES	630	930.8	0.0	- 1.2	- 2.0	840	931.2	0.0	- 0.8	- 1.6	940	931.3	0.0	- 0.7	- 1.5
67	STH 33	1958	50	NO	630	936.3	5.5	0.3	0.3	840	936.6	5.4	0.6	0.6	940	936.7	5.4	0.7	0.7
66	STH 33	UNKNOWN	50	YES	630	972.5	0.0	- 1.5	- 7.2	840	973.4	0.0	- 0.6	- 6.3	940	973.4	0.0	- 0.6	- 6.3
65	UNIVERSITY DR	1967	10	YES	550	973.3	0.0	- 9.0	- 9.0	735	974.3	0.0	- 8.0	- 8.0	810	974.5	0.0	- 7.8	- 7.8

*STANDARD COULD BE MET BY ELEVATION OF APPROACH ROAD.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table G-9

HYDRAULIC ANALYSIS SUMMARY EAST BRANCH MILWAUKEE RIVER

Structure Indentification: Number	Structure Indentification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
52	STH 28	1934	50	YES	882	926.3	0.0	- 5.1	- 5.7	1,500	930.1	0.3	- 1.3	- 1.9	1,827	930.9	0.5	- 0.5	- 1.1
51	MORRAINE DR	(C)1930	10	YES	947	929.4	0.2	- 1.7	- 6.6	1,600	932.4	0.3	1.3	- 3.6	1,943	933.0	0.3	1.9	- 3.0
50	COUNTY LINE RD	1923	10	NO*	948	931.8	0.0	0.5	- 2.5	1,600	934.7	0.0	3.4	0.4	1,944	935.2	0.0	3.9	0.9
49	CTH S	1926	50	YES	948	938.0	0.0	- 8.3	- 8.3	1,600	939.9	0.0	- 6.4	- 6.4	1,945	940.2	0.0	- 6.1	- 6.1
47	MILL RD	1905	10	YES	948	950.8	0.4	- 1.8	- 4.4	1,600	953.0	1.0	0.4	- 2.2	1,945	954.0	1.5	1.4	- 1.2
45	CTH DD	1950	10	YES	938	970.6	0.3	- 3.3	- 3.4	1,600	973.2	0.6	- 0.7	- 0.8	1,935	974.1	0.8	0.2	0.1
37	CTH SS	1929	10	YES	551	973.5	0.0	- 4.2	- 5.7	960	976.0	0.0	- 1.7	- 3.2	1,160	977.1	0.0	- 0.6	- 2.1
37A	NEW PROSPECT LN	(C)1930	10	YES	551	974.0	0.5	- 3.8	- 5.3	960	977.0	0.7	- 0.8	- 2.3	1,160	978.0	0.8	0.2	- 1.3
36	CTH F	CULVERT	50	YES	121	995.5	0.6	- 5.7	- 5.9	380	996.8	0.7	- 4.4	- 4.6	556	998.2	0.8	- 3.0	- 3.2

*STANDARD COULD BE MET BY ELEVATION OF APPROACH ROAD.

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table G-10

HYDRAULIC ANALYSIS SUMMARY CROOKED LAKE CREEK

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
44A	PARK ROAD	CULVERT	10	YES	503	975.5	2.0	- 0.7	- 0.7	780	975.8	0.0	- 0.4	- 0.4	900	976.0	0.1	- 0.2	- 0.2
44	PARK ROAD	CULVERT	10	NO	503	976.8	1.3	2.1	1.7	780	977.1	1.3	2.4	2.0	900	977.2	1.1	2.5	2.1
43	CTH GGG	1930	10	YES	503	980.1	0.0	- 7.7	- 8.1	780	980.6	0.0	- 7.2	- 7.6	900	980.8	0.0	- 7.0	- 7.4
41	AUBURN-SCOTT RD	(C)1950	10	YES	311	989.8	0.0	- 1.6	- 2.8	490	990.5	0.0	- 0.9	- 2.1	575	990.6	0.0	- 0.8	- 2.0
40	AUBURN-SCOTT RD	1955	10	YES	218	996.9	0.0	- 3.4	- 4.1	295	997.0	0.0	- 3.3	- 4.0	329	997.1	0.0	- 3.2	- 3.9
39	CTH SS	(C)1950	10	YES	93	1,002.2	0.0	- 5.0	- 5.1	133	1,002.4	0.0	- 4.8	- 4.9	152	1,002.4	0.0	- 4.8	- 4.9

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

Table G-11

HYDRAULIC ANALYSIS SUMMARY WEST BRANCH MILWAUKEE RIVER

Structure Identification: Number	Structure Identification: Name	Construction Date of Existing Bridge	Recommended Design Frequency Standard (Years)	Adequate Hydraulic Capacity	10-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	10-Year: Elevation of Upstream Water Level (Feet above MSL)	10-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	10-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	10-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	50-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	50-Year: Elevation of Upstream Water Level (Feet above MSL)	50-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	50-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	50-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)	100-Year Recurrence Interval Flood—1990 Land Use Conditions: Instantaneous Peak Discharge (CFS)	100-Year: Elevation of Upstream Water Level (Feet above MSL)	100-Year, Existing Waterway Opening: Bridge Head Loss (Feet)	100-Year, Existing Waterway Opening: Depth at Low Point in Bridge Approach Road (Feet)	100-Year, Existing Waterway Opening: Depth on Road at C/L of Bridge (Feet)
28	USH 45	1922	50	YES	2,243	945.5	0.2	- 2.2	- 2.4	3,900	947.5	0.8	- 0.2	- 0.4	4,739	948.4	1.3	0.7	0.5
27	CTH V	1964	50	NO	2,245	949.3	0.3	- 1.4	- 2.0	3,900	951.5	0.7	0.8	0.2	4,741	952.5	0.9	1.8	1.2
26	C & NWRR	1900	100	YES	2,245	950.2	0.6	- 6.9	- 6.9	3,900	952.5	0.7	- 4.6	- 4.6	4,743	953.6	0.8	- 3.5	- 3.5
25	RUSTIC DR	1908	10	NO	1,631	958.0	0.1	0.2	- 1.3	2,800	959.6	0.2	1.8	0.3	3,396	960.1	0.5	2.3	0.8
23	ELMORE RD	1923	50	NO	1,633	978.4	0.5	- 0.9	- 0.9	2,800	980.5	1.8	1.2	1.2	3,401	981.4	2.2	2.1	2.1
22	MAIN ST	(C)1910	10	YES	1,637	981.9	0.1	- 5.9	- 6.3	2,800	983.1	0.1	- 4.7	- 5.1	3,406	983.8	0.0	- 4.0	- 4.4
21	TOWN RD	1962	10	YES	1,637	989.8	0.2	- 5.0	- 5.2	2,800	990.8	0.2	- 4.0	- 4.2	3,407	991.3	0.4	- 3.5	- 3.7
20	RIVER DR	(C)1920	10	YES	1,043	993.5	0.0	- 1.0	- 2.6	1,800	995.5	0.0	1.0	- 0.6	2,166	996.0	0.0	1.5	- 0.1
19	STH 67	1927	50	YES	1,048	998.1	0.0	- 3.7	- 6.2	1,800	1,000.2	0.0	- 1.6	- 4.1	2,175	1,000.8	0.0	- 1.0	- 3.5
18	CTH K	(C)1950	10	YES	1,045	1,002.2	0.1	- 1.4	- 2.1	1,800	1,003.9	0.5	0.3	- 0.4	2,177	1,004.7	0.8	1.1	0.4
17	CTH K	1956	10	YES	618	1,005.9	0.0	- 1.9	- 2.5	1,050	1,007.8	0.5	0.0	- 0.6	1,292	1,008.8	0.7	1.0	0.4
16	CTH K	1956	10	YES	154	1,010.0	0.0	- 2.3	- 2.3	260	1,011.1	0.0	- 1.2	- 1.2	319	1,011.6	0.0	- 0.7	- 0.7
15	E FONDY DR	(C)1960	10	YES	154	1,016.2	0.1	- 7.3	- 7.8	260	1,016.8	0.1	- 6.7	- 7.2	319	1,017.1	0.1	- 6.4	- 6.9
14	CTH Y	(C)1950	10	YES	154	1,021.7	0.3	- 5.2	- 5.5	260	1,022.7	0.3	- 4.2	- 4.5	319	1,023.2	0.3	- 3.7	- 4.0
13	CTH F	CULVERT	10	YES	162	--	--	--	--	280	--	--	--	--	336	--	--	--	--

SOURCE- HARZA ENGINEERING COMPANY AND SEWRPC.

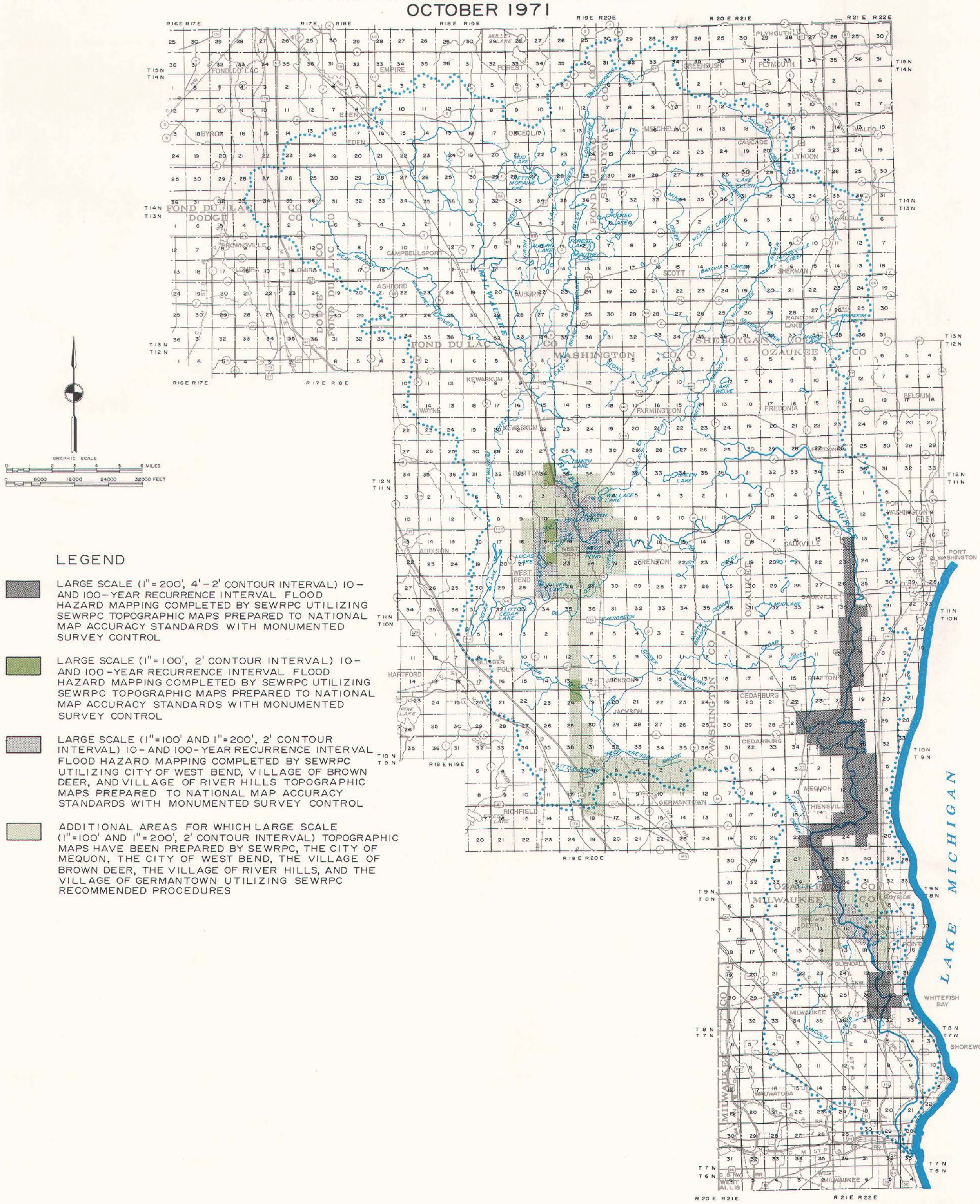
(This page intentionally left blank)

Appendix H

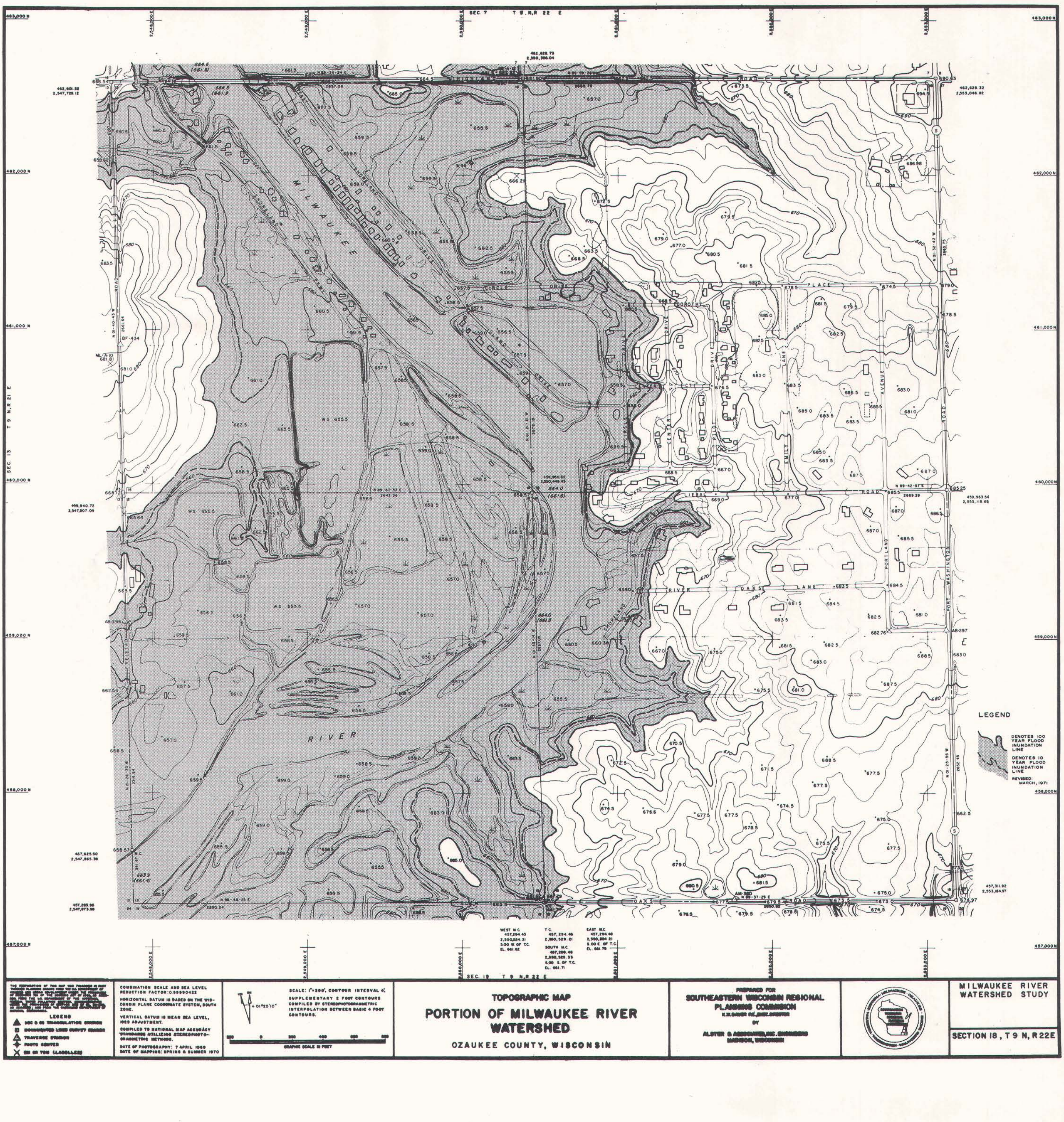
FLOOD HAZARD MAPS

Map H-1

FLOOD HAZARD AND TOPOGRAPHIC MAP SHEET INDEX
FOR THE MILWAUKEE RIVER WATERSHED
OCTOBER 1971



Map H-2
FLOOD HAZARD MAP
PORTION OF MILWAUKEE RIVER WATERSHED
OZAUKEE COUNTY, WISCONSIN



Appendix I

CORRESPONDENCE RELATIVE TO THE U. S. ARMY CORPS OF ENGINEERS REVIEW OF THE POTENTIAL ELIGIBILITY FOR FEDERAL PARTICIPATION IN THE DEVELOPMENT OF THE WAUBEKA RESERVOIR AND SAUKVILLE DIVERSION CHANNEL ALTERNATIVE FLOOD CONTROL PLAN ELEMENTS

Letter dated September 17, 1971 from U. S. Army Corps of Engineers to U. S. Congressman Henry S. Reuss

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

IN REPLY REFER TO
ENGCW-PD

17 September 1971

Honorable Henry S. Reuss
House of Representatives
Washington, D. C. 20515

Dear Mr. Reuss:

Reference is made to your letter of 19 July 1971 and to my interim reply of 20 August 1971, concerning comments by the Corps of Engineers on the report on the Milwaukee River prepared by the Southeastern Wisconsin Regional Planning Commission.

Our District Engineer in Chicago has completed a preliminary review of both the SWRPC report and the 1964 Corps of Engineers report on the Milwaukee River with a view to determining the feasibility of the prospective Saukville Division Channel and the prospective Waubeka Reservoir under current conditions and price levels. His findings on the feasibility of each plan support the findings of the SWRPC, as stated in their report. Specifically, the Saukville Diversion Channel no longer appears to be economically justified and the Waubeka Reservoir does appear to be economically justified. I would like to point out, however, that the Waubeka Reservoir project, while economically justified on the basis of comparing the total estimated benefits to the total estimated costs, is predominantly a recreation-oriented project. About 95 percent of the benefits evaluated by the SWRPC would accrue to recreation and fish and wildlife enhancement and only about 5 percent would accrue to flood control. Federal participation in the construction of such a reservoir project, at least through the programs and authorities now available to the Corps of Engineers, is very questionable.

The Federal Water Project Recreation Act of 1965, Public Law 89-72, expresses the policy of the Congress in regard to the inclusion of recreation and fish and wildlife enhancement in Federal water resources development projects. Section 9 of the Act states:

> "Nothing contained in this Act shall be taken to authorize or to sanction the construction under the Federal reclamation laws or under any Rivers and Harbors or Flood Control Act of any project in which the sum of the allocations to recreation and fish and wildlife enhancement exceeds the sum of the allocations to irrigation, hydro-electric power, municipal, domestic and industrial water supply, navigation, and flood control, except that this section shall not apply to any such project for the enhancement of anadromous fisheries, shrimp, or for the conservation of migratory birds protected by treaty, when each of the other functions of such a project has, of itself, a favorable benefit-cost ratio."

The District Engineer will be pleased to discuss the SWRPC report and the possibilities of Federal participation in the Waubeka Reservoir project with the Commission if they so desire.

Sincerely yours,

FRANCIS J. WALTER, JR.
LTC, Corps of Engineers
Assistant Director of Civil Works
for Central Divisions

Letter dated September 21, 1971 from U. S. Congressman Henry S. Reuss to Mr. Richard W. Cutler, Chairman, Milwaukee River Watershed Committee

HENRY S. REUSS
5TH DISTRICT, WISCONSIN

WASHINGTON OFFICE:
2159 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
PHONE, 202 225-3571

MILWAUKEE OFFICE:
5TH FLOOR, 211 W. WISCONSIN AVE.
MILWAUKEE, WISCONSIN 53203
PHONE: 414 272-1226

Congress of the United States
House of Representatives
Washington, D.C. 20515

COMMITTEES:
BANKING AND CURRENCY
CHAIRMAN, SUBCOMMITTEE ON INTERNATIONAL FINANCE
GOVERNMENT OPERATIONS
CHAIRMAN, CONSERVATION AND NATURAL RESOURCES SUBCOMMITTEE
JOINT ECONOMIC COMMITTEE
CHAIRMAN, INTERNATIONAL EXCHANGE AND PAYMENTS SUBCOMMITTEE

DONALD L. ROBINSON
ADMINISTRATIVE ASSISTANT

September 21, 1971

Mr. Richard W. Cutler
Chairman
Milwaukee River Watershed Committee
Southeastern Wisconsin Regional
Planning Commission
735 North Water Street
Milwaukee, Wisconsin 53202

Dear Dick:

I enclose the advisory opinion from the Corps of Engineers on the Saukville cut-off and the Waubeka Reservoir.

Their opinion confirms that the Saukville cut-off is no longer eligible for Corps of Engineers financing because of cost increases since it was first proposed in 1963 and determined to be economically feasible by the Corps in 1964.

As for the Waubeka Reservoir, the Corps reports that it is barred by Federal law. The law, passed by Congress in 1965, prohibits Corps of Engineers participation in any project in which the benefits attributable to "recreation and fish and wildlife enhancement" exceed 50 percent of all benefits. Since fully 95 percent of the projected benefits from Waubeka would be attributable to recreation and fish and wildlife enhancement, the project does not even come close to meeting the Federal standard. I have checked with other members of Congress, and there is no prospect that the 1965 law which now bars the Waubeka project will be changed.

In light of this advisory opinion from the Corps, SWRPC should make its recommendations on the assumption that neither the Saukville cut-off nor the Waubeka Reservoir will be eligible for Corps of Engineers financing.

Sincerely,

Henry S. Reuss
Member of Congress

Enclosure

(This page intentionally left blank)

Appendix J

MODEL RESOLUTION FOR ADOPTION OF THE COMPREHENSIVE PLAN FOR THE MILWAUKEE RIVER WATERSHED

WHEREAS, the Southeastern Wisconsin Regional Planning Commission, which was duly created by the Governor of the State of Wisconsin in accordance with Section 66.945(2) of the Wisconsin Statutes on the 8th day of August 1960 upon petition of the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha, has the function and duty of making and adopting a master plan for the physical development of the Region; and

WHEREAS, the several county units of government in the Milwaukee River watershed, on the 7th day of August 1967, entered into contracts with the Southeastern Wisconsin Regional Planning Commission pursuant to the provisions of Sections 66.30 and 66.945(12) of the Wisconsin Statutes for the development of a comprehensive plan for the Milwaukee River watershed leading to recommendations for the development of water-related community facilities in the watershed, including integrated proposals for water pollution abatement, water supply, drainage and flood control, land and water use, and park and public open-space reservation, to generally promote the orderly and economical development of the Milwaukee River watershed; and

WHEREAS, such plan has been completed and the Southeastern Wisconsin Regional Planning Commission did on the ___ day of ________, ___ approve a resolution adopting the comprehensive plan for the Milwaukee River watershed and has recommended such plan to the local units of government within the watershed; and

WHEREAS, such plan contains recommendations for land use development and regulation; environmental corridor land acquisition and preservation; park, parkway, and outdoor recreation land acquisition and development; floodway and floodplain regulation; stream flow recordation; pollution abatement facility construction; soil and water conservation practices; stream water quality monitoring; and water supply management and is, therefore, a desirable and workable water control and water-related community facility plan for the Milwaukee River watershed; and

WHEREAS, the aforementioned recommendations, including all studies, data, maps, figures, charts, and tables, are set forth in a published report entitled SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed, comprised of the following volumes:

Volume 1. Inventory Findings and Forecasts, published in December 1970, and

Volume 2. Alternative plans and Recommended Plan, published in October 1971; and

WHEREAS, the Commission has transmitted certified copies of its resolution adopting such comprehensive plan for the Milwaukee River watershed, together with the aforementioned SEWRPC Planning Report No. 13, to the local units of government; and

WHEREAS, the (Name of Local Governing Body) has supported, participated in the financing of, and generally concurred in the watershed and other regional planning programs undertaken by the Southeastern Wisconsin Regional Planning Commission and believes that the comprehensive plan for the Milwaukee River watershed prepared by the Commission is a valuable guide, not only to the development of the watershed but also of the community, and the adoption of such plan by the (Name of Local Governing Body) will assure a common understanding by the several governmental levels and agencies concerned and enable these levels and agencies of government to program the necessary areawide and local plan implementation work.

NOW, THEREFORE, BE IT RESOLVED that, pursuant to Section 66.945(12) of the Wisconsin Statutes, the (Name of Local Governing Body) on the _____ day of __________, 1972, hereby adopts the comprehensive plan for the Milwaukee River watershed previously adopted by the Commission as set forth in SEWRPC Planning Report No. 13 as a guide for watershed and community development.

BE IT FURTHER HEREBY RESOLVED, that the __________ clerk transmit a certified copy of this resolution to the Southeastern Wisconsin Regional Planning Commission.

____
(President, Mayor, or Chairman of the Local Governing Body)

ATTESTATION:

____
(Clerk of Local Governing Body)