PLANNING REPORT NO. 37

A WATER RESOURCES MANAGEMENT PLAN FOR THE MILWAUKEE HARBOR ESTUARY

volume two

ALTERNATIVE AND RECOMMENDED PLANS

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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A WATER RESOURCES MANAGEMENT PLAN FOR THE MILWAUKEE HARBOR ESTUARY

Volume Two

ALTERNATIVE AND RECOMMENDED PLANS

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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STATEMENT OF THE CHAIRMAN

The Southeastern Wisconsin Regional Planning Commission in 1982 undertook a comprehensive study of the water pollution, flooding, storm damage, and dredging problems of the Milwaukee Harbor estuary area. This study was conducted in response to a long-standing formal request from the Common Council of the City of Milwaukee, a request reinforced by the U. S. Environmental Protection Agency and the Wisconsin Department of Natural Resources. The primary objective of this study was to develop a workable plan for the abatement of water pollution within the Milwaukee Harbor estuary so as to meet established water use objectives in a cost-effective manner and thereby further the protection and wise use of the natural resource base.

The findings and recommendations of this study are presented in a two-volume planning report. The first volume, published in March of 1987, presents a summary of the findings of the extensive inventories conducted to provide the information required for a thorough understanding of the complex estuarine system concerned, and to facilitate the reliable analyses of water quality and sediment conditions and of the potential effects of alternative means of water quality management on those conditions as required for sound plan preparation.

This, the second volume of the report, identifies and sets forth water resource management objectives, alternative measures for meeting those objectives, the best measures available from among those alternatives, and the means for implementation of those measures. The comprehensive water resources management plan presented in this volume consists of elements addressing the means for abating water pollution in a cost-effective manner, including determination of the level of protection required to be provided by the deep tunnel combined sewer overflow abatement system under construction in the Milwaukee area, and necessary in-stream measures required to meet established water use objectives; the means for abating damage caused by flooding and storm wave action; the dredging needed to facilitate commercial navigation, and recommended means for the environmentally safe disposal of the polluted dredged material; and measures to prevent deterioration of the estuary shoreline.

Measured in terms of the importance to the economic, social, and cultural well-being of the residents of the entire seven-county Region, the central business district of Milwaukee and environs represents the most significant concentration of urban land uses in southeastern Wisconsin. These land uses and activities are located on the shorelines of the Milwaukee, Menomonee, and Kinnickinnic River estuaries and of Lake Michigan. Hence, the inner and outer harbors provide a physical setting that shapes the very image of this important area of the Region. The comprehensive water resources management plan presented in this volume would, if fully implemented, restore the waters of those harbors to a quality that will enhance that image while providing for the desired navigational, recreational, and aesthetic uses of those waters. Accordingly, it is hoped that the federal, state, and local governmental agencies concerned will, with the support of the citizens of the Region, carry out the recommendations contained in this plan.

Respectfully submitted,

Anthony F. Balestrieri
Chairman

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Chapter I

INTRODUCTION

This chapter begins the second of two volumes which together comprise the major findings and recommendations of the Milwaukee Harbor estuary comprehensive planning program. The first volume sets forth the basic principles and concepts underlying the program, and summarizes the findings of the extensive inventories and analyses conducted under the program. More specifically, the first volume describes the man-made and natural resource base of the drainage area tributary to the Milwaukee Harbor estuary; describes the hydrologic and hydraulic characteristics of the estuary; presents the existing water quality, sediment quality, and biological conditions in the estuary; identifies the sources of surface water pollution in the drainage area tributary to the estuary; and describes the mathematical simulation models and other analytical techniques used in the planning effort.

This, the second volume of the report, sets forth recommended water use objectives and supporting water quality standards for the estuary; describes the anticipated growth and change in the tributary drainage areas; and describes and evaluates alternative water quality management plans, alternative dredging and spoils disposal plans, and alternative storm damage protection and flood control plans. Importantly, this volume of the report sets forth the recommended comprehensive water resource management plan for the Milwaukee Harbor estuary.

The alternative plans and recommended comprehensive plan presented in this second volume were developed utilizing a seven-step planning process by which the important natural and man-made characteristics and principal functional relationships existing within the estuary and the tributary drainage area could be accurately described; the hydrologic, hydraulic, and water quality characteristics of the estuary simulated; and the effect of the different water resource management actions evaluated. The seven steps involved in the planning process were: 1) study design, 2) formulation of objectives and standards, 3) inventory, 4) analysis and forecast, 5) plan synthesis, 6) plan testing and evaluation, and 7) plan selection and adoption. Plan implementation, although necessarily beyond the foregoing planning process, must be considered throughout the process if the plans are to be realized. Volume One of this report dealt with the first and third steps in the planning process, while this volume deals with steps two, four, five, six, and seven: formulation of objectives and standards, analysis and forecast, plan synthesis, plan testing and evaluation, and plan selection and adoption.

A brief description of each of the seven steps constituting the planning process is contained in Chapter II of the first volume of this report, together with the basic principles and concepts underlying the comprehensive water resource management planning program for the Milwaukee Harbor estuary. Elaboration on the five steps in the planning process with which this volume is concerned is warranted here.

FORMULATION OF OBJECTIVES AND STANDARDS

It was noted in Volume One of this report that planning is a rational process for formulating and meeting objectives. 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 the standards provide the criteria for evaluating and selecting alternatives. Since objectives provide the logical basis for plan synthesis, the formulation of sound objectives is a crucial step in the planning process.

Soundly conceived water resource management objectives should be based upon, and incorporate, the knowledge of many people who are well informed about the various issues to be addressed in, and the various aspects of, the Milwaukee Harbor estuary study. Furthermore, these water quality objectives should be established with input from duly elected or appointed representatives legally assigned this responsibility, rather than being determined solely by planners and engineers. Active participation by duly elected public officials and by citizen leaders in the overall regional planning program is implicit in the structure and organization of the Regional Planning Commission. Moreover, the Commission has established advisory committees to assist in the conduct of its planning programs. One of these committees is the Technical Advisory Committee for the Milwaukee Harbor Estuary Comprehensive Water Resources Plan. One of the major tasks of this Committee is to assist the Commission in the formulation of a set of water resource management objectives, supporting principles, and standards. Chapter II of this volume sets forth the water resource management objectives and supporting principles and standards for the Milwaukee Harbor estuary and its tributary drainage area formulated by the Commission after careful review and recommendation by the Technical Advisory Committee.

ANALYSIS AND FORECASTS

The inventories of existing conditions set forth in Volume One of this report provide information about past and present natural and man-made features and their effects on water quality. Forecasts of future conditions allow estimates of water resource demands and the attendant impact on water quality conditions to be prepared and compared to the established objectives and standards. These demands can be scaled against existing water quality and water-related resource supply, and plans can be formulated to meet the deficiencies.

To analyze future water resource conditions, it is necessary to forecast the population and economic activity levels and land use conditions that will affect water quality and water-related resource supply. Because of the present uncertainty about future changes in social and economic conditions, the Commission has examined alternative future scenarios of the development of the Region based upon consideration of a range of conditions which may be expected to influence such development.[1] The principal factors considered in the development of these scenarios were: energy cost and availability, technology and conservation, population lifestyles, and economic conditions. This alternative futures approach was used as the basis for estimating the future demand on the water resources of the estuary and of the tributary watersheds. Chapter III of this volume sets forth the future scenario conditions recommended by the Advisory Committee to be used as the basis for the development of alternative water resource management plans for the Milwaukee Harbor estuary.

[1] *See SEWRPC Technical Report No. 25, Alternative Futures for Southeastern Wisconsin, December 1980.*

PLAN SYNTHESIS

It was noted in Volume One of this report that plan synthesis or design forms the basis of the planning process. The outputs of three previous steps in the planning operation—formulation of objectives and standards, conduct of inventories, and preparation of analyses and forecasts—are used to develop and design alternative plan components. The task of designing the major plan components that affect water quality—combined sewer overflows, other point sources, nonpoint sources, and in-place pollution—is complex and difficult. In addition to these water quality plan components, the plan components are envisioned to include other water resource elements relating to flooding, harbor dredging activities, navigation and anchorage, and recreation. Not only does each component constitute in itself a major plan design problem, but the pattern of interaction between the components is complex and dynamic.

In the Milwaukee Harbor estuary study, the point and nonpoint source water pollution abatement components of the regional water quality management program, as well as of the Milwaukee Metropolitan Sewerage District facility plan, are refined. Particular emphasis is given to determining the required level of protection for combined sewer overflow abatement. The water resource and water resource-related plan elements are designed to satisfy the objectives and standards formulated under the study. The process seeks to achieve the best design solutions, or abatement methods and techniques, for achieving desired levels of water quality, flood control, and navigation and recreational potential, and then tests and evaluates the expected operation and performance of the proposed solution.

PLAN TESTING AND EVALUATION

If the plans developed in the design stage of the planning process are to be practical and workable and thereby realized, some techniques must be applied to quantitatively test and evaluate alternative plans in advance of their adoption and implementation. The alternative plans must be subject to several levels of review and evaluation, including: 1) engineering and technical effectiveness and feasibility, 2) environmental impact, 3) economic and financial feasibility, 4) legality, and 5) citizen and political reaction and acceptability. The methods used to test and evaluate alternative plan elements range from the mathematical models used to simulate water quality response in the Milwaukee Harbor estuary, to interagency meetings and public hearings. To assist in the quantitative analysis of the engineering performance and technical feasibility of the alternative plan elements considered, hydrologic, hydraulic, and water quality models were developed and applied in the study. Test and evaluation, beyond the quantitative analyses permitted by the model application, involved a qualitative evaluation of the degree to which each alternative plan component met water resource objectives and standards and of the legal feasibility of the alternatives. This step in the planning process should therefore clearly demonstrate which alternative plans or portions of plans are technically sound, economically and financially feasible, legally possible, and politically practicable.

The general approach used in the selection of one plan from among the considered alternatives was 1) presentation of the alternatives and of the analyses of their technical, economic, financial, and legal feasibility to the Technical Advisory Committee for review, 2) conduct of interagency and public meetings and hearings, and 3) plan selection and adoption by the Commission. Plan selection and adoption necessarily involve both technical and nontechnical policy determinations. Accordingly, this step must be founded in the active involvement in the planning process of the various governmental bodies, technical agencies, and private interest groups concerned with water quality management of the Milwaukee Harbor estuary. The use of advisory committees and both formal and informal public hearings appears to be the most practical and effective way to involve public officials, technicians, and citizens in the planning process, and to openly arrive at agreement among the various interests on objectives and a final water resource management plan which can be jointly adopted and cooperatively implemented.

The selection of the recommended plan from among the various alternatives considered is based upon an evaluation of the many tangible and intangible factors bearing upon water-related management measures, with primary emphasis, however, upon the degree to which the various alternatives meet the recommended water use objectives and upon the accompanying cost. The recommended water resource management plan for the Milwaukee Harbor estuary is described in Chapter VII of this volume and consists of three major elements: a water quality pollution abatement plan element consisting of four subelements dealing with point sources of pollution, nonpoint sources of pollution, in-place sediments, and water quality monitoring; a dredging and spoils disposal plan element; and a storm protection and flood control plan element.

PLAN IMPLEMENTATION

It was noted in Volume One of this report that although plan implementation is not an element in the seven-step planning process, the recommended plan is not complete in a practical sense until the steps required for its implementation have been specified. Toward this end, the plan must identify the appropriate institutional and administrative structure and mechanisms to implement the plan, as well as identify any changes necessary in legislation and associated regulations relating to water resource management. Set forth in Chapter VIII of this volume are the capabilities of the various levels, units, and agencies of government concerned with, and responsible for, water resource management activities in the Milwaukee Harbor estuary analyzed in terms of meeting the water resource management objectives and supporting standards as set forth in the plan. Available federal and state financial and technical assistance programs are also identified. Because of the completely advisory role of the Commission, implementation of the recommended plan will be entirely dependent upon action by local, state, and federal agencies of government and by entities in the private sector. The Commission intends, however, to monitor progress toward plan implementation and, in cooperation with the Technical Advisory Committee, maintain coordination among the various planning and plan implementation agencies.

SCHEME OF PRESENTATION

The succeeding chapters of this volume set forth the findings of the five steps of the planning process as applied in the Milwaukee Harbor estuary planning program. Chapter II of this volume sets forth the objectives, principles, and standards which provided the basis for plan design and evaluation. Chapter III describes the forecast and planned changes in population, economic activity, and land uses which are to be accommodated in the plan. Chapter IV develops and evaluates alternative water quality management measures for control of nonpoint source pollution, combined sewer overflow and other point source pollution, and in-place pollution. Chapter V develops and evaluates alternative dredging and disposal measures; and Chapter VI develops and evaluates alternative storm damage protection and flood control measures. Together, these last three chapters provide a basis for the selection of a final comprehensive plan from among the various alternative components evaluated. Chapter VII describes the recommended comprehensive water resource management plan for the Milwaukee Harbor estuary and its tributary rivers. Finally, Chapter VIII identifies the appropriate institutional and administrative structure and mechanisms for implementing the plan.

This report can only summarize in brief fashion the large volume of information generated in the forecasting, plan design, plan test and evaluation, and plan selection and adoption phases of the Milwaukee Harbor estuary comprehensive planning program. Although the reproduction of these data in conventional report format is impossible owing to their magnitude and complexity, data from the Commission files are available to member units and agencies of government and to the general public upon request. This report, therefore, serves the additional purpose of indicating the type of data available from the Commission which may be of value to federal, state, and local units and agencies of government and private investors in making decisions concerning development within the Region.

Chapter II

WATER RESOURCE MANAGEMENT OBJECTIVES, PRINCIPLES, AND STANDARDS

INTRODUCTION

As noted in Chapter II of Volume One of this report, the formulation of water resource management objectives and supporting principles and standards for the Milwaukee Harbor estuary and its tributary drainage area is one of the important steps in the planning process applied in the estuary study. Soundly conceived water resource management objectives should be based upon and incorporate the knowledge of many people who are well informed about the various issues to be addressed in, and the various aspects of, the Milwaukee Harbor estuary study, as well as about the study area itself. To the maximum extent possible, such objectives should be established by duly elected or appointed public officials legally assigned this task, assisted as necessary not only by planners and engineers but by interested and concerned citizen leaders as well. This is particularly important because of the value judgments inherent in any set of water resource management objectives.

The active participation of duly elected public officials and citizen leaders in the overall regional planning program is implicit in the composition of the Southeastern Wisconsin Regional Planning Commission itself. Moreover, the Commission very early in its existence recognized the need to provide a broad opportunity for the active participation of elected and appointed public officials, technicians, and citizens in the regional planning process. To meet this need, the Commission established advisory committees to assist the Commission and its staff in the conduct of the regional planning program. One of these committees is the Technical Advisory Committee for the Milwaukee Harbor Estuary Comprehensive Water Resources Plan, the composition of which is presented in Chapter I of Volume One of this report. One of the important functions of this Committee is to assist in the formulation of a set of water resource management objectives, principles, and standards for the Milwaukee Harbor estuary which can provide a sound basis for plan design, test, and evaluation.

This chapter sets forth the set of water resource management objectives and supporting principles and standards formulated by the Technical Advisory Committee. Some of these objectives, principles, and standards were originally advanced by the Regional Planning Commission and its advisory committees under other regional planning programs, but were deemed relevant to the design, test, and evaluation of alternative water resource plans for the Milwaukee Harbor estuary and for the selection of a recommended plan. Others were formulated specifically as a basis for the preparation of the harbor estuary plan.

The water use objectives and supporting water quality standards established in this study, which will be presented in final form as part of the recommended plan following an evaluation of alternative plans, are advisory to, among other units and agencies of government, the Wisconsin Department of Natural Resources. The Wisconsin Statutes grant authority to the Department to establish water use objectives and water quality standards for all surface waters of the State for regulatory purposes. The Department has expressed its intent to reevaluate the currently established use objectives for the Milwaukee Harbor estuary waters in consideration of the findings and recommendations of this study. The Department is also reevaluating and revising the water quality standards which support water use objectives. The U. S. Environmental Protection Agency must approve any revisions to the state water use objectives and supporting water quality 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 similarly subject to a wide range of interpretation and application. The following definitions, therefore, have 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 the 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 primarily with the first three of these terms, an understanding of the interrelationship of the foregoing definitions and the basic concepts which they represent is essential to the following discussion of water resource management objectives, principles, and standards.

The above terminology is somewhat different from the terminology applied by the Wisconsin Department of Natural Resources in its water quality management programs. What are termed "water use objectives" in this report are referred to by the Department as "water use classifications." "Water quality standards," which in this report support water use objectives, are referred to as "water quality criteria" by the Department. For clarity and consistency, the terms "water use objectives" and "water quality standards" will be used throughout this report, including in the discussion of the existing Department water quality regulations. However, acute and chronic toxic criteria developed by the Department of Natural Resources are presented in this chapter and are referred to as criteria rather than standards, because they are preliminary and have not been formally adopted by the Department. These criteria are presented to help evaluate the potential adverse effects of toxic substances on water uses in the estuary, but were not adopted under the Milwaukee Harbor estuary study as standards necessary to support desired water uses.

WATER RESOURCE MANAGEMENT OBJECTIVES

In order to be useful in the Milwaukee Harbor estuary planning process, objectives must not only be logically sound and related in a demonstrable and measurable way to alternative water resource management proposals, but also must be consistent with, and grow out of, more comprehensive, areawide development objectives. This is essential if the harbor estuary plan is to constitute an integral element of a comprehensive plan for the physical development of the Region, and if sound coordination of other regional and local plan elements with the Milwaukee Harbor estuary plan is to be achieved.

The Southeastern Wisconsin Regional Planning Commission has, in its planning efforts to date, adopted a number of areawide development objectives relating to land use, housing, transportation, water quality management, flood control, and outdoor recreation and open space development. All of these objectives were adopted following careful review and recommendation by various advisory and coordinating committees, and after public hearings. These objectives, together with their supporting principles and standards, are set forth in other Commission planning reports. As discussed below, some of these objectives and supporting standards are directly applicable or adaptable to the Milwaukee Harbor estuary planning effort, and—together with two new objectives—are hereby recommended for adoption as water resource management and related objectives for the Milwaukee Harbor estuary.

Water Quality Management Objectives

All of the five specific water quality management objectives adopted by the Commission under its regional water quality management planning effort are directly applicable to the Milwaukee Harbor estuary planning effort. These are:

1. The development of land management and water quality control practices and facilities which will effectively serve the existing regional urban development pattern and promote implementation of the regional land use plan, meeting the anticipated need for sanitary and industrial wastewater disposal and the need for stormwater runoff control generated by the existing and proposed land uses.

2. The development of land management and water quality control practices and facilities, including instream measures, which will meet—for the watercourses tributary to the Milwaukee Harbor estuary—the recommended water use objectives and supporting water quality standards as set forth in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, and—for

the waters comprising the Milwaukee Harbor estuary—the water use objectives and supporting water quality standards as set forth on Map 2 and Table 5.

3. The development of land management and water quality control practices and facilities that are properly related to and which will enhance the overall quality of the natural and man-made environments.

4. The development of land management and water quality control practices and facilities that are economical and efficient, meeting all other objectives at the lowest possible cost.

5. The development of water quality management systems—inclusive of the governmental units and their responsibilities, authorities, policies, procedures, and resources—and supporting revenue-raising mechanisms which are effective and locally acceptable, and which will provide a sound basis for plan implementation including the planning, design, construction, operation, maintenance, repair, and replacement of water quality control practices and facilities, inclusive of sanitary sewerage systems, stormwater management systems, land management practices, and in-place pollution control measures.

Water Control Facility Development Objectives

One of the four specific water control facility development objectives previously adopted by the Commission is applicable to the Milwaukee Harbor estuary planning effort: the development of an integrated system of drainage and flood control facilities and floodland management programs which will effectively reduce flood damage under the existing land use pattern of the study area and promote the implementation of the regional land use plan, properly accommodating the anticipated hydraulic runoff quantities generated by the existing and proposed land uses. In addition to the foregoing water control facility development objective, the following two water control facility development objectives were adopted for the Milwaukee Harbor estuary planning program:

The development of structural and nonstructural shoreline protection measures to abate shoreline damages caused by flooding, fluctuating water levels, strong currents, ice activity, and wave action; and

The effective and efficient maintenance of deep water commercial navigation, waterborne commerce, anchorage protection, and associated waterborne transportation.

Recreation and Park and Open Space Objectives

Seven park and open space objectives have been adopted by the Commission under its regional park and open space planning program. One of these objectives—the provision of opportunities for participation by the resident population of the Region in extensive water-based outdoor recreation activities on the major inland lakes and rivers and on Lake Michigan, as consistent with safe and enjoyable water use and maintenance of good water quality—was adopted for the Milwaukee Harbor estuary planning program. The remaining six objectives adopted under the Commission's regional park and open space planning program are: 1) the provision of an integrated system of public general-use outdoor recreation sites and related open space areas which will allow the resident population of the Region adequate opportunity to participate in a wide range of outdoor recreation activities; 2) the preservation of sufficient high-quality open space lands for the protection of the underlying and sustaining natural resource base and the enhancement of the social and economic well being and environmental quality of the Region; 3) the efficient and economical satisfaction of outdoor recreation and related open space needs, meeting all other objectives at the lowest possible cost; 4) the provision of sufficient outdoor recreation facilities to allow the resident population of the Region adequate opportunity to participate in intensive nonresource-oriented outdoor recreation activities; 5) the provision of sufficient outdoor recreation facilities to allow the resident population of the Region adequate opportunity to participate in intensive resource-oriented outdoor recreation activities; and 6) the provision of sufficient outdoor recreation facilities to allow the resident population of the Region adequate opportunity to participate in extensive land-based outdoor recreation activities. While these park and open space objectives are applicable to the tributary drainage area of the Milwaukee Harbor estuary, they relate primarily to land use development and should be applied at the local level as a joint effort by counties, school districts, and local community recreation and planning agencies.

The other three previously adopted water control facility development objectives are: 1) the development of an integrated system of land management and water quality control facilities and pollution abatement devices adequate to ensure a quality of inland lake water necessary to achieve established water use objectives; 2) the attainment of sound groundwater resource development and protective practices to minimize the possibility for pollution and depletion of the groundwater resources; and 3) the development of an integrated system of land management and water quality control facilities and pollution abatement devices adequate to ensure the quality of surface water necessary to meet the established water use objectives and supporting water quality standards.

Principles and Standards

Complementing each of the foregoing water quality management, recreation and park and open space, and water control facility development objectives is a planning principle which supports the objective and asserts its inherent validity, and a set of quantifiable planning standards which can be used to evaluate the absolute or relative ability of alternative plan designs to meet the stated objective. Supporting principles and standards for the five applicable water quality management objectives, three water control facility development objectives, and one recreation and park and open space objective, as they relate to the Milwaukee Harbor estuary plan, are set forth in Tables 1, 2, and 3 and serve to facilitate quantitative application of the objectives during plan design, test, and evaluation.

Existing State Water Use Objectives and Water Quality Standards: Section 144.025(2)(b) of the Wisconsin Statutes requires that the Wisconsin Department of Natural Resources prepare and adopt water use objectives and supporting water quality standards that apply to all surface waters of the State. Such authority is essential if the State is to meet the requirements of the Federal Water Pollution Control Act. Water use objectives and supporting water quality standards were initially adopted for interstate waters in Wisconsin on June 1, 1967, and for intrastate waters on September 1, 1968. On October 1, 1973, the Wisconsin Natural Resources Board adopted revised water use objectives and supporting water quality standards which were set forth in Wisconsin Administrative Code Chapters NR 102, 103, and 104. On October 1, 1976, Administrative Code Chapter NR 104 was further revised. The Department of Natural Resources is currently in the process of revising water quality standards in accordance with Section 24 of the U. S. Environmental Protection Agency 1981 Municipal Wastewater Treatment Construction Grant Amendments. The results and recommendations of this study are intended to assist the Department in these revisions.

Water quality standards have been formulated for the following major water uses in the Milwaukee Harbor estuary tributary drainage area:[1] recreational use; public water supply; warmwater fish and aquatic life; coldwater fish and aquatic life; and intermediate fish and aquatic life. In addition, two variance categories—variances (a)[2] and (b)[3]—have been established by the Department of Natural Resources within the tributary drainage area. These two categories are intended to support only limited nonbody contact recreational uses and fish and aquatic organisms that are relatively tolerant of polluted water conditions. The water quality standards supporting these variance categories are generally less restrictive than the standards supporting other water use objectives. Currently, the entire Milwaukee inner harbor, as well as certain other streams in the Region, is classified as variance category (a) or (b). Furthermore, there are minimum standards which apply to all surface waters in the State. It is a goal of the Department of Natural Resources to remove variance categories, whenever possible, through the implementation of water quality management programs.

The existing water use objectives established by the Department of Natural Resources for the entire Milwaukee Harbor estuary tributary drainage area are shown on Map 1. Table 4 sets forth the water quality standards supporting these objectives.

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[1] *The terms "Milwaukee Harbor estuary tributary drainage area," "estuary direct drainage area," "outer harbor," and "inner harbor" are applied as defined in Chapter II of Volume One of this report. The Milwaukee Harbor estuary tributary drainage area includes portions of the Milwaukee River watershed lying outside the Southeastern Wisconsin Region in Fond du Lac and Sheboygan Counties.*

[2] *As set forth in Chapter NR 104.06(2)(a) of the Wisconsin Administrative Code.*

[3] *As set forth in Chapter NR 104.06(2)(b) of the Wisconsin Administrative Code.*

Table 1

WATER QUALITY MANAGEMENT OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE MILWAUKEE HARBOR ESTUARY

OBJECTIVE NO. 1

The development of land management and water quality control practices and facilities which will effectively serve the existing regional urban development pattern and promote implementation of the regional land use plan, meeting the anticipated need for sanitary and industrial wastewater disposal and the need for stormwater runoff control generated by the existing and proposed land uses.

PRINCIPLE

Sanitary sewerage and stormwater drainage systems are essential to the development and management of a safe, healthy, and attractive urban environment. The extension of existing sanitary sewerage and stormwater drainage systems and the creation of new systems can be effectively used to guide and shape urban development both spatially and temporally.

STANDARDS

1. Sanitary sewer service should be provided to all existing areas of medium-[a] or high-density[b] urban development and to all areas proposed for such development in the regional land use plan.

2. Sanitary sewer service should be provided to all existing areas of low-density[c] urban development and to all areas proposed for such development in the regional land use plan where such areas are contiguous to areas of medium- or high-density urban development. Where noncontiguous low-density development already exists, the provision of sanitary sewer service should be contingent upon the inability of the underlying soil resource base to properly support onsite absorption waste disposal systems.

3. Engineered and partially engineered storm water management facilities[d] should be provided to all existing areas of low-, medium-, and high-density urban development and to all areas proposed for such development in the regional land use plan.

4. Where public health authorities declare that public health hazards exist because of the inability of the soil resource base to properly support onsite soil absorption waste disposal systems, sanitary sewer service should be provided.

5. Lands designated as primary environmental corridors in the regional land use plan should not be served by sanitary sewers, except that development incidental to the preservation and protection of the corridors, such as parks and related outdoor recreation areas, and existing clusters of urban development in such corridors should be served by sanitary sewers when necessary. Engineering analyses relating to the sizing of sanitary sewerage facilities and stormwater management facilities should assume the permanent preservation of all undeveloped primary environmental corridor lands in natural open space uses.

6. Floodlands[e] should not be served by sanitary sewers except that development incidental to the preservation in open space uses of floodlands, such as parks and related outdoor recreation areas, and existing urban development in floodlands not recommended for eventual removal in comprehensive plans. Engineering analyses relating to the sizing of sanitary sewerage or storm water management facilities should not assume ultimate development of floodlands for urban use.

7. Significant concentrations[f] of lands covered by soils found in the regional soil survey to have very severe limitations for urban development even with the provision of sanitary sewer service should not be provided with such service. Engineering analyses relating to the sizing of sewerage or stormwater management facilities should not assume ultimate urban development of such lands for urban use.

8. The timing of the extension of sanitary sewerage facilities should, insofar as possible, seek to promote urban development in a series of complete neighborhood units, with service being withheld from any new units in a given municipal sewer service area until previously served units are substantially developed and until existing units not now served are provided with service.

9. The sizing of sanitary sewerage and stormwater management facility components should be based upon an assumption that future land use development will occur in general accordance with the adopted regional land use plan.

10. To the extent feasible, industrial wastes except clear cooling waters, as well as the sanitary wastes generated at industrial plants, should be discharged to municipal sanitary sewerage systems for ultimate treatment and disposal. The necessity to provide pretreatment for industrial wastes should be determined on an individual case-by-case basis and should consider any regulations relating thereto.

11. Rural land management practices should be given priority in areas which are designated as prime agricultural lands to be preserved in long-term use for the production of food and fiber.

Table 1 (continued)

OBJECTIVE NO. 2

The development of land management and water quality control practices and facilities, including instream measures, which will meet—for the watercourses tributary to the Milwaukee Harbor estuary—the recommended water use objectives and supporting water quality standards as set forth in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000,[9] and—for the waters comprising the Milwaukee Harbor estuary—the water use objectives and supporting water quality standards as set forth on Map 2 and Table 5.

PRINCIPLE

Sewage treatment plant effluent, industrial wastewater discharges, and rural and urban runoff are major contributors of pollutants to the streams and lakes of the Region; the location, design, construction, operation, and maintenance of sewage treatment plants, industrial wastewater outfalls, and stormwater management facilities and the quality and quantity of the wastewater from such facilities have a major effect on stream and lake water quality and the ability of that water to support the established water uses.

STANDARDS

1. The level of control of point, nonpoint, and in-place sources of pollution should be determined by water quality analyses directly related to the recommended water use objectives for the receiving surface water body. These analyses should demonstrate that the proposed level of pollution control will aid in achieving the water quality standards supporting each water use objective.

2. The type and extent of storm water treatment or associated preventive land management practices to be applied within a hydrologic unit should be determined by water quality analyses directly related to the established water use objectives for the receiving surface water body. These analyses should demonstrate that the proposed treatment level or land management practices will aid in achieving the water quality standards supporting each major water use objective.

3. Domestic livestock should be fenced out of all lakes and perennial streams, and direct storm water runoff from the associated feeding areas to the lakes and perennial streams should be avoided so as to contribute to the achievement of the established water use objectives and standards.

4. The discharge of sewage treatment plant effluent directly to inland lakes should be avoided and sewage treatment plant discharges to streams flowing into inland lakes should be located and treated so as to contribute to the achievement of the established water use objectives and standards for those lakes.

5. The specific standards for sewage treatment at all sewage treatment plants discharging effluent to Lake Michigan shall be those established by the Federal Lake Michigan Enforcement Conference, or the amendments established thereto as a result of other subsequent federal administrative and enforcement actions.

6. Existing sewage treatment plants scheduled to be abandoned within the plan design period should provide only secondary waste treatment and disinfection of effluent unless a further degree of treatment is determined to be required to meet the established water use objectives and standards for the receiving surface water body.

7. Interim sewage treatment plants deemed necessary to be constructed prior to implementation of the long-range plan should provide levels of treatment determined by water quality analyses directly related to the established water use objectives and standards for the receiving surface water body.

8. Bypassing of sewage to storm sewer systems, open channel drainage courses, and streams should be prohibited.

9. Combined sewer overflows should be eliminated or adequately treated to meet the established water use objectives and standards for the receiving body of surface water.

10. Sewage treatment plants should be designed to perform their intended function and to provide their specified level of treatment under adverse conditions of inflow, should be of modular design with sufficient standby capacity to allow maintenance to be performed without bypassing influent sewage, and should not be designed to bypass any flow delivered by the inflowing sewers, but should incorporate an emergency bypass facility sufficient to protect sewage treatment equipment against flows in excess of the design hydraulic capacity of the plant.

11. All industrial sewage treatment plants should provide the best available wastewater treatment which is economically achievable.

12. All sanitary sewage treatment plants should provide the best practicable wastewater treatment technology.

13. No pollutants should be discharged by sanitary or industrial sewage treatment plants in amounts which would preclude the achievement of the recommended water use objectives and supporting water quality standards.

Table 1 (continued)

14. The orderly transition of lands from open space, agricultural, or other rural uses to urban uses through excavation, landshaping, and construction should be planned, designed, and conducted so as to contribute to the achievement of the established water use objectives and standards.

15. The methods and level of control of point sources, nonpoint sources, combined sewer overflows, and instream sources should be determined by hydraulic, water quality, and biological analyses which demonstrate that short-term and long-term adverse impacts on aquatic life are minimized. These analyses should demonstrate that the control measures will prevent or minimize the exceedance of toxic levels of pollutants; will reduce adverse impacts in consideration of the duration, frequency, and magnitude of extreme changes in water quality conditions; will minimize the adverse impacts of bottom sediment scouring by storm sewer or combined sewer outfalls; will prevent or minimize the adverse impacts caused by the covering of benthic habitats with sediment; and will prevent or minimize the adverse impacts on the biological community diversity, productivity, and stability.

Pollution control measures should be designed to:

a. Prevent relatively rapid changes in, or extreme levels of, dissolved oxygen, temperature, and turbidity which may have a significant adverse impact on the survival, reproduction, or health of aquatic life species indigenous to the water body.

b. Prevent exceedance, at any time, of the acute toxic criteria set forth in Table 9 of this volume as applicable to the biological species present within the Milwaukee Harbor estuary study area.

c. Prevent exceedance, on a 30-day mean basis, of the chronic toxic criteria set forth in Table 9 of this volume as applicable to the biological species present within the Milwaukee Harbor estuary study area. Such chronic toxic criteria should not be exceeded for a total of more than 96 hours within any 30-day period.

d. Prevent the scouring or sediment covering of aquatic benthic organisms or valuable feeding or breeding area bottom substrates which may have a significant adverse impact on the survival, reproduction, or health of important aquatic life species indigenous to the water body.

16. Dredging of the Milwaukee Harbor estuary beyond that required to maintain adequate water depths for navigation and capacity for flood control should be provided only where dredging is found to be the most cost-effective instream measure for achieving the recommended water use objectives and supporting water quality standards for the Milwaukee Harbor estuary, as set forth on Map 2 and in Table 5. The methods and intervals of dredging should be developed to eliminate or minimize the adverse impacts of disturbed polluted bottom sediments. All dredging activities conducted for maintenance of navigation or for water quality enhancement purposes, as well as the disposal of the dredging spoils, should be conducted in conformance with all state and federal regulations concerned with the removal or disposal of bottom sediments. In those cases where release of nutrients from bottom sediments during dredging operations may create nuisance algal conditions, the dredging activities should be conducted during periods of cool water temperature—generally from October through April. Whenever possible, dredging activities should be scheduled to coincide with the least sensitive portion of the life cycle of the important aquatic life species threatened by the dredging activity.

17. Materials which can contaminate the groundwater should be stored, handled, used, and disposed of in a manner which minimizes the contamination of the groundwater system and the possibility thereby of subsequent surface water pollution.

18. Water quality should not be degraded beyond existing levels except where a demonstration of economic hardship or compelling social need is presented.

OBJECTIVE NO. 3

The development of land management and water quality control practices and facilities that are properly related to and will enhance the overall quality of the natural and man-made environments.

PRINCIPLE

The improper design, installation, application, or maintenance of land management practices, sanitary sewerage system components, and storm water management components can adversely affect the natural and man-made environments; therefore, every effort should be made in such actions to properly relate to these environments and minimize any disruption or harm thereto.

STANDARDS

1. New and replacement sewage treatment plants, as well as additions to existing plants, should, wherever possible, be located on sites lying outside of the 100-year recurrence interval floodplain. When it is necessary to use floodplain lands for sewage treatment plants, the facilities should be located outside of the floodway so as to not increase the 100-year recurrence interval flood stage, and should be floodproofed to a flood protection elevation of two feet above the 100-year recurrence interval flood stage so as to assure adequate protection against flood damage and avoid disruption of treatment and consequent bypassing of sewage during flood periods. In the event that a floodway has not been established, or if it is necessary to encroach upon an approved floodway, the hydraulic effect of such encroachment should be evaluated on the basis of an equal degree of encroachment for a significant reach on both sides of the stream, and the degree of encroachment should be limited so as not to raise the peak stage of the 100-year recurrence interval flood by more than 0.1 foot.

Table 1 (continued)

2. Existing sewage treatment plants located in the 100-year recurrence interval floodplain should be floodproofed to a flood protection elevation of two feet above the 100-year recurrence interval flood stage so as to assure adequate protection against flood damage and avoid disruption of treatment and consequent bypassing of sewage during flood periods.

3. The location of new and replacement of old sewage treatment plants or stormwater storage and treatment facilities should be properly related to the existing and proposed future urban development pattern as reflected in the regional land use plan and to any community or neighborhood unit development plans prepared pursuant to, and consistent with, the regional land use plan.

4. New and replacement sewage treatment plants, as well as additions to existing plants, should be located on sites large enough to provide for adequate open space between the plant and existing or planned future urban land uses; should provide adequate area for expansion to ultimate capacity as determined in the regional sanitary sewerage system plan; and should be located, oriented, and architecturally designed so as to complement their environs and to present an attractive appearance consistent with their status as public works.

5. The disposal of sludge from sewage treatment plants should be accomplished in the most efficient manner possible, consistent, however, with any adopted rules and regulations pertaining to air quality control and solid waste disposal.

6. Devices used for long-term or short-term storage of pollutants which are collected through treatment of wastewater or through the application of land management practices should, wherever possible, be located on sites lying outside of the 100-year recurrence interval floodplain. When it is necessary to use floodplain lands for such facilities, such devices should be located outside of the floodway so as not to increase the 100-year recurrence interval flood stage, and should be floodproofed to a flood protection elevation of two feet above the 100-year recurrence interval flood stage so as to assure adequate protection against flood damage and to avoid redispersal of the pollutants into natural waters during flood periods. In the event that a floodway has not been established, or if it is necessary to encroach upon an approved floodway, the hydraulic effect of such encroachment shall be evaluated on the basis of an equal degree of encroachment for a significant reach on both sides of the stream and the degree of encroachment shall be limited so as not to raise the peak stage of the 100-year recurrence interval flood by more than 0.1 foot. This standard is not intended to preclude the construction of storm water detention-retention facilities, such as small-scale cascade basins in series along a stream channel, which by their design require emplacement within a floodway or floodplain. In these cases, the effects on water quality and upstream flood stages must be considered explicitly.

OBJECTIVE NO. 4

The development of land management and water quality control practices and facilities that are economical and efficient, meeting all other objectives at the lowest possible cost.

PRINCIPLE

The total resources of the Region are limited and any undue investment in water pollution control systems must occur at the expense of other public and private investment; total pollution abatement costs, therefore, should be minimized while meeting and achieving all water quality standards and objectives.

STANDARDS

1. The sum of sanitary sewerage system operating and capital investment costs should be minimized.

2. The sum of stormwater control facility and related land management practice operating and capital investment costs should be minimized.

3. The total number of sanitary sewerage systems and sewage treatment facilities should be minimized in order to effect economies of scale and concentrate responsibility for water quality management. Where physical consolidation of sanitary sewer systems is uneconomical, administrative and operational consolidation should be considered in order to obtain economy in manpower utilization and to minimize duplication of administrative, laboratory, storage, and other necessary services, facilities, and equipment. The total number of diffuse pollution control facilities should be minimized in order to concentrate the responsibility for water quality management.

4. Maximum feasible use should be made of all existing and committed pollution control facilities, which should be supplemented with additional facilities only as necessary to serve the anticipated wastewater management needs generated by substantial implementation of the regional land use plan, while meeting pertinent water quality use objectives and standards.

5. The use of new or improved materials and management practices should be allowed and encouraged if such materials and practices offer economies in materials or construction costs or by their superior performance lead to the achievement of water quality objectives at a lesser cost

6. Sanitary sewerage systems, sewage treatment plants, and storm water management facilities should be designed for staged or incremental construction where feasible and economical so as to limit total investment in such facilities and to permit maximum flexibility to accommodate changes in the rate of population growth and the rate of economic activity growth, changes in water use objectives and standards, or changes in the technology for wastewater management.

Table 1 (continued)

7. When technically feasible and otherwise acceptable, alignments for new sewer construction should coincide with existing public rights-of-way in order to minimize land acquisition or easement costs and disruption to the natural resource base.

8. Clearwater infiltration and inflow to the sanitary sewerage system should be reduced to the cost-effective level.

9. Sanitary sewerage systems and storm water management systems should be designed and developed concurrently to effect engineering and construction economies as well as to assure the separate function and integrity of each of the two systems; to immediately achieve the pollution abatement and drainage benefits of the integrated design; and to minimize disruption of the natural resource base and existing urban development.

OBJECTIVE NO. 5

The development of water quality management institutions—inclusive of the governmental units and their responsibilities, authorities, policies, procedures, and resources—and supporting revenue-raising mechanisms which are effective and locally acceptable, and which will provide a sound basis for plan implementation including the planning, design, construction, operation, maintenance, repair, and replacement of water quality control practices and facilities, inclusive of sanitary sewerage systems, stormwater management systems, land management practices, and in-place pollution control measures.

PRINCIPLE

The activities necessary for the achievement of the established water use objectives and supporting standards are expensive; technically, administratively, and legally complex; and important to the economic and social well being of the residents of the Region. Such activities require a continuing, long-term commitment and attention from public and private entities. The conduct of such activities requires that the groups designated as responsible for plan implementation have sufficient financial and technical capabilities, legal authorities, and general public support to accomplish the specific tasks identified.

STANDARDS

1. Each designated management agency should develop and establish a system of user charges and industrial cost recovery to maintain accounts to support the necessary operation, maintenance, and replacement expenditures.

2. Maximum utilization should be made of existing institutional structures in order to minimize the number of agencies designated to implement the recommended water quality control measures, and the creation of new institutions should be recommended only where necessary.

3. To the greatest extent possible, the responsibility for water pollution control and abatement should be assigned to the most immediate local public agency or to the most directly involved private entity.

4. Each designated management group should have legal authority, financial resources, technical capability, and practical autonomy sufficient to assure the timely accomplishment of its responsibilities in the achievement of the recommended water use objectives and supporting standards.

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[a] *Medium-density development is defined as that development having an average dwelling unit density of 4.4 dwelling units per net residential acre, and a net lot area per dwelling unit ranging from 6,231 to 18,980 square feet.*

[b] *High-density development is defined as that development having an average dwelling unit density of 12.0 dwelling units per net residential acre and a net lot area per dwelling unit ranging from 2,439 to 6,230 square feet.*

[c] *Low-density development is defined as that development having an average dwelling unit density of 1.2 dwelling units per net residential acre and a net lot area per dwelling unit ranging from 18,981 to 62,680 square feet.*

[d] *Engineered stormwater management facilities are defined here as the systems or subsystems of stormwater catchment, conveyance, storage, and treatment facilities comprised of structural controls including natural and man-made surface drains, subsurface piped drains, or combinations thereof, and of pumping stations, surface or subsurface storage or detention basins, and other appurtenances associated therewith, and sized to accommodate estimated flows or quantities from the tributary drainage area as a result of a specified meteorologic or hydrologic event.*

[e] *Floodlands are defined as those lands, including floodplains, floodways, and channels, subject to inundation by the 100-year recurrence interval flood or where such data are not available, the maximum flood of record.*

[f] *Areas larger than 160 acres in extent.*

[g] *Water use objectives for the Milwaukee Harbor estuary were not set forth in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000. The plan recommended that water use objectives for the Milwaukee Harbor estuary be established following further study of the complex hydraulic, biological, sediment, and pollutant loading conditions within the estuary.*

Source: SEWRPC.

Table 2

WATER CONTROL FACILITY DEVELOPMENT OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE MILWAUKEE HARBOR ESTUARY

OBJECTIVE NO. 1

The development of an integrated system of drainage and flood control facilities and floodland management programs which will effectively reduce flood damage under the existing land use pattern of the watershed and promote the implementation of the regional land use plan, properly accommodating the anticipated hydraulic runoff loadings generated by the existing and proposed land uses.

PRINCIPLE

Reliable local municipal stormwater 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 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 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 0.1[a] 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 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 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 modifications, dikes, and floodwalls should be restricted to the minimum number and extent absolutely necessary for the protection of existing and proposed land use development, which is consistent with the land use element of the comprehensive watershed plan. The upstream and downstream effect of such structural works on flood discharges and stages shall be determined, and any such structural works which may significantly increase upstream or downstream peak flood discharges should be used only in conjunction with complementary

Table 2 (continued)

facilities for the storage and movement of the incremental floodwaters through the watershed stream system. Channel modifications, dikes, or floodwalls shall not increase the height of the 100-year recurrence interval flood by more than 0.1 foot in any unprotected upstream or downstream stream reaches. Increases in flood stages in excess of 0.1 foot resulting from any channel, dike, or floodwall construction shall be contained within the upstream or downstream extent of the channel, dike, or floodwall, except where topographic or land use conditions could accommodate the increased stage without creating additional flood damage potential.

7. The height of dikes 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.

8. The construction of channel modifications, dikes, 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 modifications, dikes, or floodwalls are actually constructed and operative. Any development in a former floodway or floodplain located to the landward side of any dike or floodwall shall be provided with adequate drainage so as to avoid ponding and associated damages.

9. 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.

10. 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 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]

PRINCIPLE

Floodlands that are unoccupied by, and not committed to, urban development should be retained in an essentially natural open space condition supplemented with the development of selected areas for public recreational uses. Maintaining floodlands in open uses will serve to protect one riverine community from the adverse effects of the actions of others by discouraging floodland development which would significantly aggravate existing flood problems or create new flood problems upstream or downstream; will preserve natural floodwater conveyance and storage capacities; will avoid increased peak flood discharges and stages; will contribute to the preservation of wetland, woodland, and wildlife habitat as part of a continuous linear system of open space, and will immeasurably enhance the quality of life for both the urban and rural population by preserving and protecting the recreational, aesthetic, ecological, and cultural values of riverine areas.

STANDARDS

1. All public land acquisitions, easements, floodland use regulations, and other measures intended to eliminate the need for water control facilities shall, in all areas not already in intensive urban use or committed to such use, encompass at least all of the riverine areas lying within the 100-year recurrence interval flood inundation line.

2. Where hydraulic floodways are to be delineated, they shall to the maximum extent feasible accommodate existing, committed, and planned floodplain land uses.

3. In the determination of a hydraulic floodway, the hydraulic effect of the potential floodplain encroachment represented by the floodway shall be evaluated on the basis of an equal degree of encroachment for a significant reach on both sides of the stream, and the degree of encroachment shall be limited so as to not raise the peak stage of the 100-year recurrence interval flood by more than 0.1 foot. Larger stage increases may be acceptable if appropriate legal arrangements are made with affected local units of government and property owners.

OBJECTIVE NO. 2

The development of structural and nonstructural shoreline protection measures to abate shoreline damages caused by flooding, fluctuating water levels, strong currents, ice activity, and wave action.

PRINCIPLE

Structural shoreline protection measures, such as bulkheads, revetments, and breakwaters, as well as nonstructural shoreline protection measures, such as required setback distances for buildings, must be properly designed and developed in order to abate shoreline erosion and reduce attendant property damages, aesthetic impacts, and risks to human safety which result from such erosion and damages.

STANDARDS

1. At a minimum, all shoreline protection structures should be sized for design waves expected for a 100-year recurrence interval high-water level of Lake Michigan, or 584.5 feet[b] above National Geodetic Vertical Datum.

Table 2 (continued)

2. All shoreline protection structures should be designed to:

   a. Protect the base of the structure against wave scouring.

   b. Avoid structural damage or erosion on the landward side of the structure by storm waves, or provide for the positive drainage of any water which overtops the structure.

   c. Provide measures to prevent excessive erosion along the flanks of the structure.

   d. Provide adequate bedding materials to prevent undercutting of the structure.

3. All shoreline areas not protected by a structure should be graded to a stable slope of not steeper than one on two and one-half, and have adequate vegetative cover.

4. Nonstructural shoreline protection measures within the Milwaukee Harbor estuary direct drainage area should be based on a 100-year period of expected shoreline erosion and damage.

5. Structural as well as nonstructural shoreline protection measures should be properly related to existing urban development, and disruptive impacts to residential areas and to public access sites should be minimized.

OBJECTIVE NO. 3

The effective and efficient maintenance of deep water commercial navigation, waterborne commerce, anchorage protection, and associated waterborne transportation.

PRINCIPLE

Waterborne transportation is an important element of the regional transportation system, contributing to the economic development of the Region. Within the Region, waterborne transportation facilities consist entirely of port facilities linking the Region to major national and international seaways.

STANDARDS

1. Adequate port facilities should be provided to service ocean-going vessels, tanker vessels, car ferries, barges, and large Great Lakes cargo freighters, and to facilitate the loading and unloading of bulk, heavy, liquid, and general cargo.

2. The Milwaukee outer harbor and the interconnected river channels that form the Port of Milwaukee should be maintained so as to provide at established Lake Michigan low water datum the depths indicated on Map 17 in Chapter V. The Milwaukee River from E. Buffalo Street to the E. North Avenue dam shall not be considered navigable by deep draft commercial vessels, but only by small pleasure craft.

3. Any instream pollution abatement measures installed for water quality enhancement purposes should be designed, constructed, and operated so as not to interfere with existing or expected future navigation, waterborne commerce, and water-based transportation.

4. Adequate structural shore protection measures should be provided to protect Port of Milwaukee facilities from flooding, shoreline erosion, and ice and wave damage.

5. Slips and other anchorages regularly used for the on and off loading of commercial vessels shall be designed to protect moored vessels from wave damage.

[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 of SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, November 1968.*

[b] *The 100-year recurrence interval lake level is defined as the instantaneous static lake level with a 1 percent chance of exceedance in any given year. Therefore, effects of wave height and wave run-up are not reflected in the 100-year stage. Effects of present outlet channels, diversions, and lake-level regulations are incorporated, however.*

Source: SEWRPC.

Table 3

RECREATION AND PARK AND OPEN SPACE OBJECTIVE, PRINCIPLE, AND STANDARDS FOR THE MILWAUKEE HARBOR ESTUARY

OBJECTIVE

The provision of opportunities for participation by the resident population of the Region in extensive water based outdoor recreation activities on the major inland lakes and rivers and on Lake Michigan, consistent with safe and enjoyable lake use and maintenance of good water quality.

PRINCIPLE

The major inland lakes and rivers of the Region and Lake Michigan accommodate participation in extensive water based recreation activities, including canoeing, fishing, ice fishing, motor boating, sailing, and water skiing, which may involve unique forms of physical exercise or simply provide opportunities for rest and relaxation within a particularly attractive natural setting. Participation in extensive water based recreation activities requires access to the major inland lakes and rivers and Lake Michigan and such access should be available to the general public.

STANDARDS

1. The maximum number of public access points consistent with safe and enjoyable participation in extensive water based recreation activities should be provided on the major inland lakes throughout the Region. To meet this standard the following guidelines for access points available for use by the general public on various sized major inland lakes should be met as indicated below:

Size of Major Lake (acres)	Minimum Number of Access Points—Public and Private	Optimum Number of Parking Spaces
50-199	1	$\frac{A}{16.6} - \frac{D}{10}$ [a] Minimum: 6 [b]
200 or more	Minimum of 1 or 1 per 1,000 acres of usable surface [c]	$\frac{A}{15.9} - \frac{D}{10}$ [d] Minimum: 12

2. The proper quantity of public access points consistent with safe and enjoyable participation in the various extensive water based recreation activities should be provided on major rivers throughout the Region. To meet this standard the maximum interval between access points on canoeable rivers[e] should be 10 miles.

3. A sufficient number of boat launch ramps consistent with safe and enjoyable participation in extensive water based outdoor recreation activities should be provided along the Lake Michigan shoreline within harbors of refuge. To meet this standard the following guidelines for the provision of launch ramps should be met:

Minimum Per Capita Facility Requirements (ramps per 1,000 residents)	Design Standards				Maximum Distance Between Harbors of Refuge
	Typical Location of Facility	Facility Area Requirements	Suggested Support Facilities, Services, and Backup Lands	Support Facility Area Requirements	
0.025	Type I Sites, defined as large outdoor recreation sites having a multicounty service area; Type II Sites, defined as intermediate size sites having a countywide or multicommunity service area; and Type III Sites, defined as intermediate size sites having a multineighborhood service area	0.015 acre per ramp	Rest rooms Parking (40 car and trailer spaces per ramp)	-- 0.64 acres per ramp minimum	15 miles

Table 3 (continued)

4. A sufficient number of boat slips consistent with safe and enjoyable participation in extensive water based outdoor recreation activities should be provided at marinas within harbors of refuge along the Lake Michigan shoreline. To meet this standard the following guidelines for the provision of boat slips should be met:

Minimum Per Capita Facility Requirements (boat slips per 1,000 residents)	Design Standards			Support Facility Area Requirements
	Typical Location of Facility	Facility Area Requirements	Suggested Support Facilities, Services, and Backup Lands	
1.3	Type I Sites, defined as large outdoor recreation sites having a multicounty service area; Type II Sites, defined as intermediate size sites having a countywide or multicommunity service area; and Type III Sites, defined as intermediate size sites having a multineighborhood service area	--	Fuel, concessions, rest rooms Parking Storage and maintenance	-- 0.01 acre per boat slip 0.01 acre per boat slip

[a] *The survey of boat owners conducted under the regional park study indicated that for lakes of 50-199 acres, the typical mix of fast boating activities is as follows: water skiing—49 percent; motor boating—35 percent; and sailing—16 percent. The minimum area required per boat for safe participation in these activities is as follows: water skiing—20 acres; motor boating—15 acres; and sailing—10 acres. Assuming the current mix of boating activities in conjunction with the foregoing area requirements, it is found that 16.6 acres of "usable" surface water are required per boat on lakes of 50-199 acres. The number ot fast boats which can be accommodated on a given lake of this size range is the usable surface area of that lake expressed in acres (A) divided by 16.6. The optimum number of parking spaces for a given lake is the number of fast boats which the lake can accommodate reduced by the number of fast boats in use at any one time by owners of property with lake frontage. The latter figure is estimated as 10 percent of the number of dwelling units (D) on the lake.*

[b] *The minimum number of parking spaces relates only to parking to accommodate slow boating activities such as canoeing and fishing and is applicable only in the event that the application of the standard indicated a need for less than six parking spaces for fast boating activities. No launch ramp facilities would be provided for slow boating activities.*

[c] *Usable surface water is defined as that area of a lake which can be safely utilized for motor boating, sailing, and water skiing. This area includes all surface water which is a minimum distance of 200 feet from all shorelines and which is free of submerged or surface obstacles and at least five feet in depth.*

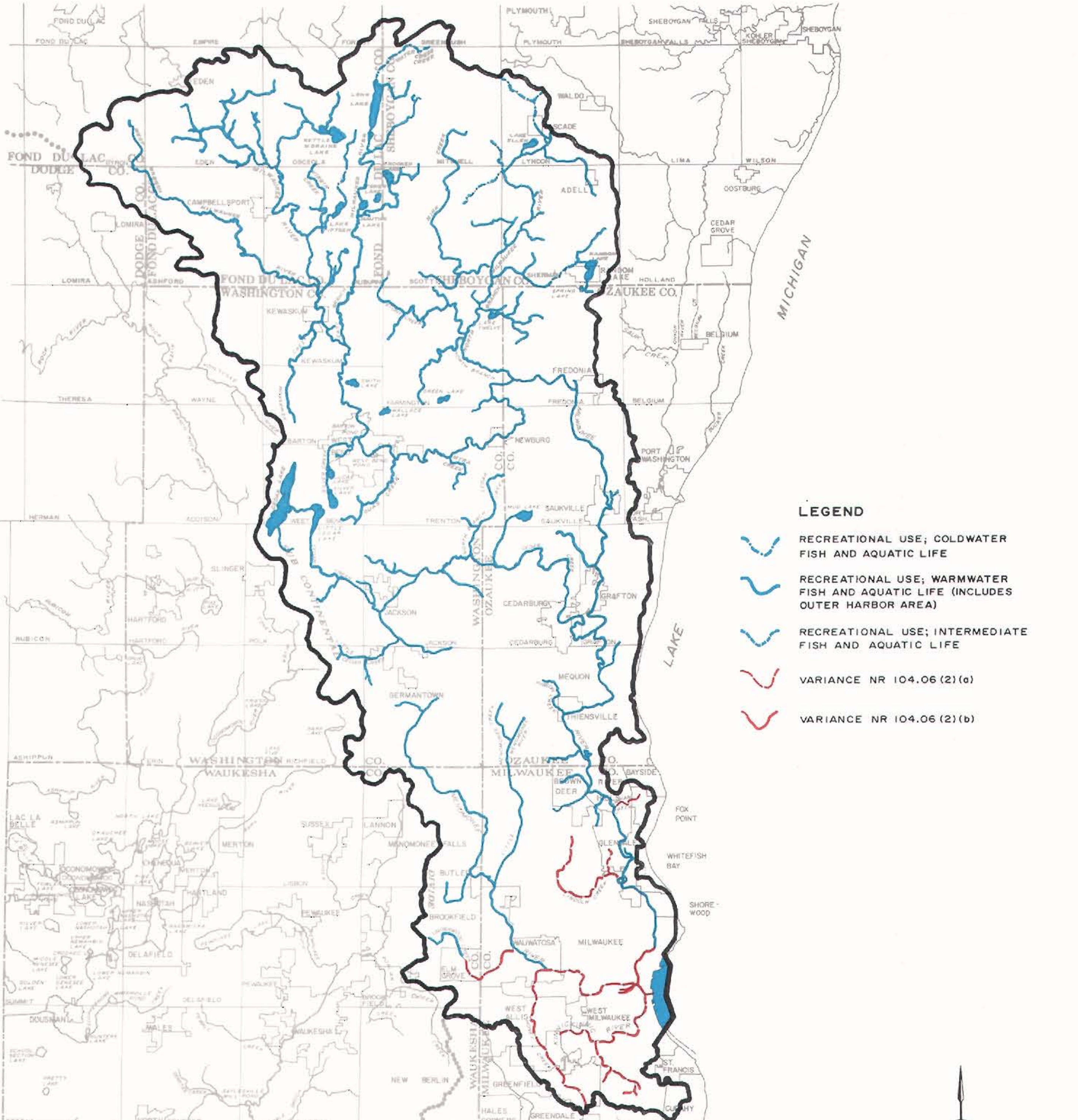
[d] *The survey of boat owners conducted under the regional park study indicated that, for lakes of 200 acres or more, the typical mix of fast boating activities is as follows: water skiing—43 percent; motor boating—33 percent; and sailing—24 percent. The minimum area required per boat for safe participation in these activities is as follows: water skiing—20 acres; motor boating—15 acres; and sailing—10 acres. Assuming the current mix of boating activities in conjunction with the foregoing area requirements, it is found that 15.9 acres of "usable" surface water are required per boat on lakes of 200 acres or more. The number of fast boats which can be accommodated on a given lake of this size range is the usable surface area of that lake expressed in areas (A) divided by 15.9. The optimum number of parking spaces for a given lake is the number of fast boats which the lake can accommodate reduced by the number of fast boats in use at any one time by owners of property with lake frontage. The latter figure is estimated as 10 percent of the number of dwelling units (D) on the lake.*

[e] *Canoeable rivers are defined as those rivers which have a minimum width of 50 feet over a distance of at least 10 miles.*

Source: SEWRPC.

Map 1

EXISTING WATER USE OBJECTIVES ADOPTED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES FOR SURFACE WATERS WITHIN THE ENTIRE MILWAUKEE HARBOR ESTUARY TRIBUTARY DRAINAGE AREA: 1985



The water use objectives currently being applied in the Milwaukee, Menomonee, and Kinnickinnic River watersheds by the Wisconsin Department of Natural Resources as shown on this map are set forth in Chapters NR 102 through NR 104 of the Wisconsin Administrative Code. All of the 9.2 miles of streams of the Milwaukee Harbor estuary are classified for variance categories which have been established and are intended to support only limited, nonbody-contact recreational uses, and fish and aquatic organisms which are tolerant of polluted water conditions. The Milwaukee outer harbor is classified for full recreational use and warmwater fish and aquatic life. One of the important objectives of the Milwaukee Harbor estuary study is to develop recommendations for a revised set of water use objectives and supporting water quality standards to be applied to the estuary.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 4

EXISTING DEPARTMENT OF NATURAL RESOURCES WATER USE OBJECTIVES AND WATER QUALITY STANDARDS FOR SURFACE WATERS IN THE ENTIRE MILWAUKEE HARBOR ESTUARY TRIBUTARY DRAINAGE AREA: 1985

	Individual Water Use Objectives Applicable to Surface Waters in the Milwaukee Harbor Estuary Tributary Drainage Area								Combinations of Water Use Objectives Applicable to Surface Waters in the Milwaukee Harbor Estuary Tributary Drainage Area					
Water Quality Parameters	Recreational Use	Variance NR104.06 (2)(a)[p]	Variance NR104.06 (2)(b)[q]	Public Water Supply	Warmwater Fish and Aquatic Life	Coldwater Fish and Aquatic Life	Intermediate Fish and Aquatic Life[q]	Minimum Standards[a]	Variance (a) and Minimum Standards[a]	Variance (b) and Minimum Standards[a]	Intermediate Fish and Aquatic Life, Recreational Use, and Minimum Standards[a]	Warmwater Fish and Aquatic Life, Recreational Use, and Minimum Standards[a]	Coldwater Fish and Aquatic Life, Recreational Use, and Minimum Standards[a]	Coldwater Fish and Aquatic Life, Recreational Use, Public Water Supply, and Minimum Standards[a]
Maximum Temperature ($^{\circ}$F)[o]	--	89[b,e]	89[b,c,e]	--	89[b,e]	--[b,d,e]	89[b,e]	--	89[b,e]	89[b,c,e]	89[b,e]	89[b,e]	--[b,d,e]	--[b,d,e]
pH Range (standard units)	--	6.0-9.0[f]	6.0-9.0[f]	--	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	--	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]
Minimum Dissolved Oxygen (mg/l)	--	2.0[e]	2.0[e]	--	5.0[e]	6.0[e]	3.0[e]	--	2.0[e]	2.0[e]	3.0[e]	5.0[e]	6.0[e]	6.0[e]
Maximum Fecal Coliform (counts per 100 ml)	200-400[g]	1,000-2,000[h]	1,000[i]	200-400[g]	--	--	--	--	1,000-2,000[h]	1,000[i]	200-400[g]	200-400[g]	200-400[g]	200-400[g]
Maximum Total Residual Chlorine (mg/l)	--	0.01	0.01	--	0.01	0.002	0.5	--	0.01	0.01	0.5	0.01	0.002	0.002
Maximum Un-ionized Ammonia Nitrogen (mg/l)	--	0.04	0.04	--	0.04	0.02	--	--	0.04	0.04	--	0.04	0.02	0.02
Total Ammonia Nitrogen (mg/l)	--	--	--	--	--	--	3/6[j]	--	--	--	3/6[j]	--	--	--
Maximum Total Dissolved Solids (mg/l)	--	--	--	500-750[k]	--	--	--	--	--	--	--	--	--	500-750[k]
Other	--	--[n]	--[n]	--[l]	--[n]	--[m,n]	--[n]	--	--[n]	--[n]	--[n]	--[n]	--[m,n]	--[l,m,n]

[a] *All waters shall meet the following minimum standards at all times and under all flow conditions: Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in the waters of the State. Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in the waters of the State. Materials producing color, odor, taste, or unsightliness shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

[b] *There shall be no temperature changes that may adversely affect aquatic life. Natural daily and seasonal temperature fluctuations shall be maintained. The maximum temperature rise at the edge of the mixing zone above the existing natural temperature shall not exceed 5°F for streams and 3°F for lakes.*

[c] *Maximum temperatures shall not exceed 89°F at any time at the edge of mixing zones established by the Department of Natural Resources under NR 102.03(4).*

[d] *There shall be no significant artificial increases in temperature where natural trout or salmon reproduction is to be protected. Dissolved oxygen shall not be lowered to less than 7.0 mg/l during the trout spawning season. The dissolved oxygen in the Great Lakes tributaries used by salmonids for spawning runs shall not be lowered below natural background levels during the period of habitation.*

[e] *Dissolved oxygen and temperature standards apply to streams and the epilimnion of stratified lakes and to the unstratified lakes; the dissolved oxygen standard does not apply to the hypolimnion of stratified inland lakes. Trends in the period of anaerobic conditions in the hypolimnion of deep inland lakes should be considered important to the maintenance of their natural water quality, however.*

[f] *The pH shall be within the range of 6.0 to 9.0 standard units, with no change greater than 0.5 unit outside the estimated natural seasonal maximum and minimum.*

[g] *Shall not exceed a monthly geometric mean of 200 counts per 100 milliliters (ml) based on not fewer than five samples per month, nor a monthly geometric mean of 400 counts per 100 ml in more than 10 percent of all samples during any month.*

[h] *Shall not exceed a monthly geometric mean of 1,000 counts per 100 ml based on not fewer than five samples per month, nor a monthly geometric mean of 2,000 counts per 100 ml in more than 10 percent of all samples during any month.*

[i] *Shall not exceed a monthly geometric mean of 1,000 counts per 100 ml based on not fewer than five samples per month.*

[j] *Ammonia nitrogen (as N) at all points in the receiving water shall not be greater than 3 mg/l during warm temperature conditions, nor greater than 6 mg/l during cold temperatures, to minimize the zone of toxicity and to reduce dissolved oxygen depletion caused by oxidation of the ammonia.*

[k] *Not to exceed 500 mg/l as a monthly average or 750 mg/l at any time.*

[l] *The intake water supply shall be such that by appropriate treatment and adequate safeguards it will meet the established Drinking Water Standards.*

[m] *Streams classified as trout waters by the DNR (Wisconsin Trout Streams, publication 213-72) shall not be altered from natural background conditions by effluents that influence the stream environment to such an extent that trout populations are adversely affected.*

[n] *Unauthorized concentrations of substances are not permitted that alone or in combination with other materials present are toxic to fish or other aquatic life. The determination of the toxicity of a substance shall be based upon the available scientific data base. References to be used in determining the toxicity of a substance shall include, but not be limited to: Quality Criteria for Water, EPA-440/9-76-003, U. S. Environmental Protection Agency, Washington, D. C., 1976; Water Quality Criteria 1972, EPA-R3-73-003, National Academy of Sciences, National Academy of Engineering, U. S. Government Printing Office, Washington, D. C., 1974; and the Federal Register, "Environmental Protection Agency, Water Quality Criteria Documents; Availability," November 28, 1980. Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, or undefined toxicity to fish and other biota shall be resolved in accordance with the methods specified in Water Quality Criteria 1972 and Standard Methods for the Examination of Water and Wastewater, 14th Edition, American Public Health Association, New York, 1975, or other methods approved by the Department of Natural Resources.*

[o] *Lake Michigan thermal discharge standards, which are intended to minimize the effects on aquatic biota, apply to facilities discharging heated water directly to Lake Michigan, excluding that from municipal waste and water treatment plants and vessels or ships. Such discharges shall not raise the temperature of Lake Michigan at the boundary of the mixing zone established by the Wisconsin Department of Natural Resources by more than 3°F and, except for the Milwaukee outer harbor, thermal discharges shall not increase the temperature of Lake Michigan at the boundary of the established mixing zones during the following months above the following limits:*

January, February, March	*45°F*	*July, August, September*	*80°F*
April	*55°F*	*October*	*65°F*
May	*60°F*	*November*	*60°F*
June	*70°F*	*December*	*50°F*

After a review of the ecological and environmental impact of thermal discharges in excess of a daily average of 500 million British thermal units (BTU's) per hour, mixing zones are established by the Department of Natural Resources. Any plan or facility, the construction of which is commenced on or after August 1, 1974, shall be so designed that the thermal discharges therefrom to Lake Michigan comply with mixing zones established by the Department. In establishing a mixing zone, the Department will consider ecological and environmental information obtained from studies conducted subsequent to February 1, 1974, and any requirements of the Federal Water Pollution Control Act Amendments of 1972, or regulations promulgated thereto.

[p] *As set forth in NR 104.06(2)(a) of the Wisconsin Administrative Code.*

[q] *As set forth in NR 104.06(2)(b) of the Wisconsin Administrative Code.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

These standards are statements of the physical, chemical, and biological characteristics of the water that must be maintained if the water is to be suitable for the specified uses. Chapter 144 of the Wisconsin Statutes recognizes that different standards may be required for different waters or portions thereof. As set forth in that chapter by the State Legislature, in all cases the "standards of quality shall be such as to protect the public interest which includes the protection of the public health and welfare and the present and prospective future use of such waters for public and private water supplies, propagation of fish and aquatic life and wildlife, domestic and recreational purposes, and agricultural, commercial, industrial and other legitimate uses."[4]

A total of 409.8 miles of streams and 21 major inland lakes cover a total surface area of 3,422 acres within the watershed drainage area upstream of the Milwaukee Harbor estuary direct drainage area. A total of 371.4 miles of streams, or 91 percent of the total, and all of the major inland lakes are currently classified for recreational use and warmwater fish and aquatic life. About 4.2 miles of streams, or 1 percent of the total, are classified for recreational use and coldwater fish and aquatic life. The recreational use and intermediate fish and aquatic life objective applies to about 1.2 miles of streams, or less than 1 percent of the total. The variance category (a) applies to the remaining 33.0 miles of streams, or 8 percent of the total.

Of the 9.2 miles of streams within the drainage area directly tributary to the Milwaukee Harbor estuary, 4.6 miles, or 50 percent, are classified for variance category (a), and 4.6 miles, or 50 percent, are classified for variance category (b). The Milwaukee outer harbor is classified for recreational use and warmwater fish and aquatic life.

Recommended Water Use Objectives and Water Quality Standards: As already noted, recommended water use objectives for the entire Milwaukee Harbor estuary tributary drainage area are shown on Map 2. Water quality standards supporting these recommended objectives for the watercourses tributary to the harbor estuary are set forth in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000; and for the harbor estuary in Table 5. The applicable standards from SEWRPC Planning Report No. 30 are set forth in Table 6.

The water quality standards for un-ionized ammonia nitrogen, dissolved oxygen, and residual chlorine set forth in the regional water quality management plan have been revised under the Milwaukee Harbor estuary planning program. The regional water quality management plan recommended maximum standards of 0.02 milligram per liter (mg/l) un-ionized ammonia nitrogen for the protection of coldwater and warmwater fish and aquatic life, and 0.2 mg/l un-ionized ammonia nitrogen for the protection of limited fish and aquatic life. Recent studies have indicated, however, that the toxicity of un-ionized ammonia nitrogen varies substantially with the pH and temperature of the water. As a result, the U. S. Environmental Protection Agency (EPA) has recommended that the criteria for un-ionized ammonia nitrogen be calculated as a function of pH and temperature.[5] The EPA-recommended criteria have been adopted under the Milwaukee Harbor estuary planning program and are set forth in Table 5. The EPA concluded that differences in sensitivities to un-ionized ammonia nitrogen toxicity between coldwater and warmwater fish and aquatic life are inadequate to warrant different criteria for coldwater and warmwater species. Rather, the effects of differences in sensitivities can be addressed through the determination of site-specific criteria in accordance with EPA guidelines.[6] The adopted criteria set forth in Table 5 allow the application of site-specific criteria, where appropriate.

The regional water quality management plan recommended minimum dissolved oxygen standards of 2.0 mg/l for the support of recreational and limited recreational uses, 3.0 mg/l for the support of limited fish and aquatic life, 5.0 mg/l for the support of warmwater fish and aquatic life, and 6.0 mg/l for the support of coldwater fish and

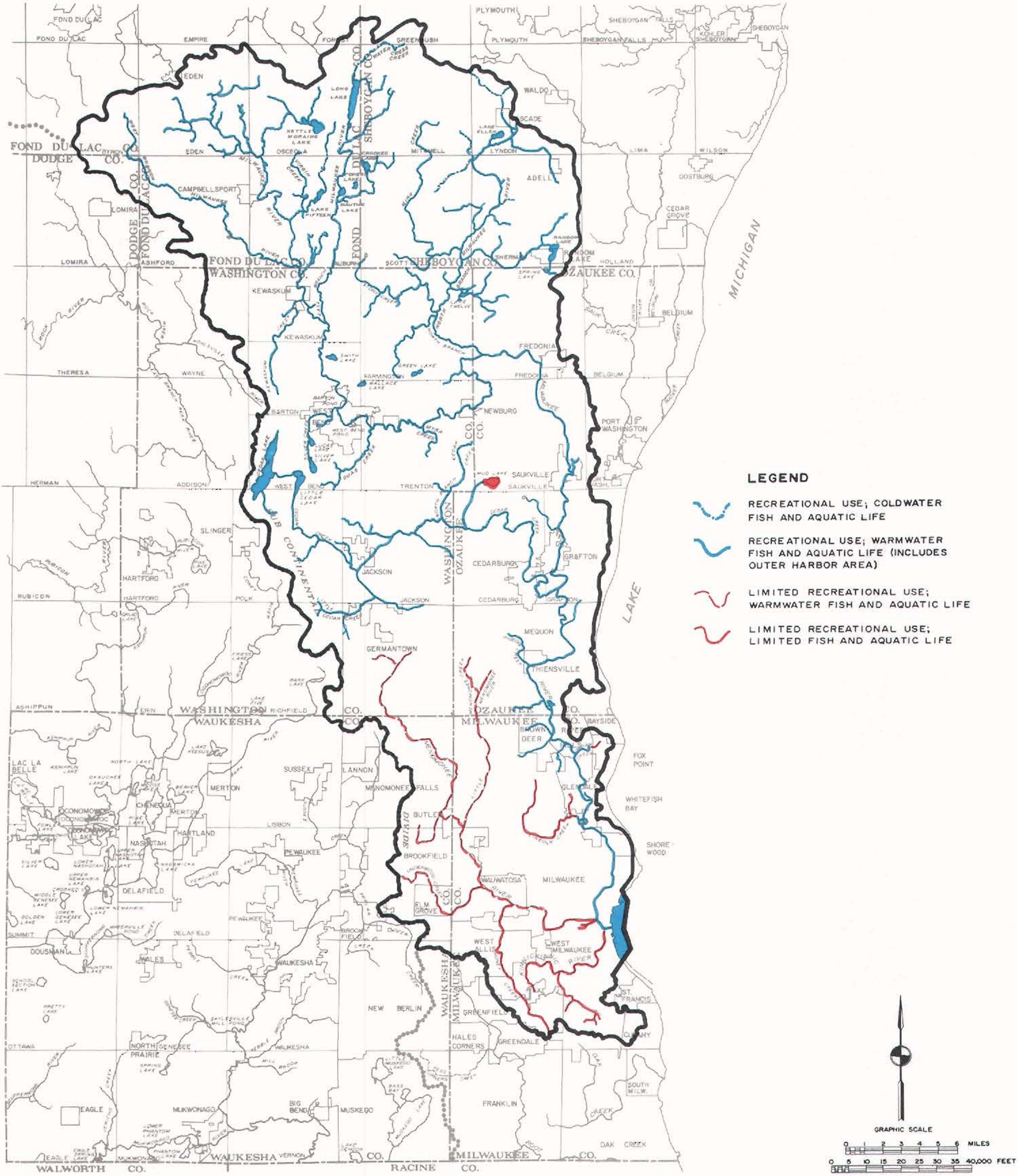
[4] *Wisconsin Statute Section 144.025(2)(b).*

[5] *U. S. Environmental Protection Agency, "Water Quality Criteria for the Protection of Aquatic Life and Its Uses, Ammonia," January 1983.*

[6] *U. S. Environmental Protection Agency, Guidelines for Deriving Numerical Aquatic Site-Specific Criteria by Modifying National Criteria, December 1982.*

Map 2

PRELIMINARY RECOMMENDED WATER USE OBJECTIVES FOR SURFACE WATERS WITHIN THE MILWAUKEE HARBOR ESTUARY TRIBUTARY DRAINAGE AREA



Recommended water use objectives for the tributary surface waters upstream of the estuary direct drainage area are set forth in the adopted regional water quality management plan. That plan did not include recommendations for water use objectives in the Milwaukee Harbor estuary. One of the important objectives of the Milwaukee Harbor estuary study is the development of recommended water use objectives for the estuary. Preliminary recommended objectives are shown on this map. The 3.1 miles of the Milwaukee River within the Milwaukee Harbor estuary and all of the outer harbor are initially recommended for recreational use and the maintenance of warmwater fish and aquatic life. Two alternative sets of water use objectives were initially considered for the remaining 6.1 miles of streams within the estuary, or 66 percent of the total stream mileage in the estuary: 1) recreational use and the maintenance of warmwater fish and aquatic life; and 2) limited recreational use and the maintenance of limited fish and aquatic life. These 6.1 miles of stream include the Menomonee and Kinnickinnic River portions of the estuary and the associated shipping canals. The objectives of limited recreational use and the maintenance of limited fish and aquatic life were initially assigned to the Menomonee and Kinnickinnic River portions of the estuary. This initial assignment was made on the condition that if it were determined later in the study that the standards associated with higher use objectives are achievable, such higher use objectives would be considered. The final recommended water use objectives are discussed in Chapters IV and VII.

Source: SEWRPC.

aquatic life. The dissolved oxygen standard to support recreational and limited recreational uses was intended to prevent odor and aesthetic problems which occur under anoxic conditions. To support fish and aquatic life, the dissolved oxygen standards have been modified under the Milwaukee Harbor estuary study to reflect acute and chronic adverse impacts and seasonal effects.[7] Adopted dissolved oxygen standards for fish and aquatic life set forth in Table 5 apply to the entire water column within the Milwaukee Harbor estuary, and include minimum levels ranging from 4.5 to 6.5 mg/l on a 30-day mean basis, from 5.0 to 9.5 mg/l on a 7-day mean basis, from 3.0 to 8.0 mg/l on a 1-day mean basis, and from 1.5 to 3.0 mg/l for an absolute minimum level not to be violated. Seven-day mean and 1-day mean standards are established to protect organisms during their embryonic, larval, and early juvenile life stages, when these organisms are most sensitive to low levels of dissolved oxygen.

For total residual chlorine, the regional water quality management plan recommended maximum standards of 0.5 mg/l for the support of limited fish and aquatic life, 0.01 mg/l for the support of warmwater fish and aquatic life, and 0.002 mg/l for the support of coldwater fish and aquatic life. These standards were reevaluated with respect to acute and chronic toxicity data set forth in a 1983 draft report by the U. S. Environmental Protection Agency.[8] The report indicated that insufficient toxicity data were available to establish different standards for the support of coldwater and warmwater fish, and for limited fish and aquatic life classifications. For all fish and aquatic life classifications, the U. S. Environmental Protection Agency recommended a 30-day mean standard of 0.0083 mg/l to prevent chronic toxicity and an absolute standard of 0.014 mg/l, not to be exceeded, to prevent acute toxicity. These values were adopted for use in the Milwaukee Harbor estuary planning program.

Within the Milwaukee Harbor estuary watershed drainage area, but upstream of the estuary direct drainage area, approximately 332.5 miles of perennial streams, or 81 percent of the total, and 20 of the 21 major inland lakes in the study area are recommended for recreational use and the maintenance of warmwater fish and aquatic life. About 4.2 miles of streams, or 1 percent of the total, are recommended for recreational use and the maintenance of coldwater fish and aquatic life. Limited recreational use and the maintenance of warmwater fish and aquatic life are recommended for 39.8 miles of streams, or 10 percent of the total. Limited recreational use and the maintenance of limited fish and aquatic life are recommended for the remaining 33.3 miles of streams, or 8 percent of the total, and for the remaining lake—Mud Lake in Ozaukee County—having an areal extent of 245 acres. Recommended water use objectives for surface waters located within the Southeastern Wisconsin Region upstream of the Milwaukee Harbor estuary are set forth in the regional water quality management plan. Recreational use and the maintenance of warmwater fish and aquatic life are recommended for those tributary surface waters located outside the Southeastern Wisconsin Region within Fond du Lac and Sheboygan Counties, except Watercress Creek in Fond du Lac County. Watercress Creek is recommended to remain classified for recreational use and the maintenance of coldwater fish and aquatic life.

The recommended water use objectives for the tributary surface waters upstream of the estuary direct drainage area and within the Southeastern Wisconsin Region are the same as those set forth in SEWRPC Planning Report No. 30. Planning Report No. 30 did not recommend water use objectives for those water bodies located within the Milwaukee River watershed but outside the Region, or for the surface waters within the estuary direct drainage area. Water use objectives for all surface waters within the entire tributary drainage area—inclusive of those surface waters located outside the Region and those within the estuary direct drainage area—are, however, recommended in this chapter.

The 3.1 miles of the Milwaukee River within the Milwaukee Harbor estuary are recommended for recreational use and the maintenance of warmwater fish and aquatic life. The Milwaukee outer harbor

[7] *The modifications to the dissolved oxygen standards set forth in the regional water quality management plan were developed in accordance with guidelines set forth in "Ambient Water Quality Criteria for Dissolved Oxygen, Freshwater Aquatic Life," U. S. Environmental Protection Agency, 1983.*

[8] *U. S. Environmental Protection Agency, "Ambient Aquatic Life Water Criteria for Chlorine," September 28, 1983.*

Table 5

RECOMMENDED WATER USE OBJECTIVES AND WATER QUALITY STANDARDS FOR SURFACE WATERS IN THE MILWAUKEE HARBOR ESTUARY STUDY AREA: 2000

	Individual Water Use Objectives Applicable to Surface Waters in the Milwaukee Harbor Estuary Study Area							Combinations of Water Use Objectives Applicable to Surface Waters in the Milwaukee Harbor Estuary Study Area				
Water Quality Parameters	Recreational Use	Limited Recreational Use	Public Water Supply	Coldwater Fish and Aquatic Life	Warmwater Fish and Aquatic Life	Limited Fish and Aquatic Life	Minimum Standards[a]	Limited Fish and Aquatic Life, Limited Recreational Use, and Minimum Standards[a]	Warmwater Fish and Aquatic Life, Limited Recreational Use, and Minimum Standards[a]	Warmwater Fish and Aquatic Life, Recreational Use, and Minimum Standards[a]	Coldwater Fish and Aquatic Life, Recreational Use, and Minimum Standards[a]	Coldwater Fish and Aquatic Life, Recreational Use, Public Water Supply, and Minimum Standards[a]
Maximum Temperature (°F)[t]	--	--	--	--[b,c,d]	89[b,d]	89[b,d]	--	89[b,d]	89[b,d]	89[b,d]	--[b,c,d]	--[b,c,d]
pH Range (standard units)	--	--	--	6.0-9.0[e]	6.0-9.0[e]	6.0-9.0[e]	--	6.0-9.0[e]	6.0-9.0[e]	6.0-9.0[e]	6.0-9.0[e]	6.0-9.0[e]
Minimum Dissolved Oxygen (mg/l)[d]												
30-Day Mean	2.0	2.0	--	6.5	5.5	4.5	--	4.5	5.5	5.5	6.5	6.5
7-Day Mean	2.0	2.0	--	9.5[h]	6.0[f]	5.0[j]	--	5.0[j]	6.0[f]	6.0[f]	9.5[h]	9.5[h]
1-Day Mean	2.0	2.0	--	5.0-8.0[i]	4.0-5.0[g]	3.0-4.0[k]	--	3.0-4.0[k]	4.0-5.0[g]	4.0-5.0[g]	5.0-8.0[i]	5.0-8.0[i]
Absolute	--	--	--	3.0	2.5	1.5	--	1.5	2.5	2.5	3.0	3.0
Maximum Fecal Coliform (counts per 100 ml)	200-400[l]	200-400[l]	200-400[l]	--	--	--	--	200-400[l]	200-400[l]	200-400[l]	200-400[l]	200-400[l]
Maximum Total Residual Chlorine (mg/l)												
30-Day Mean	--	--	--	0.0083	0.0083	0.0083	--	0.0083	0.0083	0.0083	0.0083	0.0083
Absolute	--	--	--	0.014	0.014	0.014	--	0.014	0.014	0.014	0.014	0.014
Maximum Un-ionized Ammonia Nitrogen (mg/l)	--	--	--	--[o]	--[o]	--[o]	--	--[o]	--[o]	--[o]	--[o]	--[o]
Maximum Total Phosphorus (mg/l)												
Streams[m]	0.1	--	--	--	--	--	--	--	--	0.1	0.1	0.1
Inland Lakes[n]	0.02	--	--	--	--	--	--	--	--	0.02	0.02	0.02
Maximum Total Dissolved Solids (mg/l)	--	--	500-750[p]	--	--	--	--	--	--	--	--	500-750[p]
Other	--	--	--[q]	--[r,s]	--[s]	--[s]	--	--[s]	--[s]	--[s]	--[r,s]	--[q,r,s]

[a]All waters shall meet the following minimum standards at all times and under all flow conditions: Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in the waters of the State. Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in the waters of the State. Materials producing color, odor, taste, or unsightliness shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant, or aquatic life.

[b]There shall be no temperature changes that may adversely affect aquatic life. Natural daily and seasonal temperature fluctuations shall be maintained. The maximum temperature rise at the edge of the mixing zone above the existing natural temperature shall not exceed 5°F for streams and 3°F for lakes.

[c]There shall be no significant artificial increases in temperature where natural trout or stocked salmon reproduction is to be protected. The maximum temperature shall not exceed 77°F.

[d]Dissolved oxygen and temperature standards apply to the entire water column within streams and to the epilimnion of stratified lakes and to the unstratified lakes; the dissolved oxygen standard does not apply to the hypolimnion of stratified inland lakes. Trends in the period of anaerobic conditions in the hypolimnion of stratified inland lakes should be considered important to the maintenance of water quality, however.

[e]The pH shall be within the range of 6.0 to 9.0 standard units, with no change greater than 0.5 unit outside the estimated natural seasonal maximum and minimum.

[f]A minimum dissolved oxygen standard of 6.0 mg/l for a 7-day mean applies only between March 15 and July 31 for the support of embryonic, larval, and early juvenile stages of warmwater species.

[g]A minimum dissolved oxygen standard of 5.0 mg/l for a 1-day mean applies only between March 15 and July 31 for the support of embryonic, larval, and early juvenile stages of warmwater species. For the remainder of the year, a minimum dissolved oxygen standard of 4.0 mg/l for a 1-day mean applies.

[h]A minimum dissolved oxygen standard of 9.5 mg/l for a 7-day mean applies only between September 1 and April 30 for the support of embryonic and larval stages of coldwater species.

[i]A minimum dissolved oxygen standard of 8.0 mg/l for a 1-day mean applies only between September 1 and April 30 for the support of embryonic and larval stages of coldwater species. For the remainder of the year, a minimum dissolved oxygen standard of 5.0 mg/l for a 1-day mean applies.

[j]A minimum dissolved oxygen standard of 5.0 mg/l for a 7-day mean applies only between March 15 and July 31 for the support of embryonic, larval, and early juvenile stages of limited species.

[k]A minimum dissolved oxygen standard of 4.0 mg/l for a 1-day mean applies only between March 15 and July 31 for the support of embryonic, larval, and early juvenile stages of limited species. For the remainder of the year, a minimum dissolved oxygen standard of 3.0 mg/l for a 1-day mean applies.

[l]Shall not exceed a monthly geometric mean of 200 per 100 milliliters (ml) based on not fewer than five samples per month, nor a monthly geometric mean of 400 per 100 ml in more than 10 percent of all samples during any month.

[m]The total phosphorus standard for streams of 0.1 mg/l applies to the Milwaukee outer harbor. The stream standard was considered appropriate for the outer harbor because the hydraulic residence time of the harbor is relatively short—an average of 1 to 2 days—and because the phosphorus levels in the outer harbor, which average 0.06 mg/l, have generally not resulted in excessive algal levels.

[n]The values presented for inland lakes are the critical total phosphorus concentrations which apply only during spring, when maximum mixing is underway.

[o]To protect coldwater, warmwater, and limited fish and aquatic life, the following criteria shall apply for un-ionized ammonia nitrogen (NH_3-N):

1. The concentration at all times shall not exceed the acute toxicity value calculated by:

$$\text{Acute Toxicity Value for Un-ionized Ammonia Nitrogen (mg/l)} = 0.822 \left[0.15 \times \frac{f(T)}{fa(pH)} \right]$$

where:

At water temperatures equal to or greater than 10°C, f(T) = 1

$$\text{At water temperatures less than } 10^{\circ}C,\ f(T) = \frac{1 + 10^{9.73-pH}}{1 + 10^{pKT-pH}}$$

$$pKT = 0.09 + \frac{2730}{T(^{\circ}C) + 273.2}$$

$$fa(pH) = 1 + 10^{1.03(7.32-pH)}$$

2. The average concentration over any 30-consecutive-day period shall not exceed the chronic toxicity value calculated by:

$$\text{Chronic Toxicity Value for Un-ionized Ammonia Nitrogen (mg/l)} = 0.822 \left[0.031 \times \frac{f(T)}{fc(pH)} \right]$$

where:

At pH levels equal to or greater than 7.7 standard units, fc(pH) = 1

At pH levels less than 7.7 standard units, $fc(pH) = 10^{0.74(7.7-pH)}$

The chronic toxic value should not be exceeded for a total duration of more than 96 hours within any 30-day period. These un-ionized ammonia nitrogen criteria may be modified, if appropriate, to reflect local site-specific conditions and to protect only those fish and aquatic life species or age or size classes that occur, or are desired, within a certain water body. Such site-specific modifications shall be conducted in conformance with the guidelines set forth in U. S. Environmental Protection Agency, "Guidelines for Deriving Numerical Aquatic Site-Specific Criteria by Modifying National Criteria," Office of Research and Development, December 1982. These site-specific criteria modifications, however, should be used with caution because of a relative scarcity of toxicity information on less sensitive fish and aquatic life species.

[p]Not to exceed 500 mg/l as a monthly average, or 750 mg/l at any time.

[q]The intake water supply shall be such that by appropriate treatment and adequate safeguards it will meet the established Drinking Water Standards.

Footnotes to Table 5 (continued)

[r] *Streams classified as trout waters shall not be altered from natural background conditions by effluents that influence the stream environment to such an extent that trout populations are adversely affected.*

[s] *Unauthorized concentrations of substances are not permitted that alone or in combination with other materials present are toxic to fish or other aquatic life. Acute and chronic toxic criteria developed by the Wisconsin Department of Natural Resources are set forth in Table 9 for 13 water quality parameters. The parameters set forth in Table 9 are the most likely parameters to be of concern in the Milwaukee Harbor estuary. Criteria for toxic substances not listed in Table 9 should be determined based upon the available data and procedures set forth in Quality Criteria for Water, EPA-440/9-76-003, U. S. Environmental Protection Agency, Washington, D. C., 1976; Water Quality Criteria 1972, EPA-R3-73-003, National Academy of Sciences, National Academy of Engineering, U. S. Government Printing Office, Washington, D. C., 1974; and the Federal Register, "Environmental Protection Agency, Water Quality Criteria Documents; Availability," November 28, 1980; the Federal Register, "Water Quality Criteria, Request for Comments," February 7, 1984; or other data sources and procedures approved by the Wisconsin Department of Natural Resources.*

[t] *Lake Michigan thermal discharge standards, which are intended to minimize the effects on aquatic biota, apply to facilities discharging heated water directly to Lake Michigan, excluding that from municipal waste and water treatment plants and vessels or ships. Such discharges shall not raise the temperature of Lake Michigan at the boundary of the mixing zone established by the Department of Natural Resources by more than 3°F and, except for the Milwaukee Harbor, thermal discharges shall not increase the temperature of Lake Michigan at the boundary of the established mixing zones during the following months above the following limits:*

January, February, March	45°F	July, August, September	80°F
April	55°F	October	65°F
May	60°F	November	60°F
June	70°F	December	50°F

After a review of the ecological and environmental impact of thermal discharges in excess of a daily average of 500 million British thermal units (BTU's) per hour, mixing zones are established by the Department of Natural Resources. Any plant or facility shall be so designed that the thermal discharges therefrom to Lake Michigan comply with mixing zones established by the Department. In establishing a mixing zone, the Department will consider ecological and environmental information obtained from studies conducted subsequent to February 1, 1974, and any requirements of the Federal Water Pollution Control Act Amendments of 1972, or regulations promulgated thereto.

Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

is also recommended for recreational use and the maintenance of warmwater fish and aquatic life. It was concluded that, because of the existing and proposed commercial, residential, and recreational land uses adjoining the Milwaukee River and outer harbor, the maintenance of recreational use and of warmwater fish and aquatic life would be publicly desired.

Two alternative sets of water use objectives are feasible within the remaining 6.1 miles of streams within the estuary, or 66 percent of the total stream mileage in the estuary, as shown on Map 2: 1) recreational use and the maintenance of warmwater fish and aquatic life; and 2) limited recreational use and the maintenance of limited fish and aquatic life. These 6.1 miles of stream include the Menomonee and Kinnickinnic River portions of the estuary and the associated shipping canals. It may be feasible to achieve the water quality standards supporting recreational use and the maintenance of warmwater fish and aquatic life in the Menomonee and Kinnickinnic River portions of the estuary. The objectives of limited recreational use and the maintenance of limited fish and aquatic life were initially assigned to the Menomonee and Kinnickinnic River portions of the estuary. However, if it is determined that the standards associated with higher use objectives are achievable, then, under present stream classification policies, the DNR would classify the stream for the higher use. Thus, these policies may need to be modified if the limited recreation and limited fish and aquatic life objectives are selected, and later it is determined that standards associated with a higher use are obtainable. The alternative analyses conducted under this study evaluate the attainability, and the costs, of achieving these higher use objectives.

Table 7 compares the existing water use objectives established by the Wisconsin Department of Natural Resources, as shown on Map 1, to the recommended water use objectives shown on Map 2 for the tributary surface waters located upstream of the Milwaukee Harbor estuary direct drainage area. Table 8 compares the existing water use objectives to the recommended water use objectives for the surface waters within the direct drainage area to the Milwaukee Harbor estuary. The recommended water use objectives are in conformance with the national water use objectives cited in the Federal Clean Water Act, which call for the attainment whenever practicable of water quality which is sufficient to support the protection and propagation of fish, shellfish, and wildlife and to support human recreation in and on the waters. The final recommended water use objectives for the surface waters within the direct drainage area to the Milwaukee Harbor estuary, as set forth in Chapter VII of this volume, are based upon analyses of the feasibility and costs of achieving the supporting water quality standards.

The water quality standards set forth in Table 5 are intended to support uses such as swimming, wading, boating, and fishing under the recreational use objective. Under the limited recreational use objective, swimming and wading are not permitted uses, and the recreational value of boating and fishing

Table 6

RECOMMENDED WATER USE OBJECTIVES AND WATER QUALITY STANDARDS USED IN THE DEVELOPMENT OF THE REGIONAL WATER QUALITY MANAGEMENT PLAN FOR LAKES AND STREAMS IN THE SOUTHEASTERN WISCONSIN REGION: 2000[a]

Water Quality Parameters	Individual Water Use Objectives[b] Applicable to Southeastern Wisconsin Inland Lakes and Streams								Combinations of Water Use Objectives Applicable to Southeastern Wisconsin Inland Lakes and Streams				
	Recreational Use	Limited Recreational Use	Public Water Supply	Warmwater Fishery	Trout Fishery	Salmon Spawning Fishery	Limited Fishery	Minimum Standards[c]	Limited Fishery and Aquatic Life, Limited Recreational Use, and Minimum Standards[c]	Warmwater Fishery and Aquatic Life, Limited Recreational Use, and Minimum Standards[c]	Warmwater Fishery and Aquatic Life, Recreational Use, and Minimum Standards[c]	Trout Fishery and Aquatic Life, Recreational Use, and Minimum Standards[c]	Salmon Spawning Fishery and Aquatic Life, Recreational Use, and Minimum Standards[c]
Maximum Temperature (°F)[q]	--	--	--	89[d,g]	--[d,e,g]	--[d,e,g]	89[d,g]	--	89[d,g]	89[d,g]	89[d,g]	--[d,e,g]	--[d,e,g]
pH Range (S.U.)	--	--	--	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	--	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]	6.0-9.0[f]
Minimum Dissolved Oxygen (mg/l)	2.0	2.0	--	5.0[g]	6.0[g,h]	5.0[g,i]	3.0[g]	--	3.0[g]	5.0[g]	5.0[g]	6.0[g,h]	5.0[g,i]
Maximum Fecal Coliform (Counts per 100 ml)	200-400[j]	200-400[j]	200-400[j]	--	--	--	--	--	200-400[j]	200-400[j]	200-400[j]	200-400[j]	200-400[j]
Maximum Total Residual Chlorine (mg/l)	--	--	--	0.01	0.002	0.002	0.5	--	0.5	0.01	0.01	0.002	0.002
Maximum Un-ionized Ammonia Nitrogen (mg/l)	--	--	--	0.02[r]	0.02[r]	0.02[r]	0.2[s]	--	0.2[s]	0.02[r]	0.02[r]	0.02[r]	0.02[r]
Maximum Total Phosphorus[k] (mg/l)													
Streams	0.1	--	--	--	--	--	--	--	--	--	0.1	0.1	0.1
Lakes	0.02	--	--	--	--	--	--	--	--	--	0.02	0.02	--
Maximum Total Dissolved Solids (mg/l)	--	--	500-750[l]	--	--	--	--	--	--	--	--	--	--
Other[p]	--	--	--[m]	--[o]	--[n]	--[o]	--[o]	--	--[o]	--[o]	--[o]	--[n,o]	--[o]

[a] *Includes SEWRPC interpretations of all basic water use categories established by the Wisconsin Department of Natural Resources and additional categories established under the areawide water quality management planning program, plus those combinations of water use categories applicable to the Southeastern Wisconsin Region. It is recognized that under both extremely high and extremely low flow conditions, instream water quality levels can be expected to violate the established water quality standards for short periods of time without damaging the overall health of the stream. It is important to note the critical differences between the official state and federally adopted water quality standards—composed of "use designations" and "water quality criteria"—and the water use objectives and supporting standards of the Regional Planning Commission described here. The U. S. Environmental Protection Agency and the Wisconsin Department of Natural Resources, being regulatory agencies, utilize water quality standards as a basis for enforcement actions and compliance monitoring. This requires that the standards have a rigid basis in research findings and in field experience. The Commission, by contrast, must forecast regulations and technology far into the future, documenting the assumptions used to analyze conditions and problems which may not currently exist anywhere, much less in or near southeastern Wisconsin. As a result, more recent—and sometimes more controversial—study findings must sometimes be applied. This results from the Commission's use of the water quality standards as criteria to measure the relative merits of alternative plans.*

[b] *Standards presented in the table are applicable to lakes larger than 50 acres in surface area and to major streams of the Region as set forth in Map 1.*

[c] *All waters shall meet the following minimum standards at all times and under all flow conditions: substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in waters of the State. Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in the waters of the State. Materials producing color, odor, taste, or unsightliness shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

[d] *There shall be no temperature changes that may adversely affect aquatic life. Natural daily and seasonal temperature fluctuations shall be maintained. The maximum temperature rise at the edge of the mixing zone above the existing natural temperature shall not exceed 5°F for streams and 3°F for lakes.*

[e] *There shall be no significant artificial increases in temperature where natural trout or stocked salmon reproduction is to be protected.*

[f] *The pH shall be within the range of 6.0 to 9.0 standard units with no change greater than 0.5 unit outside the estimated natural seasonal maximum and minimum.*

[g] *Dissolved oxygen and temperature standards apply to streams and the epilimnion of stratified lakes and to the unstratified lakes; the dissolved oxygen standard does not apply to the hypolimnion of stratified inlake lakes. Trends in the period of anaerobic conditions in the hypolimnion of stratified inland lakes should be considered important to the maintenance of water quality, however.*

[h] *Dissolved oxygen shall not be lowered to less than 7.0 mg/l during the trout spawning season.*

[i] *The dissolved oxygen in the Great Lakes tributaries used by stock salmonids for spawning runs shall not be lowered below natural background during the period of habitation.*

[j] *Shall not exceed a monthly geometric mean of 200 per 100 ml based on not less than five samples per month nor a monthly geometric mean of 400 per 100 ml in more than 10 percent of all samples during any month.*

[k] *The values presented for lakes are the critical total phosphorus concentrations which apply only during spring when maximum mixing is underway. In streams classified for recreational use, the total phosphorus concentration shall not exceed 0.1 mg/l. A phosphorus standard does not apply to streams and lakes classified for limited recreational use.*

[l] *Not to exceed 500 mg/l as a monthly average nor 750 mg/l at any time.*

[m] *The intake water supply shall be such that by appropriate treatment and adequate safeguards it will meet the established Drinking Water Standards.*

[n] *Streams classified as trout waters shall not be altered from natural background by effluents that influence the stream environment to such an extent that trout populations are adversely affected.*

[o] *Unauthorized concentrations of substances are not permitted that alone or in combination with other materials present are toxic to fish or other aquatic life. The determination of the toxicity of a substance shall be based upon the available scientific data base. References to be used in determining the toxicity of a substance shall include, but not be limited to, Quality Criteria for Water. EPA-440/9-76-003, U. S. Environmental Protection Agency, Washington, D.C., 1976, and Water Quality Criteria 1972. EPA-R3-73-003, National Academy of Sciences, National Academy of Engineering, U. S. Government Printing Office, Washington, D.C., 1974. Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, or undefined toxicity to fish and other biota shall be resolved in accordance with the methods specified in Water Quality Criteria 1972 and Standard Methods for the Examination of Water and Wastewater, 14th Edition, American Public Health Association, New York, 1975, or other methods approved by the Department of Natural Resources.*

[p] *Waters important to overall environmental integrity including trout streams, scientific areas, wild and scenic areas, endangered species habitat, and waters of high recreational potential all are subject to further pollution analysis and special standards and effluent criteria. See Wisconsin Administrative Code Chapter NR 104.02(4)(a), whereby this is to be determined by the Wisconsin Department of Natural Resources on a case-by-case basis. No waters in southeastern Wisconsin are currently designated under this category as of 1977.*

[q] *Lake Michigan thermal discharge standards, which are intended to minimize the effects on aquatic biota, apply to facilities discharging heated water directly to Lake Michigan, excluding that from municipal waste and water treatment plants and vessels or ships. Such discharges shall not raise the temperature of Lake Michigan at the boundary of the mixing zone established by the Wisconsin Department of Natural Resources by more than 3°F and, except for the Milwaukee and Port Washington Harbors, thermal discharges shall not increase the temperature of Lake Michigan at the boundary of the established mixing zones during the following months above the following limits:*

January, February, March	*45°F*	*July, August, September*	*80°F*
April	*55°F*	*October*	*65°F*
May	*60°F*	*November*	*60°F*
June	*70°F*	*December*	*50°F*

After a review of the ecological and environmental impact of thermal discharges in excess of a daily average of 500 million BTU per hour, mixing zones are established by the Department of Natural Resources. Any plant or facility, the construction of which is commenced on or after August 1, 1974, shall be so designed that the thermal discharges therefrom to Lake Michigan comply with mixing zones established by the Department. In establishing a mixing zone, the Department will consider ecological and environmental information obtained from studies conducted subsequent to February 1, 1974, and any requirements of the Federal Water Pollution Control Act Amendments of 1972, or regulations promulgated thereto.

[r] *This level of un-ionized ammonia is assumed to be present at the temperature range of 70-75°F and pH of 8.0 standard units, which are generally the critical conditions in the Region, and at ammonia-nitrogen concentrations of about 0.4 mg/l or greater, and has been recommended by the U. S. EPA as a water quality standard for the protection of fish and other aquatic life of the types found in the natural waters of the Region.*

[s] *This level of un-ionized ammonia is assumed to be present at the temperature range of 70-75°F and pH of 8.0 standard units, which are generally the critical conditions in the Region, and at ammonia-nitrogen concentrations of about 3.5 mg/l or greater, and has been identified by the U. S. EPA as a maximum concentration for the protection of tolerant species of insect life and forage minnows and other aquatic life of the types found in the Region.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 7

COMPARISON OF 1985 WISCONSIN DEPARTMENT OF NATURAL RESOURCES-ADOPTED WATER USE OBJECTIVES TO THE RECOMMENDED WATER USE OBJECTIVES FOR THE TRIBUTARY SURFACE WATERS LOCATED UPSTREAM OF THE MILWAUKEE HARBOR ESTUARY DIRECT DRAINAGE AREA

Watershed	Surface Water Identification	Water Use Objectives Adopted by the DNR: 1985	Preliminary Recommended Water Use Objectives	Rationale for Recommended Revision
Kinnickinnic River	Wilson Park Creek and the Kinnickinnic River from its headwaters to S. Chase Avenue	Variance (a)[a] for less restricted uses	Limited recreational use; limited fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives. Channel modifications preclude the attainment of full recreational use and warmwater fish and aquatic life objectives
Menomonee River	North Branch and west branch of the Menomonee River, and main stem of the Menomonee River from its headwaters to confluence with Honey Creek	Recreational use; warmwater fish and aquatic life	Limited recreational use; warmwater fish and aquatic life	Phosphorus levels cannot practicably be sufficiently reduced to prevent excessive aquatic plant growth and provide for full recreational use
	Main stem of the Menomonee River from confluence with Honey Creek to USH 41	Variance (a)[a] for less restricted uses	Limited recreational use; warmwater fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives. Phosphorus levels cannot practicably be sufficiently reduced to prevent excessive aquatic plant growth and provide for full recreational use
	Main stem of the Menomonee River from USH 41 to Falk Corporation dam	Variance (a)[a] for less restricted uses	Limited recreational use; limited fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives. Channel modifications, as well as excessive phosphorus levels, preclude the attainment of full recreational use and warmwater fish and aquatic life objectives
	Little Menomonee River and Little Menomonee Creek	Recreational use; warmwater fish and aquatic life	Limited recreational use; warmwater fish and aquatic life	Phosphorus levels cannot practicably be sufficiently reduced to prevent excessive aquatic plant growth and provide for full recreational use
	Butler Ditch	Recreational use; warmwater fish and aquatic life	Limited recreational use; warmwater fish and aquatic life	Phosphorus levels cannot practicably be sufficiently reduced to prevent excessive aquatic plant growth and provide for full recreational use

Table 7 (continued)

Watershed	Surface Water Identification	Water Use Objectives Adopted by the DNR: 1985	Preliminary Recommended Water Use Objectives	Rationale for Recommended Revision
Menomonee River (continued)	Underwood Creek from its headwaters to Watertown Plank Road	Recreational use; warmwater fish and aquatic life	Limited recreational use; warmwater fish and aquatic life	Phosphorus levels cannot practicably be sufficiently reduced to prevent excessive aquatic plant growth and provide for full recreational uses
	Underwood Creek downstream of Watertown Plank Road	Variance (a)[a] for less restricted uses	Limited recreational use; limited aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives. Channel modifications preclude the attainment of full recreational use and warmwater fish and aquatic life objectives
	Honey Creek	Variance (a)[a] for less restricted uses	Limited recreational use; limited fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives. Channel modifications preclude the attainment of full recreational use and warmwater fish and aquatic life objectives
Milwaukee River	Lincoln Creek from its headwaters to N. Green Bay Avenue	Variance (b)[b] for less restricted uses	Limited recreational use; limited fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives. Channel modifications preclude the attainment of full recreational use and warmwater fish and aquatic life objectives
	Lincoln Creek from N. Green Bay Avenue to its confluence with the Milwaukee River	Variance (a)[a] for less restricted uses	Recreational use; warmwater fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives
	Indian Creek from its headwaters to IH 43	Variance (a)[a] for less restricted uses	Limited recreational use; limited fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives. Channel modifications preclude the attainment of full recreational use and warmwater fish and aquatic life objectives

Table 7 (continued)

Watershed	Surface Water Identification	Water Use Objectives Adopted by the DNR: 1985	Preliminary Recommended Water Use Objectives	Rationale for Recommended Revision
Milwaukee River (continued)	Indian Creek from IH 43 to its confluence with the Milwaukee River	Variance (a)[a] for less restricted uses	Recreational use; warmwater fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives
	Silver Creek (Sheboygan County) from the Random Lake sewage treatment plant to road crossing located about one-quarter mile upstream of the Ozaukee County line	Recreational use; intermediate fish and aquatic life; NR 104.02 (3)(a)	Recreational use; warmwater fish and aquatic life	Implementation of water pollution abatement measures in this reach located outside the Region consistent with the measures recommended in the regional water quality management plan is expected to result in water quality sufficient to satisfy the water quality standards supporting upgraded water use objectives
	Nichols Creek from headwaters to STH 28, Chalmers Creek, Melius Creek, Gooseville Creek, Watercress Creek, and the portion of Fifteen Creek located in Sections 2 and 3, T13N, R19E	Recreational use; coldwater fish and aquatic life	Recreational use; coldwater fish and aquatic life	No revision recommended
	Main stem of Milwaukee River from its headwaters to the E. North Avenue dam, and all other tributaries to the Milwaukee River above the E. North Avenue dam not specifically cited in this table	Recreational use; warmwater fish and aquatic life	Recreational use; warmwater fish and aquatic life	No revision recommended

[a]As set forth in NR 104.06 (2)(a) of the Wisconsin Administrative Code.

[b]As set forth in NR 104.06 (2)(b) of the Wisconsin Administrative Code.

Source: Wisconsin Department of Natural Resources and SEWRPC.

activities would likely be reduced. However, under both the recreational use and limited recreational use objectives, public health would be protected by the application of a fecal coliform standard.

The standards set forth in Table 5 to support fish and aquatic life are primarily intended to prevent unacceptable short-term and long-term adverse effects on fish, benthic invertebrate, and zooplankton communities. Data on water quality conditions suitable for the growth and propagation of aquatic plant species indicate that plants are generally less sensitive to adverse water quality conditions than are aquatic animals. Aquatic life can tolerate some stress and occasional adverse effects; thus, the protection of all species all of the time may not be absolutely essential. The standards are intended to provide a reasonable level of protection for those species that would be expected to exist in the waters under each of the water use objective classifications. Common fish species present under a coldwater use classification include salmon and trout. Common fish species present under a warmwater use classification include largemouth and smallmouth bass, northern pike, walleye, bluegill, pumpkinseed, green sunfish, black crappie, yellow

Table 8

COMPARISON OF 1985 WISCONSIN DEPARTMENT OF NATURAL RESOURCES-ADOPTED WATER USE OBJECTIVES TO THE RECOMMENDED WATER USE OBJECTIVES FOR THE SURFACE WATERS WITHIN THE MILWAUKEE HARBOR ESTUARY DIRECT DRAINAGE AREA

Watershed	Surface Water Identification	Water Use Objectives Adopted by the DNR: 1985	Preliminary Recommended Water Use Objectives	Rationale for Recommended Revision
Kinnickinnic River	Kinnickinnic River from S. Chase Avenue to its confluence with the Milwaukee River	Variance (a)[a] for less restricted uses	Recreational use and warmwater fish and aquatic life; and limited recreational use and limited fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan, together with measures recommended in the Milwaukee Harbor estuary study, may result in water quality sufficient to satisfy the water quality standards supporting full recreational use and warmwater fish and aquatic life objectives. However, limited recreational use and limited fish and aquatic life objectives are also considered for this portion of the Kinnickinnic River because of the intensive industrial use of lands adjacent to the river
Menomonee River	Main stem of the Menomonee River from Falk Corporation dam to confluence with the Milwaukee River	Variance (a)[a] for less restricted uses	Recreational use and warmwater fish and aquatic life; and limited recreational use and limited fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan, together with measures recommended in the Milwaukee Harbor estuary study, may result in water quality sufficient to satisfy the water quality standards supporting full recreational use and warmwater fish and aquatic life objectives. However, limited recreational use and limited fish and aquatic life objectives are also considered for this portion of the Menomonee River because of the intensive industrial use of lands adjacent to the river
	South Menomonee Canal and Burnham Canal	Variance (b)[b] for less restricted uses	Recreational use and warmwater fish and aquatic life; and limited recreational use and limited fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan, together with measures recommended in the Milwaukee Harbor estuary study, may result in water quality sufficient to satisfy the water quality standards supporting full recreational use and warmwater fish and aquatic life objectives. However, limited recreational use and limited fish and aquatic life objectives are also considered for these canals because of the intensive industrial use of lands adjacent to the canals

Table 8 (continued)

Watershed	Surface Water Identification	Water Use Objectives Adopted by the DNR: 1985	Preliminary Recommended Water Use Objectives	Rationale for Recommended Revision
Milwaukee River	Main stem of the Milwaukee River from the E. North Avenue dam to its mouth at Lake Michigan	Variance (b)[b] for less restricted uses	Recreational use; warmwater fish and aquatic life	Implementation of the water pollution abatement measures recommended in the regional water quality management plan, together with measures recommended in the Milwaukee Harbor estuary study, may result in water quality sufficient to satisfy the water quality standards supporting full recreational use and warmwater fish and aquatic life objectives
Kinnickinnic, Menomonee, and Milwaukee Rivers	Milwaukee Outer Harbor	Recreational use; warmwater fish and aquatic life	Recreational use; warmwater fish and aquatic life	No revision recommended

[a]*As set forth in NR 104.06(2)(a) of the Wisconsin Administrative Code.*

[b]*As set forth in NR 104.06(2)(b) of the Wisconsin Administrative Code.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

perch, and channel catfish. Common fish species present under a limited use classification include carp, white sucker, fathead minnow, goldfish, and bullhead.

Acute and Chronic Toxicity: For each of the fish and aquatic life use classifications, a range of adverse effects may be shown over a range of water quality conditions. These adverse effects include acute—or short-term—toxic effects, and chronic—or long-term—toxic effects. Criteria have been developed to identify acute and chronic toxic concentrations of selected substances. These criteria, as set forth in Table 9, have not, however, been adopted as standards under the Milwaukee Harbor estuary study because only preliminary determinations of the toxic values have been made by the Department of Natural Resources. The criteria are, however, designated by reference in Table 5 as indicative of toxic concentrations. Alternative water pollution abatement plans were evaluated for their achievement of the water use objectives through the application of the supporting water quality standards set forth in Table 5, and the toxic criteria set forth in Table 9. A second evaluation was made in cases where the standards and criteria were not met under a particular alternative plan. Where these standards and criteria were violated, the acute and chronic toxic relationships set forth herein were used to define the type of adverse impact and severity of the impact that could be expected. These evaluations were based upon the extent and duration of the violations, as well as the indicated effect of the violations.

Acute toxicity generally refers to the death, immobilization, or loss of equilibrium of an organism occurring in a relatively short time period. An acute toxic level is usually expressed as the concentration of a substance at which 50 percent of the tested organisms are acutely affected within 96 hours. Based on acute toxicity test results for several species of fish and invertebrates within a use classification, an acute toxicity criterion, which should not be exceeded, is determined. This criterion is intended to protect the most sensitive

Table 9

PRELIMINARY ACUTE AND CHRONIC TOXICITY CRITERIA
DEVELOPED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Water Quality Parameter	Acute Toxicity Criteria[a]		Chronic Toxicity Criteria[b]	
	Coldwater Fish and Aquatic Life	Warmwater and Limited Fish and Aquatic Life	Coldwater Fish and Aquatic Life	Warmwater and Limited Fish and Aquatic Life
Arsenic	1,500	1,500	290	290
Cadmium	3.8	74.3	$0.17(1.004)^H$	$0.17(1.004)^H$
Chromium (hexavalent)	$1.82(H)^{0.76}$	$1.82(H)^{0.76}$	$0.30(H)^{0.76}$	$0.30(H)^{0.76}$
Chromium (trivalent)	$7{,}139 + 0.02H^2$	$6{,}958 + 0.47H^2$	57	$54.8 + 0.006H^2$
Copper	$20.4(1.006)^H$	$20.6(1.002)^H$	10.0	$13.1(1.001)^H$
Cyanide	57	95	5.6	10.7
Lead	$8.4(H)^{1.05}$	$8.4(H)^{1.05}$	$0.0014(H)^{2.35}$	$0.0026(H)^{2.13}$
Mercury	2.22	2.22	0.2	0.2
Nickel	$194.2(H)^{0.91}$	$284(H)^{0.49}$	$0.004(H)^{2.07}$	$2.4(H)^{1.008}$
Polychlorinated Biphenyls	1.03	2.02	0.014	0.012
Selenium	1,030	1,030	50	77
Silver	$1.12 + 0.0002H^2$	$0.90 + 0.001H^2$	7.91	7.91
Zinc	$109.6 + 3.54H$	$109.6 + 3.54H$	71.1	71.1

NOTE: All criteria are maximum values expressed in μg/l.
H = water hardness in mg/l.

[a] *Acute toxicity criteria should never be exceeded.*

[b] *Chronic toxicity criteria should not be exceeded on a 30-day mean basis. The chronic criteria should not be exceeded for more than 96 hours during any 30-day period.*

Source: Wisconsin Department of Natural Resources.

species tested within the use classification from acute toxic effects. Acute toxicity criteria developed by the Wisconsin Department of Natural Resources for selected substances are set forth in Table 9.

Chronic toxicity refers to adverse effects which may occur over a relatively long time period. Chronic effects may include reduced long-term survival, reduced growth, or reduced reproduction of fish and invertebrate species; toxicity to aquatic plant species; and the bioconcentration of the substance such that humans or wildlife that consume aquatic organisms may be adversely affected. A residue value may be calculated from bioconcentration data and from allowable concentrations of a substance within animal body tissue which prevents aquatic organisms from exceeding U. S. Food and Drug Administration guidelines for human consumption, and which protects wildlife which consume aquatic organisms from adverse chronic effects. Chronic toxicity tests are generally conducted for at least a 30-day period. Based on chronic toxicity test results for several species of fish and invertebrates within a use classification, a final chronic value is calculated. This value is intended to protect the most sensitive species tested within the use classification from chronic toxic effects. A final chronic value for fish and invertebrates, toxic levels for important aquatic plant species, and a residue value designed to protect humans and wildlife that consume aquatic organisms are determined for a substance. The lowest of these values is referred to as the chronic toxicity criterion, which should not be exceeded by the mean concentration measured from all samples collected during any 30-day period. Furthermore, the chronic toxicity criterion should not be exceeded for a cumulative duration of more than 96 hours within any 30-day period. A chronic toxicity criterion should also not exceed the acute toxicity criterion. Chronic toxicity criteria developed by the Wisconsin Department of Natural Resources for selected substances are set forth in Table 9.

The combined use of acute and chronic toxicity criteria is intended to identify the maximum long-term mean concentration of a substance which will provide a water quality generally suited to the protection and maintenance of desired fish and aquatic life, while restricting the severity and duration of violations of the maximum long-term mean concentration so that the total exposure to the substance will not cause unacceptable chronic or acute effects. The criteria are designed to protect aquatic organisms from acute and chronic toxicity, and to prevent excessive bioconcentration by aquatic organisms. Although the criteria are developed based only on tests on selected species, the U. S. Environmental Protection Agency reports that other species, including food organisms, should either be more resistant to toxicity than the most sensitive species tested, or be adaptable enough to overcome the toxic effects of the substance.[9]

The acute and chronic toxicity criteria are numerical limits designed to protect the vast majority of organisms against short-term and long-term impacts. The research data used to generate these limits can, however, be used to illustrate the extent and severity of adverse effects which occur over a range of concentrations of a substance. Acute and chronic effects on various fish and invertebrate species are presented below for a range of concentrations of dissolved oxygen, ammonia nitrogen, chlorine, cyanide, polychlorinated biphenyls, and 11 metals—arsenic, cadmium, hexavalent chromium, trivalent chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. The criteria for the metals apply only to the active, or acid-soluble, concentrations of the metals.[10] The data are presented separately for coldwater, warmwater, and limited fish species, and for invertebrates. Data are included only for species which have been identified in Wisconsin surface waters. Since dissolved oxygen is a water quality parameter of primary concern in the Milwaukee Harbor estuary study, the severity and type of acute or chronic effect are shown for a range of dissolved oxygen concentrations. For the remaining substances, the maximum, minimum, and geometric mean acute and chronic toxic concentrations are shown for each species. The mean toxic concentrations were used to determine the probability of species within the water use category having toxic levels equal to or greater than indicated levels. The acute toxicity value shown is the LC50—or that concentration of

[9]*C. E. Stephan, D. I. Mount, et al., "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Life and Its Uses," U. S. Environmental Protection Agency, July 5, 1983.*

[10]*The active, or acid-soluble, concentration of a metal is expressed as that concentration measured by acidifying the sample to a pH of four standard units with nitric acid, and then passing the sample through a 0.47-micrometer membrane filter.*

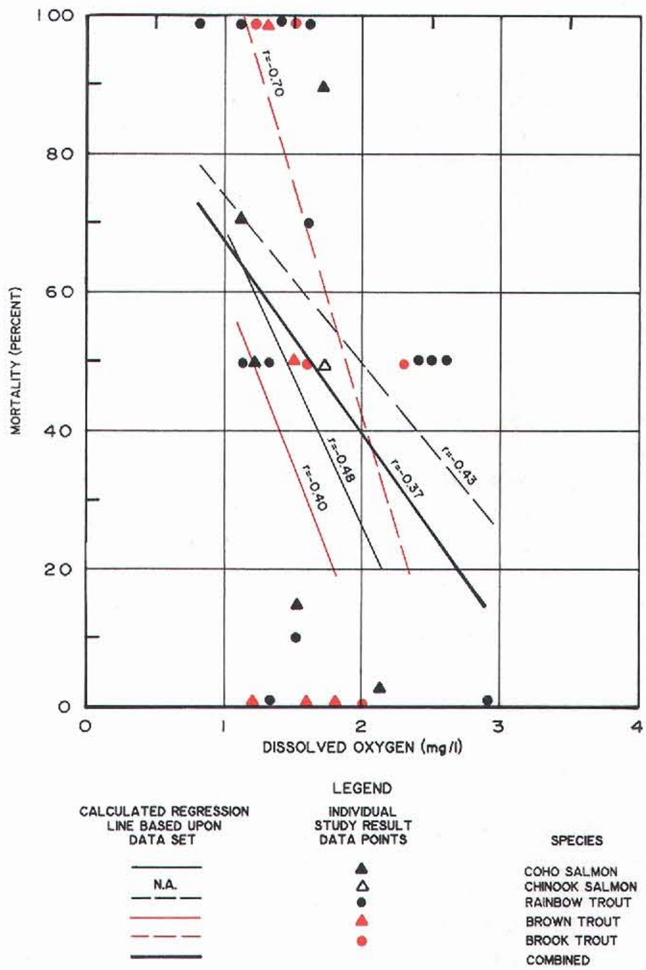
a substance at which 50 percent of the organisms tested were acutely affected within a 96-hour period.

In order to standardize and facilitate the comparison of chronic toxicity data for dissolved oxygen from various studies, the data were normalized to control levels. In other words, within each study the control values were established as 100 percent, and the normalized value under reduced dissolved oxygen concentrations was calculated by dividing the study value by the control value. Thus, long-term survival, growth rates, and reproductive success—as expressed by hatch time and feeding time—are all presented on a normalized basis as a percent of the control values.

The relationship of acute and chronic concentrations to the water quality conditions presented herein was used in the study to help describe and evaluate the potential impact of violating the adopted water quality standards or toxic criteria under alternative Milwaukee Harbor estuary management plans. The relationships were used to identify which species or groups of organisms would likely be adversely affected, the severity of impacts upon these organisms, and, for dissolved oxygen, the types of impacts which could be expected. These data allow the health, diversity, and general composition of aquatic communities expected under alternative management plans to be qualitatively assessed so that informed judgments can be made concerning the degree to which desired water use objectives will be achieved.

Figure 1

ACUTE TOXIC DISSOLVED OXYGEN LEVELS FOR COLDWATER FISH SPECIES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

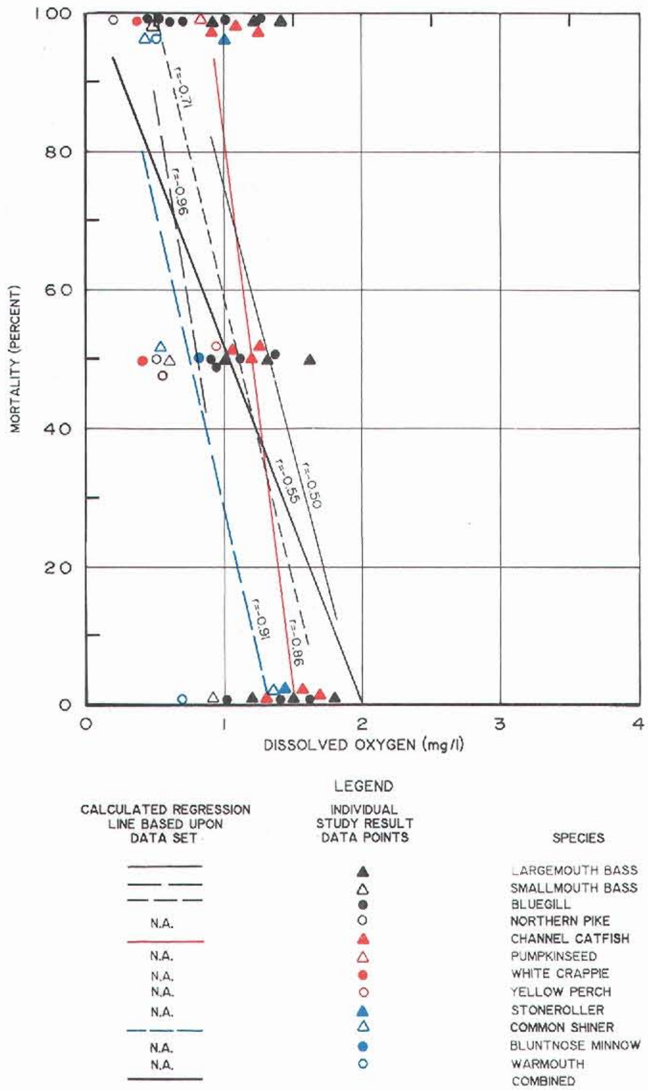
Dissolved Oxygen: Acute dissolved oxygen levels for coldwater fish species, warmwater fish species, and limited fish species are set forth in Figures 1, 2, and 3, respectively. The figures show mortality levels at various dissolved oxygen concentrations for five coldwater fish species, 12 warmwater fish species, and three limited fish species. As expected, the coldwater fish species are the most sensitive to low levels of dissolved oxygen, with some mortality being reported at a dissolved oxygen concentration of nearly 2.6 mg/l. The limited fish species are the least sensitive to low dissolved oxygen levels, with no significant mortality reported until the dissolved oxygen levels were 0.4 mg/l. The warmwater fish species were moderately affected by low dissolved oxygen levels, with some mortality occurring at 1.6 mg/l of dissolved oxygen.

The most significant reported chronic effects of low dissolved oxygen levels are reduced long-term survival, growth, and reproduction. Other chronic effects which have been reported for fish include avoidance of areas with low dissolved oxygen levels, reduced swimming ability, and changes in the respiratory metabolism.[11] Concentrations of dissolved oxygen which have caused avoidance reactions in fish are presented in Table 10. These avoidance reactions may be biologically important if use of migration or spawning routes or access to

[11] *P. Doudoroff and D. L. Shumway, Dissolved Oxygen Requirements of Freshwater Fishes, FAO Fisheries Technical Paper No. 86, June 1970.*

Figure 2

ACUTE TOXIC DISSOLVED OXYGEN LEVELS FOR WARMWATER FISH SPECIES



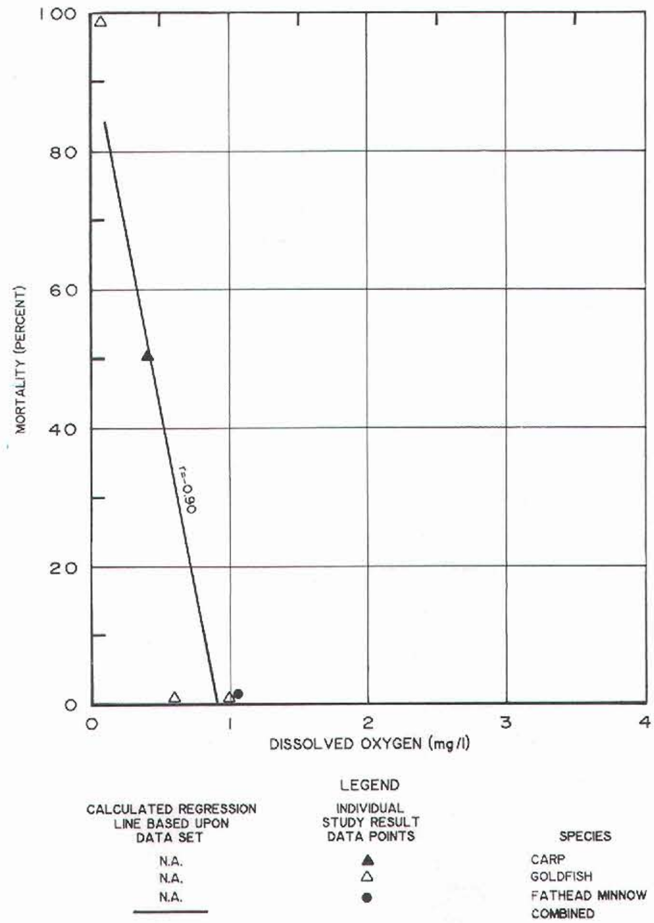
Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

important feeding or habitat areas are prevented or restricted by avoidance of waters with low dissolved oxygen levels.

Chronic effects over a range of dissolved oxygen levels for coldwater fish species are presented in Figures 4 through 8. Figure 4 shows the effect of dissolved oxygen levels on the long-term survival of lake trout. The figure shows that long-term survival of young lake trout can be reduced substantially at even relatively high levels of dissolved oxygen. For example, at a dissolved oxygen concentration of 5.0 mg/l, the long-term survival of young lake trout

Figure 3

ACUTE TOXIC DISSOLVED OXYGEN LEVELS FOR LIMITED FISH SPECIES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Table 10

DISSOLVED OXYGEN CONCENTRATIONS WHICH HAVE CAUSED AVOIDANCE REACTIONS IN FISH

Species	Dissolved Oxygen (mg/l)	
	Slight Avoidance	Strong Avoidance
Coldwater Species[a]		
Chinook Salmon	4.5	3.0
Coho Salmon	6.0	3.0
Warmwater Species[b]		
Walleye	4.0	2.0
Largemouth Bass	4.5	1.5
Bluegill	3.0	1.5

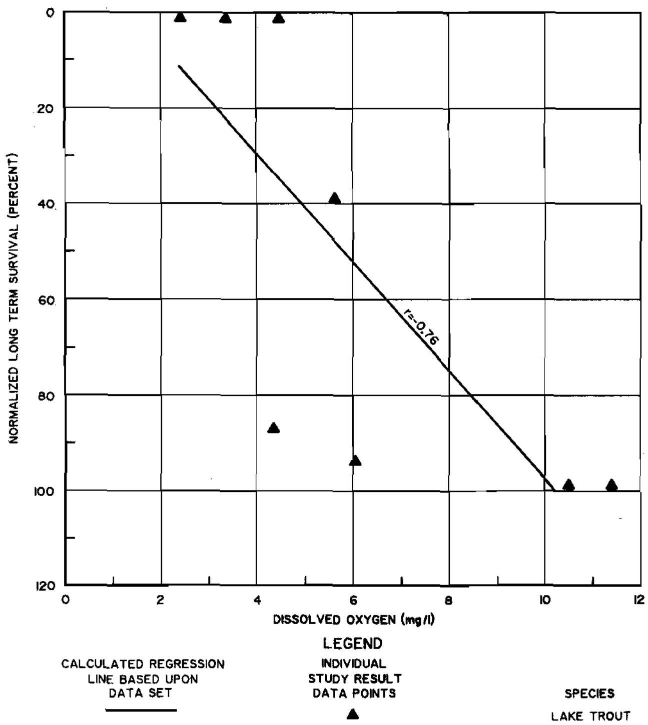
[a]*P. Doudoroff and D. L. Shumway, Dissolved Oxygen Requirements of Freshwater Fishes, FAO Fisheries Technical Paper No. 86, June 1970.*

[b]*J. C. Davis, "Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: A Review," Journal of Fisheries Research Board of Canada Vol. 31(12). 1195-2332, 1975.*

Source: SEWRPC.

Figure 4

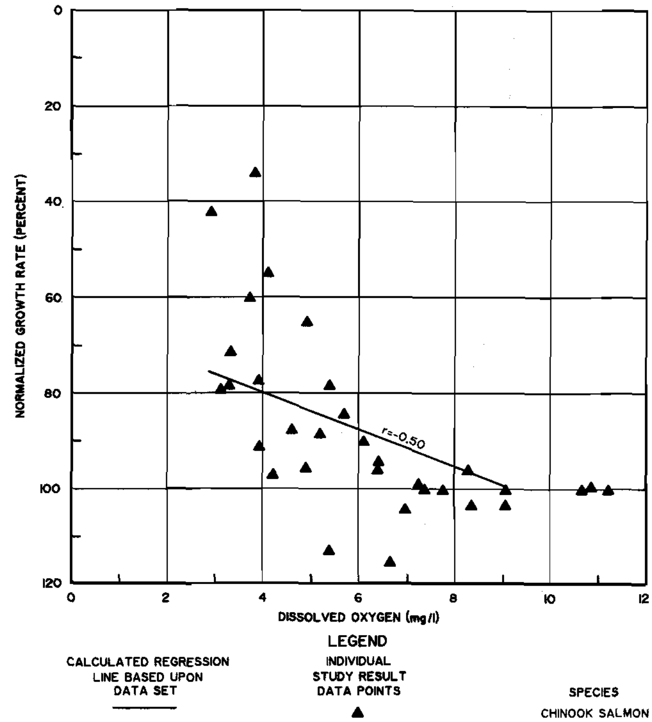
CHRONIC DISSOLVED OXYGEN LEVELS FOR COLDWATER FISH SPECIES: LONG-TERM SURVIVAL



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 5

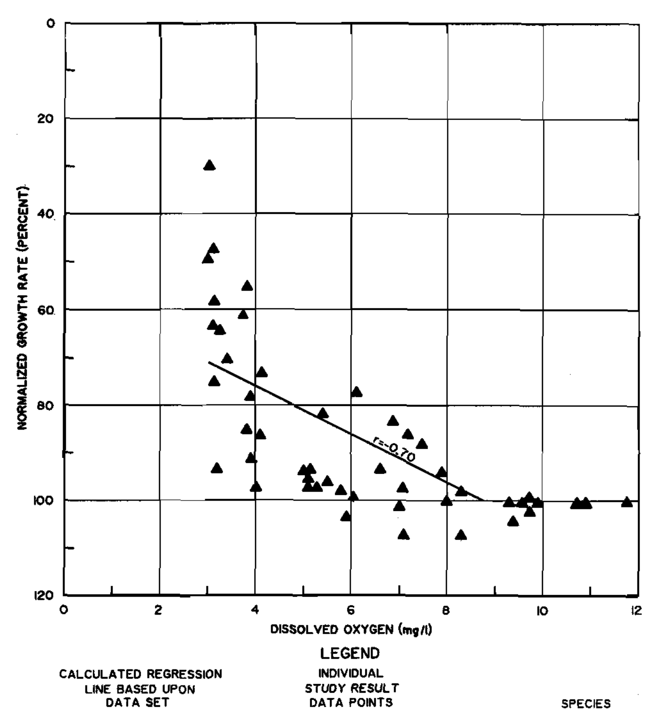
CHRONIC DISSOLVED OXYGEN LEVELS FOR COLDWATER SPECIES: GROWTH (WEIGHT)—CHINOOK SALMON



Source: U. S. Environmental Protection Agency and SEWRPC.

Figure 6

CHRONIC DISSOLVED OXYGEN LEVELS FOR COLDWATER SPECIES: GROWTH (WEIGHT)—COHO SALMON



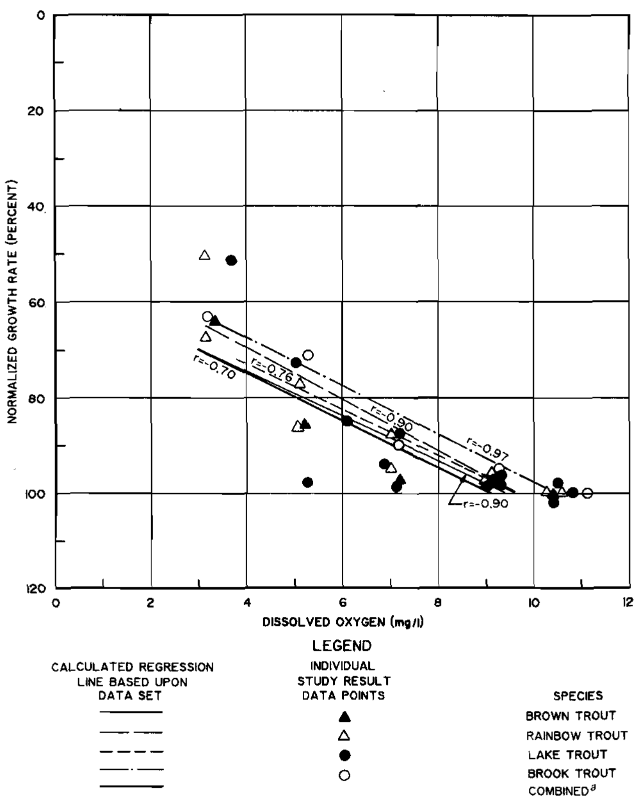
Source: U. S. Environmental Protection Agency and SEWRPC.

would be only about 40 percent of the survival rate expected under optimal dissolved oxygen levels. Figures 5 through 7 illustrate the impact of dissolved oxygen levels on the growth of coldwater fish species.

In general, chinook salmon and coho salmon, as shown in Figures 5 and 6, respectively, are less susceptible to reduced growth effects than are trout species, as shown in Figure 7. Figure 8 shows the relationship between reproductive success and dissolved oxygen levels for lake trout. The reproductive success is expressed as the time required for 90 percent of the trout eggs to hatch, and as the time required for these hatched trout to begin feeding. Studies have indicated that at longer hatch and feeding times, the survival of young fish can be reduced. The figure shows that at a dissolved oxygen concentration of 5.0 mg/l, the hatch time and feeding time may be 4 percent and 25 percent longer, respectively, than under optimal dissolved oxygen conditions.

Figure 7

CHRONIC DISSOLVED OXYGEN LEVELS FOR COLDWATER SPECIES: GROWTH (WEIGHT)—TROUT

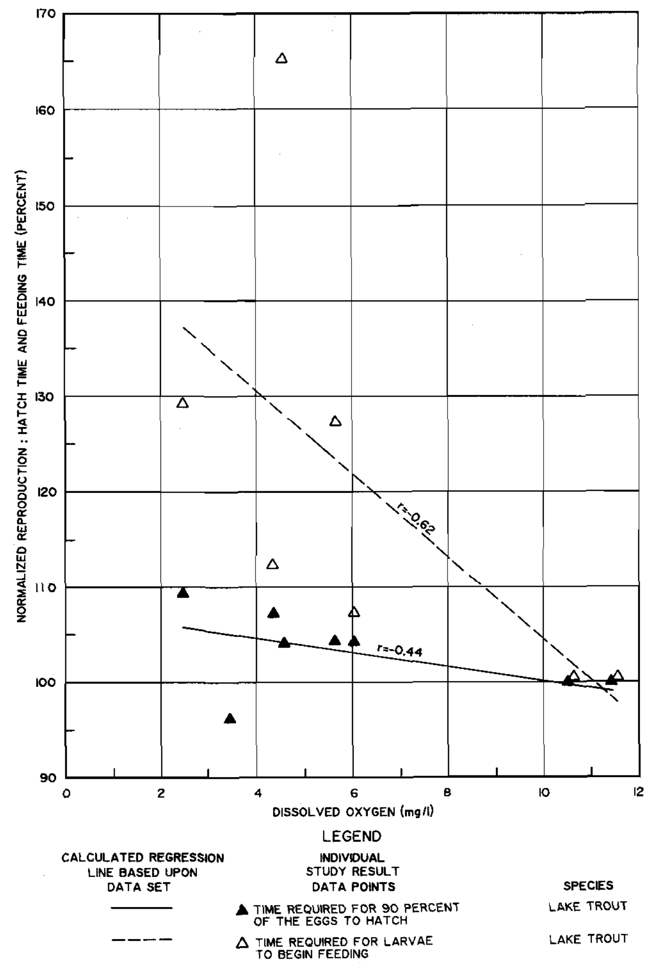


[a]Combined includes Brown Trout, Rainbow Trout, Lake Trout, Brook Trout, Coho Salmon, and Chinook Salmon.

Source: U. S. Environmental Protection Agency and SEWRPC.

Figure 8

CHRONIC DISSOLVED OXYGEN LEVELS FOR COLDWATER SPECIES: REPRODUCTION



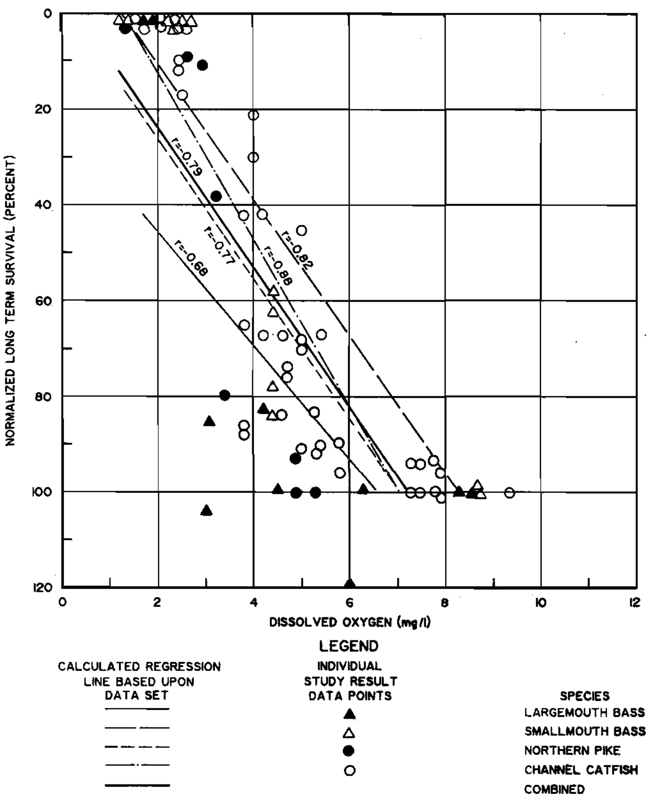
Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Chronic effects over a range of dissolved oxygen levels for warmwater fish species are presented in Figures 9 through 13. Figure 9 shows the relationship of dissolved oxygen levels to long-term survival for four warmwater species. At a dissolved oxygen concentration of 5.0 mg/l, the long-term survival of the various species tested would range from 54 to 82 percent of the survival rate expected under optimal dissolved oxygen levels. Figures 10 and 11 illustrate the effect of dissolved oxygen levels on the growth of warmwater fish as measured by weight and by length, respectively. Generally, the figures indicate that warmwater species are less susceptible to reduced length growth than to reduced weight growth as a result of low dissolved oxygen levels. Figures 12 and 13 show the effect of dissolved oxygen levels on the reproductive success of three and four warmwater fish species, respectively. Figure 12, which presents hatch time as a function of dissolved oxygen levels, indicates that lower dissolved oxygen concentrations tend to result in longer hatch times, which in turn may result in reduced survival of the young fish. Other studies have indicated that very low levels of dissolved oxygen—less than 2 mg/l—are needed before significant adverse effects on reproduction can be detected in some warmwater fish species.[12] Both Figure 12 and Figure 13 indicate that channel catfish are the most sensitive to the dissolved oxygen levels tested.

[12]*A. R. Carlson and L. J. Herman, "Effect of Long-Term Reduction and Diel Fluctuation in Dissolved Oxygen on Spawning of Black Crappie, Pomixis nigromaculatus," Transactions of the American Fisheries Society Vol. 107(5): 742-746, 1978.*

Figure 9

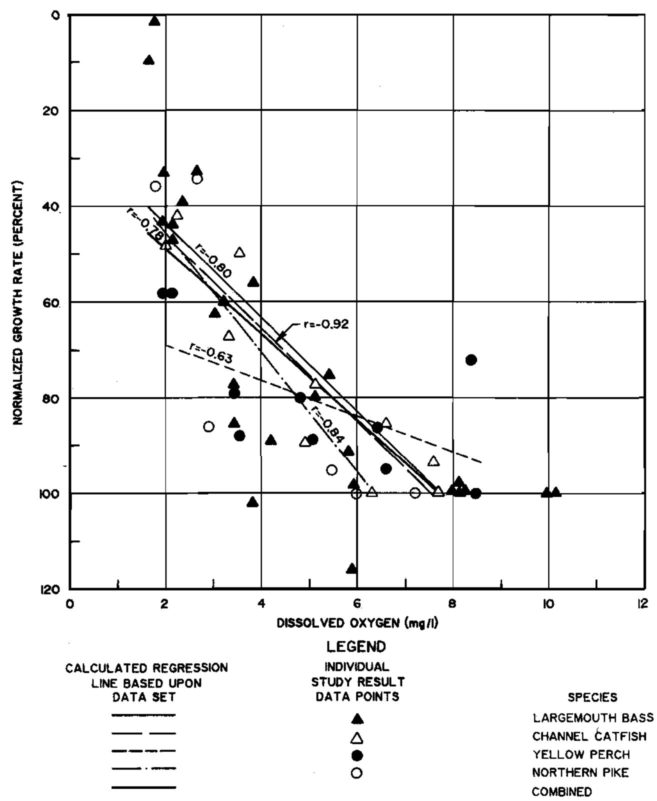
CHRONIC DISSOLVED OXYGEN LEVELS FOR WARMWATER SPECIES: LONG-TERM SURVIVAL



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 10

CHRONIC DISSOLVED OXYGEN LEVELS FOR WARMWATER SPECIES: GROWTH (WEIGHT)



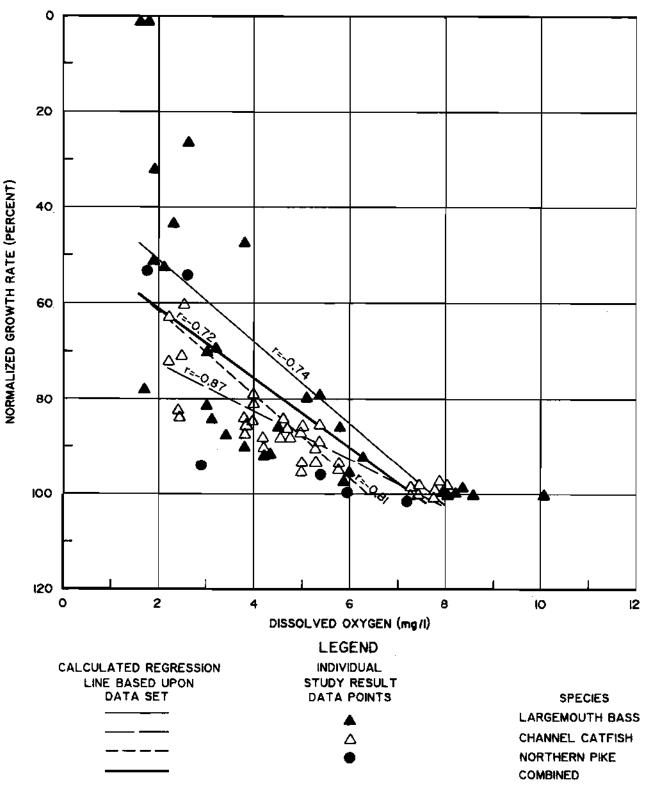
Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

The chronic effects of dissolved oxygen levels on limited fish species are shown in Figures 14 through 16. Figure 14 indicates that the long-term survival of young fathead minnows is strongly influenced by the dissolved oxygen level, with an estimated long-term survival rate of 72 percent of optimal at a dissolved oxygen concentration of 5.0 mg/l. Figure 15 shows the impact of dissolved oxygen levels on the growth of fathead minnows and carp. At lower levels of dissolved oxygen, the growth of carp, as measured in weight, is more susceptible to reduction than is the growth of fathead minnows, as measured in length. The reproductive success of fathead minnows, as measured by spawnings per female, eggs per spawning, and eggs per female for one spawning season, is shown in Figure 16 as a function of dissolved oxygen levels. All three measurements of spawning production are reduced as dissolved oxygen levels decrease.

Ammonia Nitrogen: The toxicity of ammonia nitrogen to aquatic organisms is primarily attributable to the un-ionized form of ammonia, with the ionized form being less toxic. The concentration of un-ionized ammonia is primarily determined by the concentration of total ammonia, and by the pH and temperature of the water. Concentrations of un-ionized ammonia are highly influenced by pH, with higher levels of un-ionized ammonia occurring at higher pH levels. However, the acute toxicity of un-ionized ammonia nitrogen generally decreases as pH increases, as shown in Figure 17 for rainbow trout and coho salmon, both coldwater fish species; for fathead minnow, a limited fish species; and for daphnia, a zooplankton. This reduced toxicity, however, begins to level off at a pH of about 7.5 standard units. Thus, as pH levels increase, the concentration of un-ionized ammonia increases, but the toxicity of that un-ionized ammonia

Figure 11

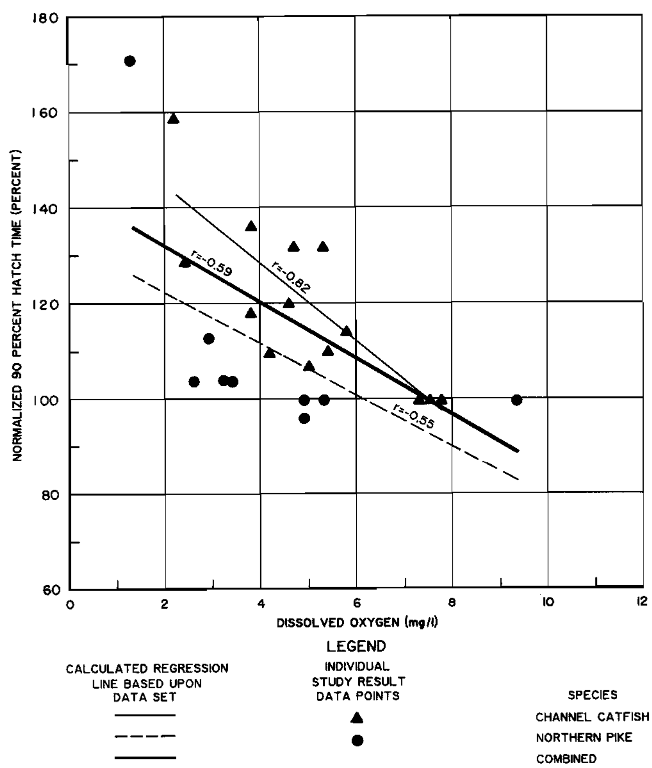
CHRONIC DISSOLVED OXYGEN LEVELS FOR WARMWATER SPECIES: GROWTH (LENGTH)



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 12

CHRONIC DISSOLVED OXYGEN LEVELS FOR WARMWATER SPECIES: REPRODUCTION–TIME REQUIRED FOR 90 PERCENT OF THE EGGS TO HATCH



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

decreases. Overall, as pH levels increase, the toxicity of total ammonia nitrogen generally increases, because the increase in un-ionized ammonia nitrogen levels has a greater effect than does the reduced toxicity of the un-ionized ammonia.

In order to facilitate the comparison of acute and chronic toxicity data for un-ionized ammonia nitrogen from different studies, it was necessary to standardize the pH and temperature conditions by correcting the reported toxic levels of un-ionized ammonia nitrogen to a common pH and temperature.

The standardization procedures used were those set forth in a U. S. Environmental Protection Agency report.[13] The EPA report indicated that correction of reported toxic levels of un-ionized ammonia nitrogen to a common temperature is necessary only where the reported temperature is less than 10°C. Study results where the reported temperature was less than 10°C were corrected to a common temperature by the following equation:

$$ATEMP = ATOX \times \frac{(1 + 10^{9.73\text{-}pH})}{(1 + 10^{PKT\text{-}pH})}$$

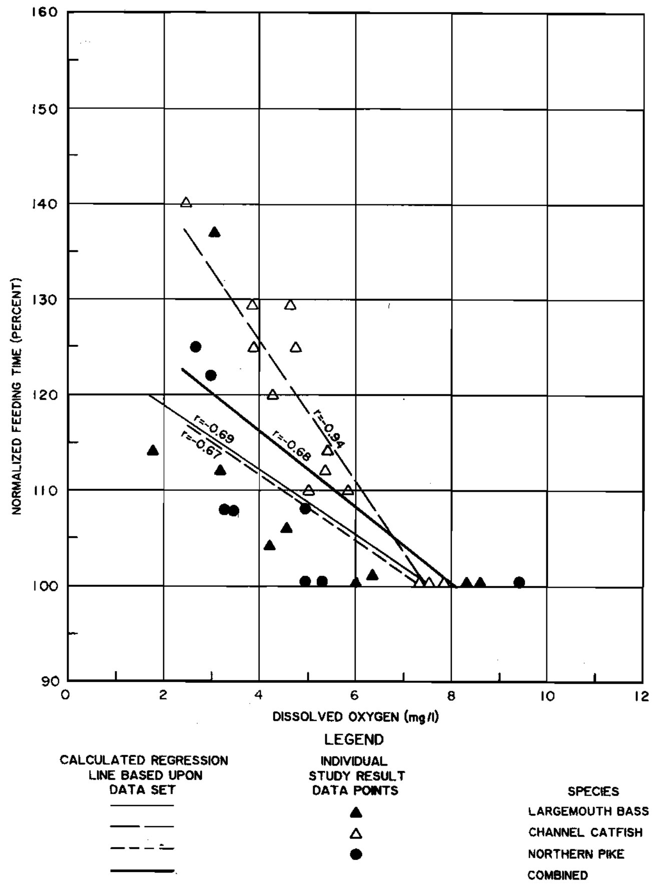
where:

ATEMP = Temperature-corrected toxic level of un-ionized ammonia nitrogen (mg/l),

[13] *U. S. Environmental Protection Agency, "Ambient Water Quality Criteria for Ammonia," 1983.*

Figure 13

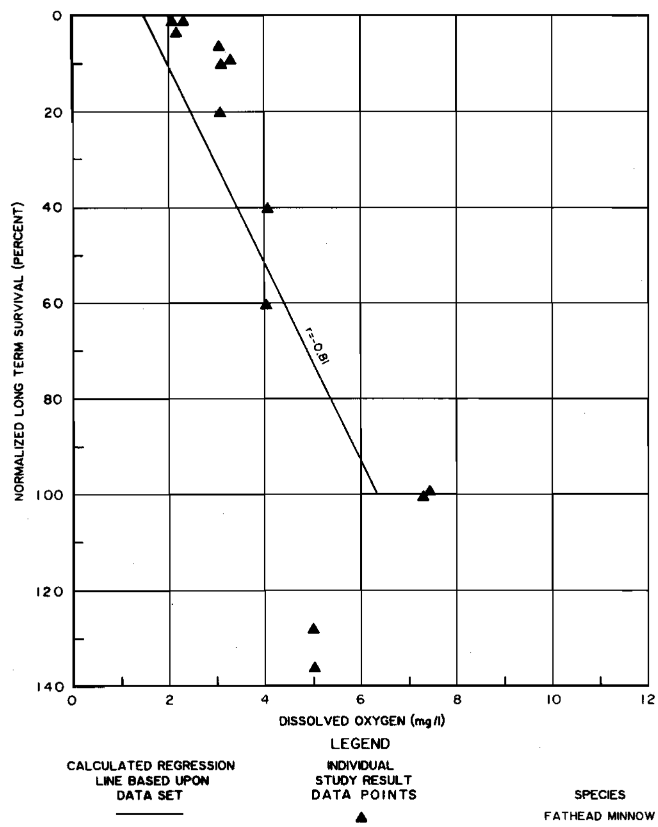
CHRONIC DISSOLVED OXYGEN LEVELS FOR WARMWATER SPECIES: REPRODUCTION—TIME REQUIRED FOR LARVAE TO BEGIN FEEDING



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 14

CHRONIC DISSOLVED OXYGEN LEVELS FOR LIMITED SPECIES: LONG-TERM SURVIVAL



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

ATOX = Initial toxic level of un-ionized ammonia nitrogen reported in study (mg/l),

pH = The initial pH (standard units) measured in the study, and

$$pKT = 0.09 + \frac{2730}{T(^\circ C) + 273.2}$$

The temperature-corrected toxic levels of un-ionized ammonia nitrogen were then corrected to a common pH, which represents a high level of pH under which toxicity of un-ionized ammonia nitrogen would no longer be pH-dependent, by the following equation:

$$APH = ATEMP \times (1 + 10^{1.03[7.32-pH]})$$

where:

APH = pH-corrected toxic level of un-ionized ammonia nitrogen (mg/l),

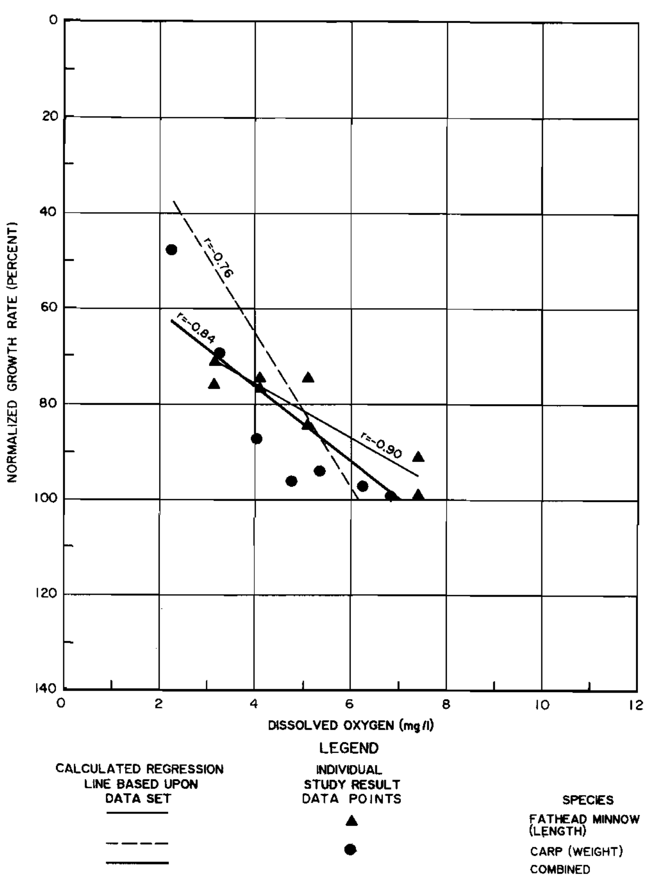
ATEMP = Temperature-corrected toxic level of un-ionized ammonia nitrogen (mg/l), and

pH = The initial pH (standard units) measured in the study.

The pH- and temperature-corrected acute toxicity levels of un-ionized ammonia nitrogen are set forth in Figure 18 for fish and invertebrates. The mean

Figure 15

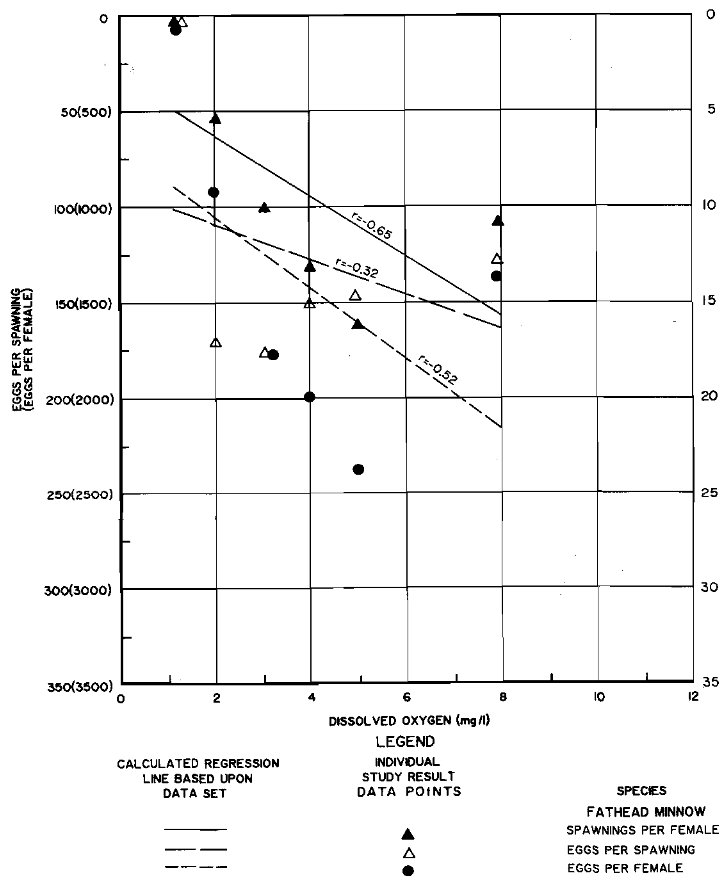
CHRONIC DISSOLVED OXYGEN LEVELS FOR LIMITED SPECIES: GROWTH



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 16

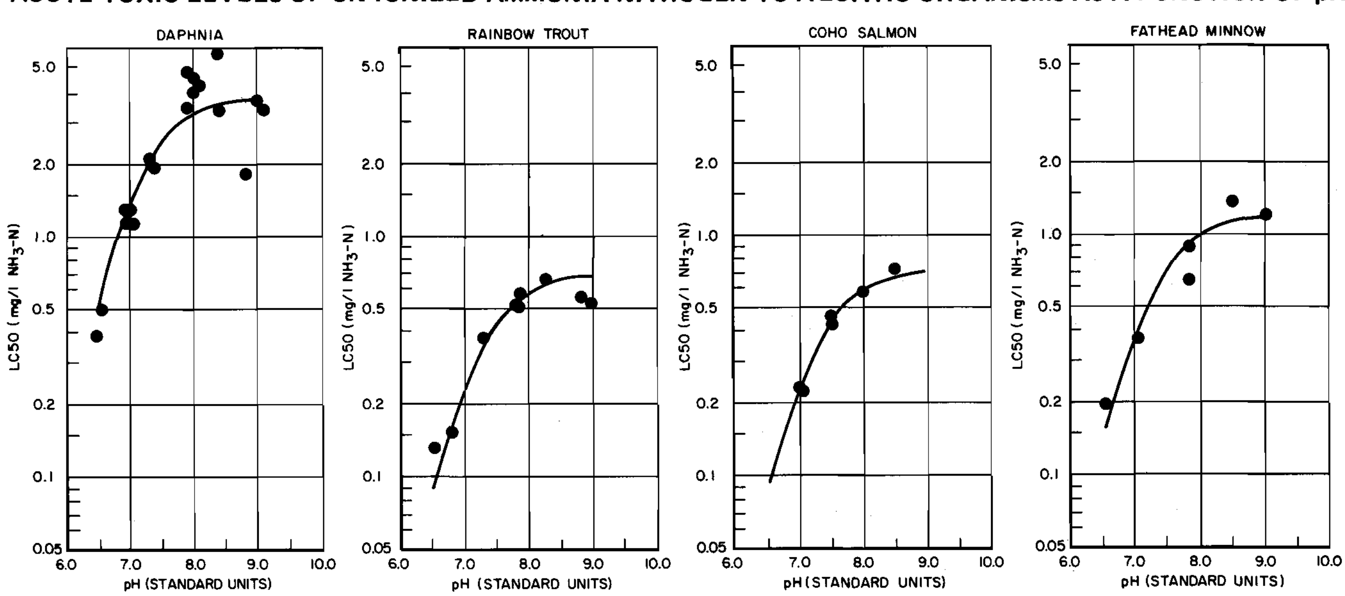
CHRONIC DISSOLVED OXYGEN LEVELS FOR LIMITED SPECIES: REPRODUCTION



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 17

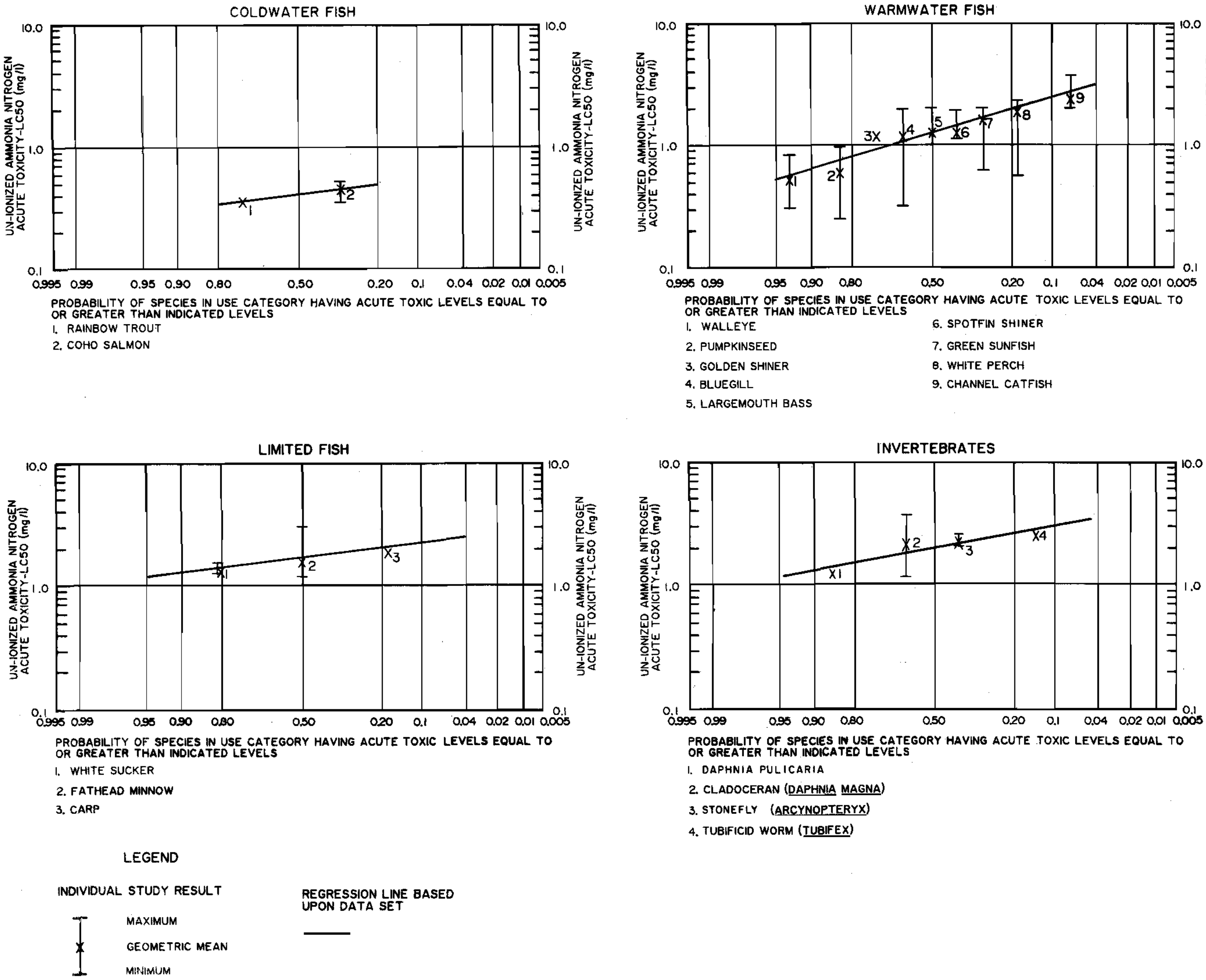
ACUTE TOXIC LEVELS OF UN-IONIZED AMMONIA NITROGEN TO AQUATIC ORGANISMS AS A FUNCTION OF pH



Source: U. S. Environmental Protection Agency, "Ambient Water Quality Criteria for Ammonia," 1983.

Figure 18

ACUTE TOXIC UN-IONIZED AMMONIA NITROGEN LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

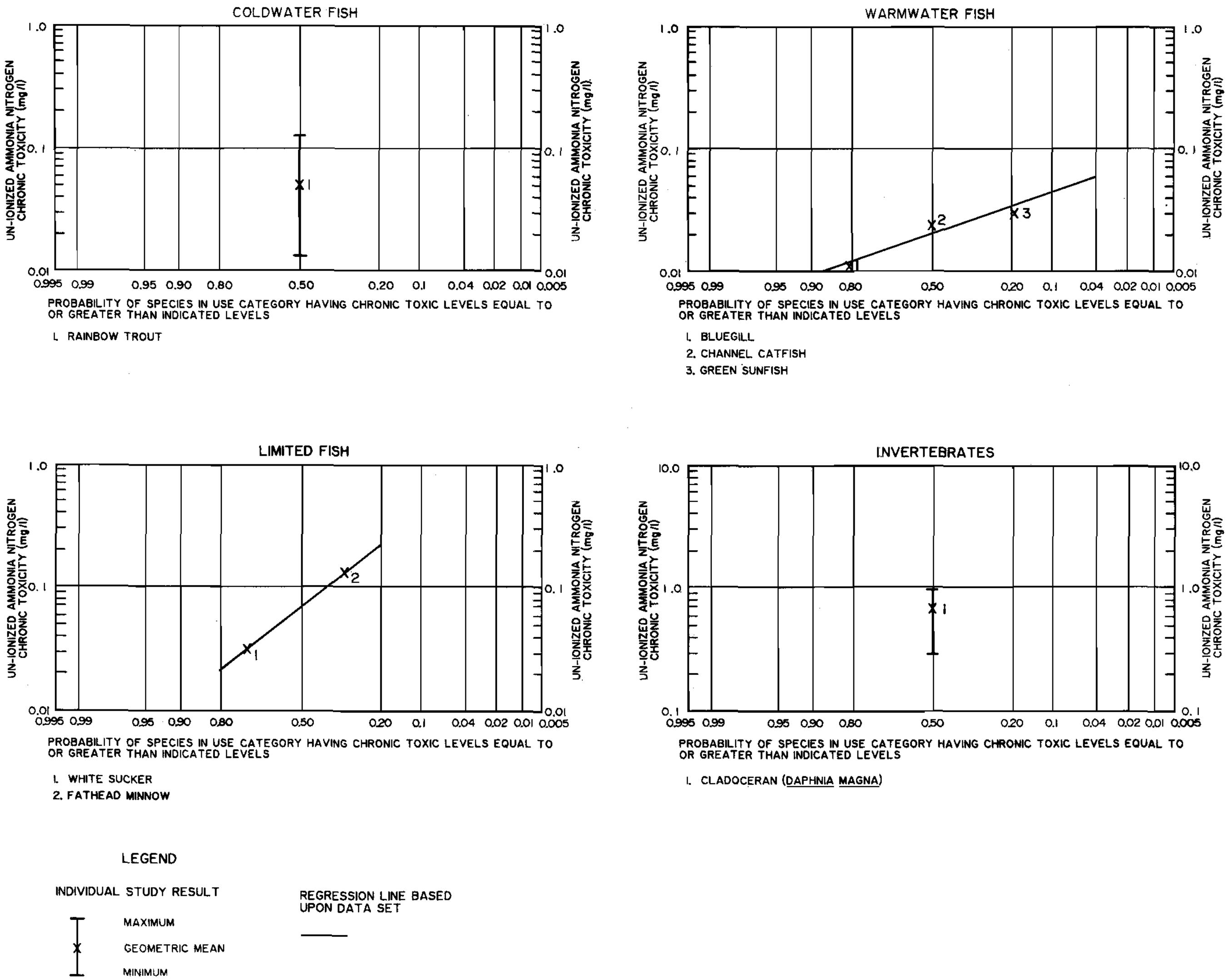
species acute toxic levels of un-ionized ammonia nitrogen for fish range from 0.5 mg/l for walleye to 2.4 mg/l for channel catfish. For invertebrates, the mean species acute toxic levels range from 1.1 mg/l for a cladoceran to 2.5 mg/l for a tubificid worm. Mean species temperature- and pH-corrected chronic toxic levels of un-ionized ammonia nitrogen, as shown in Figure 19, range from 0.05 mg/l for white sucker to 0.8 mg/l for a cladoceran.

Chlorine: Mean species acute toxic levels of chlorine for fish, as shown in Figure 20, range from 45 micrograms per liter (μg/l) for pugnose shiner to 267 μg/l for largemouth bass. Mean acute toxic levels for invertebrates range from 76 μg/l for a copepod to 266 μg/l for a scud. Chronic toxic levels of chlorine are shown in Figure 21 for one fish species and two invertebrate species, with the mean levels ranging from 5.3 μg/l for a cladoceran to 17 μg/l for a fathead minnow.

Cyanide: Acute toxic levels of cyanide for fish and invertebrate species are shown in Figure 22. The mean species acute toxic levels for fish lie within a relatively narrow range: from 88 μg/l for rainbow trout to 138 μg/l for bluegill. Mean acute levels for

Figure 19

CHRONIC TOXIC UN-IONIZED AMMONIA NITROGEN LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

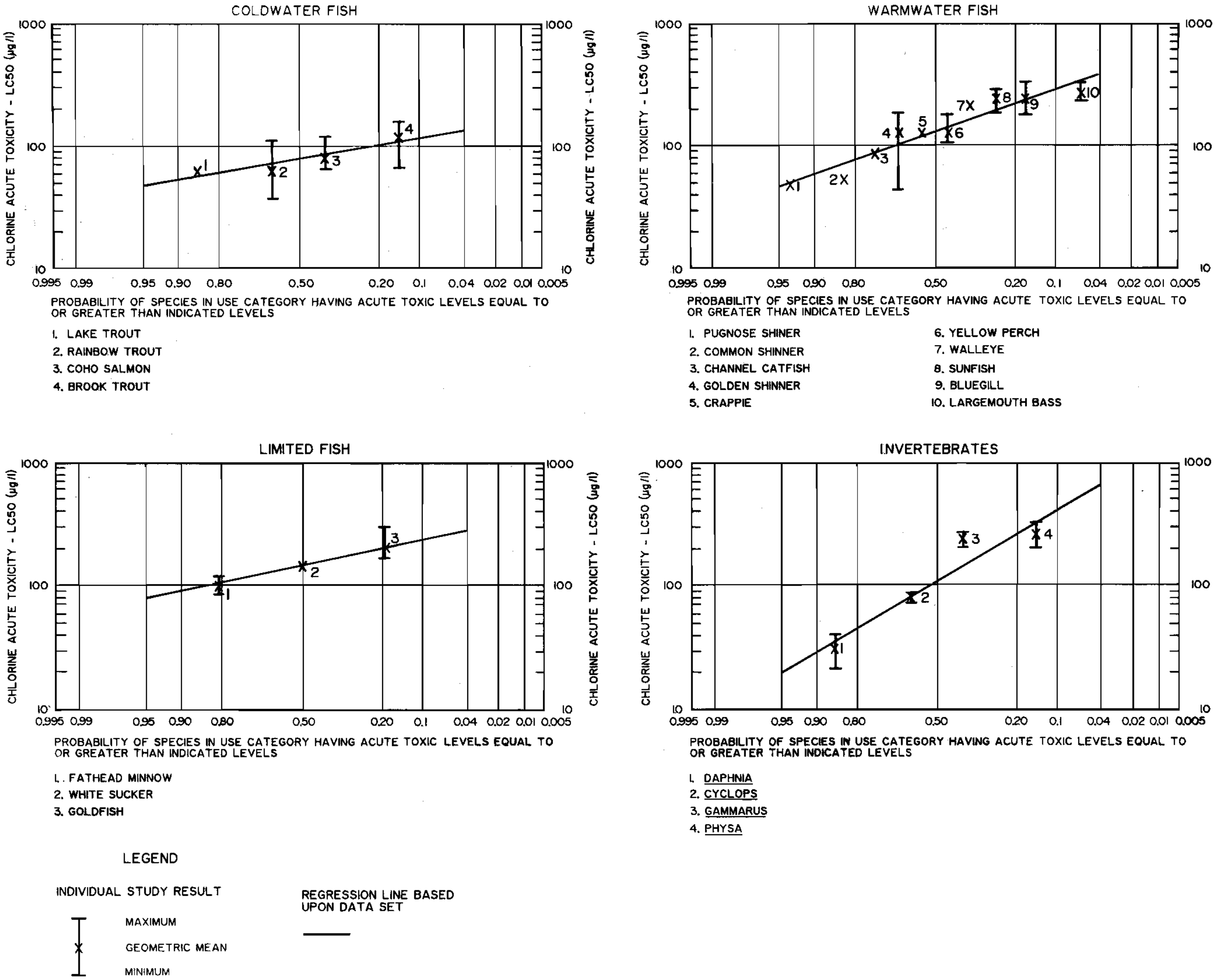
invertebrates are generally higher than those for fish species, ranging from 96 μg/l for a cladoceran to 432 μg/l for a snail. Single chronic toxic values are shown in Figure 23 for three fish species and one invertebrate species. The chronic toxic values range from 7 μg/l for brook trout to 18 μg/l for a scud, an invertebrate.

Polychlorinated Biphenyls (PCB's): Acute toxic levels of PCB's for fish and invertebrate species are shown in Figure 24. The mean species acute toxic levels for fish range from 1.0 μg/l for rainbow trout to 24.7 μg/l for fathead minnow. The acute toxic levels for invertebrates are substantially higher than the toxic levels for fish, ranging from 92 μg/l for a scud to 283 μg/l for damselfly. Mean chronic toxic levels of PCB's for fish range from 0.008 μg/l for channel catfish and bluegill to 0.12 μg/l for white sucker, as shown in Figure 25. Chronic toxic levels for invertebrates range from 0.011 μg/l for a snail to 0.18 μg/l for a scud and for a mosquito.

Arsenic: Acute toxic levels of arsenic for fish and invertebrate species are shown in Figure 26. The mean species acute toxic levels for fish range from 15,000 μg/l for brook trout to nearly 30,000

Figure 20

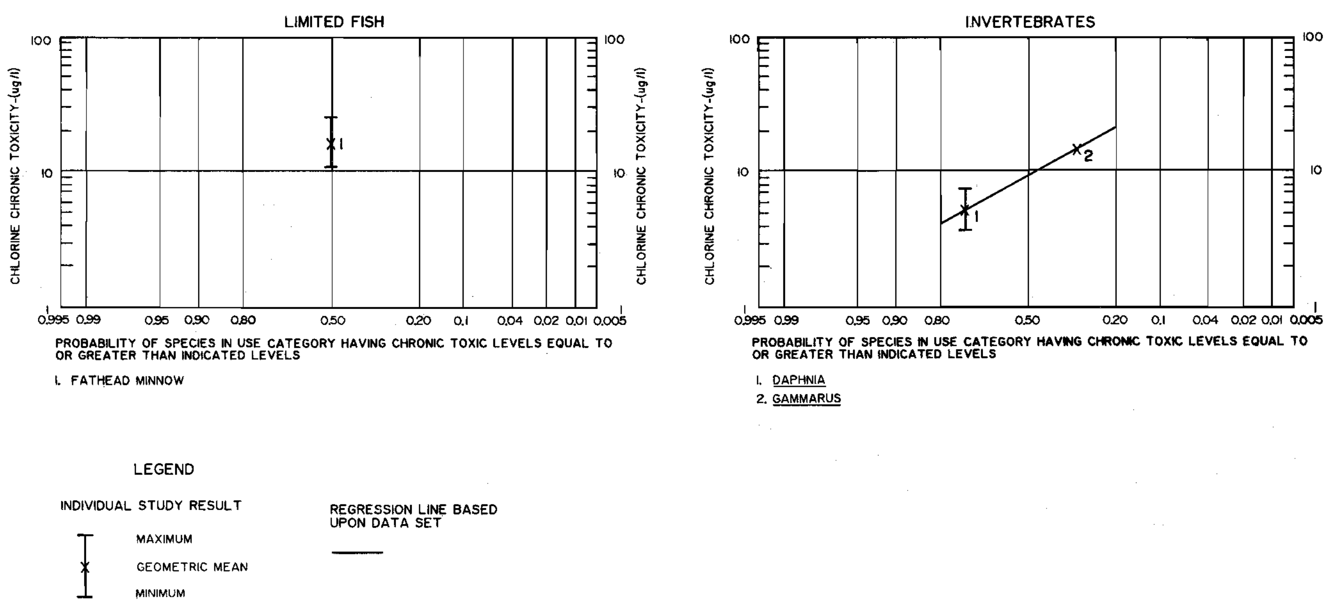
ACUTE TOXIC CHLORINE LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 21

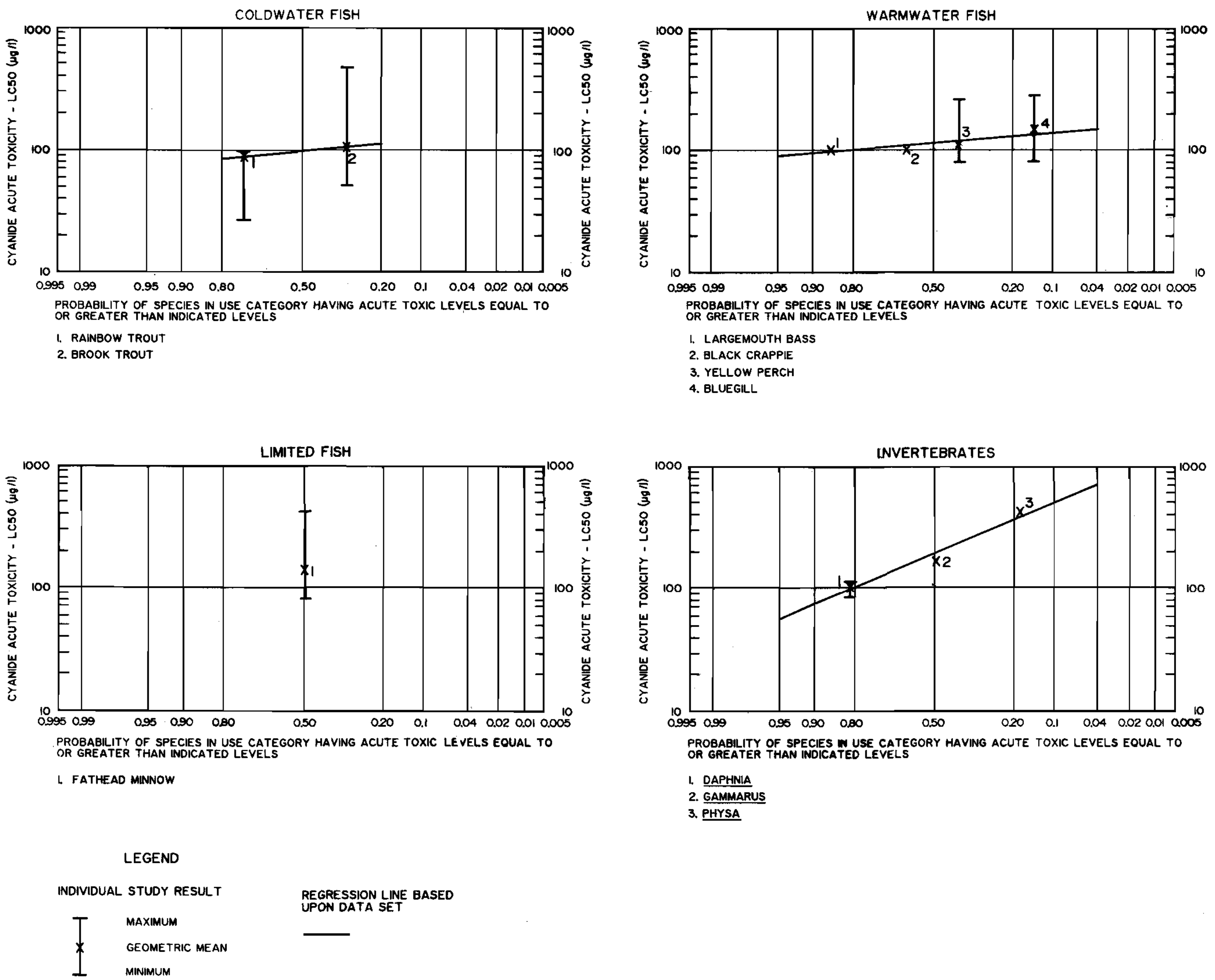
CHRONIC TOXIC CHLORINE LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 22

ACUTE TOXIC CYANIDE LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

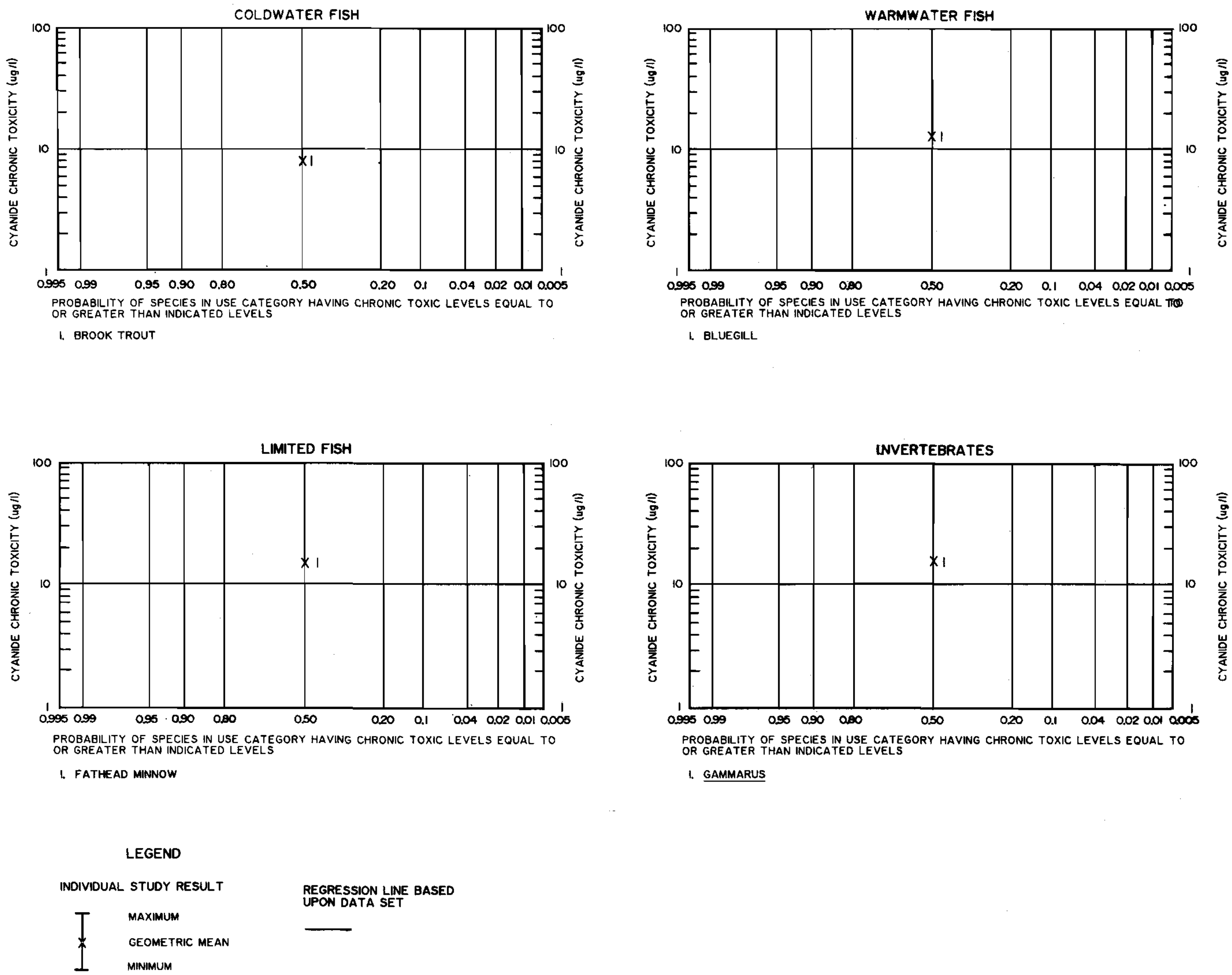
µg/l for goldfish. The invertebrate species tested have substantially lower acute toxic levels of arsenic than do the fish species, with mean species acute levels ranging from 810 µg/l for the cladoceran Simocephalus serrulatus to 1,490 µg/l for another cladoceran, Daphnia pulex. Only one chronic value has been determined for arsenic—that being a level of 3,030 µg/l for fathead minnow.

Cadmium: A relatively large range in mean species acute toxic levels of cadmium is shown in Figure 27 for fish and invertebrates. Mean acute toxic levels for fish range from 1.8 µg/l for chinook salmon to 15,610 µg/l for green sunfish. Coldwater fish species are substantially more sensitive to cadmium than are warmwater or limited fish species. Mean acute toxic levels for invertebrates range from 10.6 µg/l for a cladoceran to 8,400 µg/l for a snail. Mean chronic toxic levels of cadmium for fish range from 1.6 µg/l for chinook salmon to 50 µg/l for bluegill, as shown in Figure 28. Chronic levels for invertebrates generally exceed levels for fish, ranging from 40 µg/l for caddisfly to 977 µg/l for a beetle.

Chromium (Hexavalent): Significant quantities of both hexavalent chromium and trivalent chromium may exist in surface water bodies, and either can be readily converted to the other under appropriate natural conditions. Because the chemical and toxicological properties of the two valence forms are substantially different, and the toxicities of the two forms have not been shown to be additive,

Figure 23

CHRONIC TOXIC CYANIDE LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

acute and chronic toxic levels of hexavalent chromium and trivalent chromium are presented separately herein.

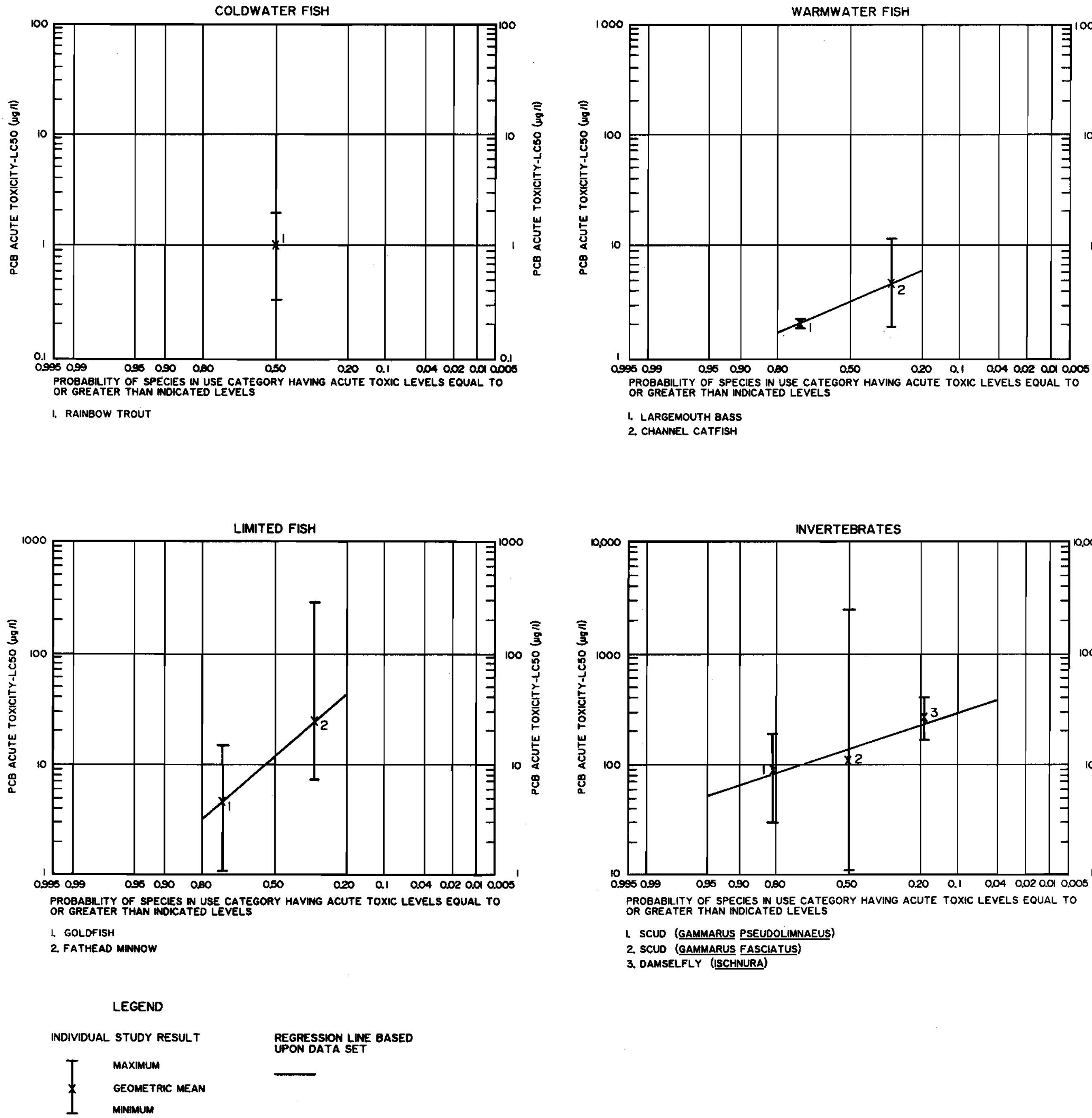
Acute toxic levels of hexavalent chromium are set forth in Figure 29 for fish and invertebrates. The mean species acute toxic levels for fish range from 39,200 μg/l for fathead minnow to 134,200 μg/l for bluegill. Invertebrates are much more sensitive to hexavalent chromium, with the mean species toxic levels ranging from 41 μg/l for a cladoceran to nearly 25,000 μg/l for a snail. Mean species chronic toxic levels of hexavalent chromium, as set forth in Figure 30, range from 61 μg/l for a cladoceran to about 2,000 μg/l for fathead minnow.

Chromium (Trivalent): Figure 31 sets forth acute toxic levels of trivalent chromium for fish and invertebrate species. The mean species acute toxic levels for fish range from 4,100 μg/l for goldfish to 23,100 μg/l for bluegill.

The invertebrate species tested have a relatively large range in mean acute toxic levels—ranging from 2,000 μg/l for mayfly to 64,000 μg/l for

Figure 24

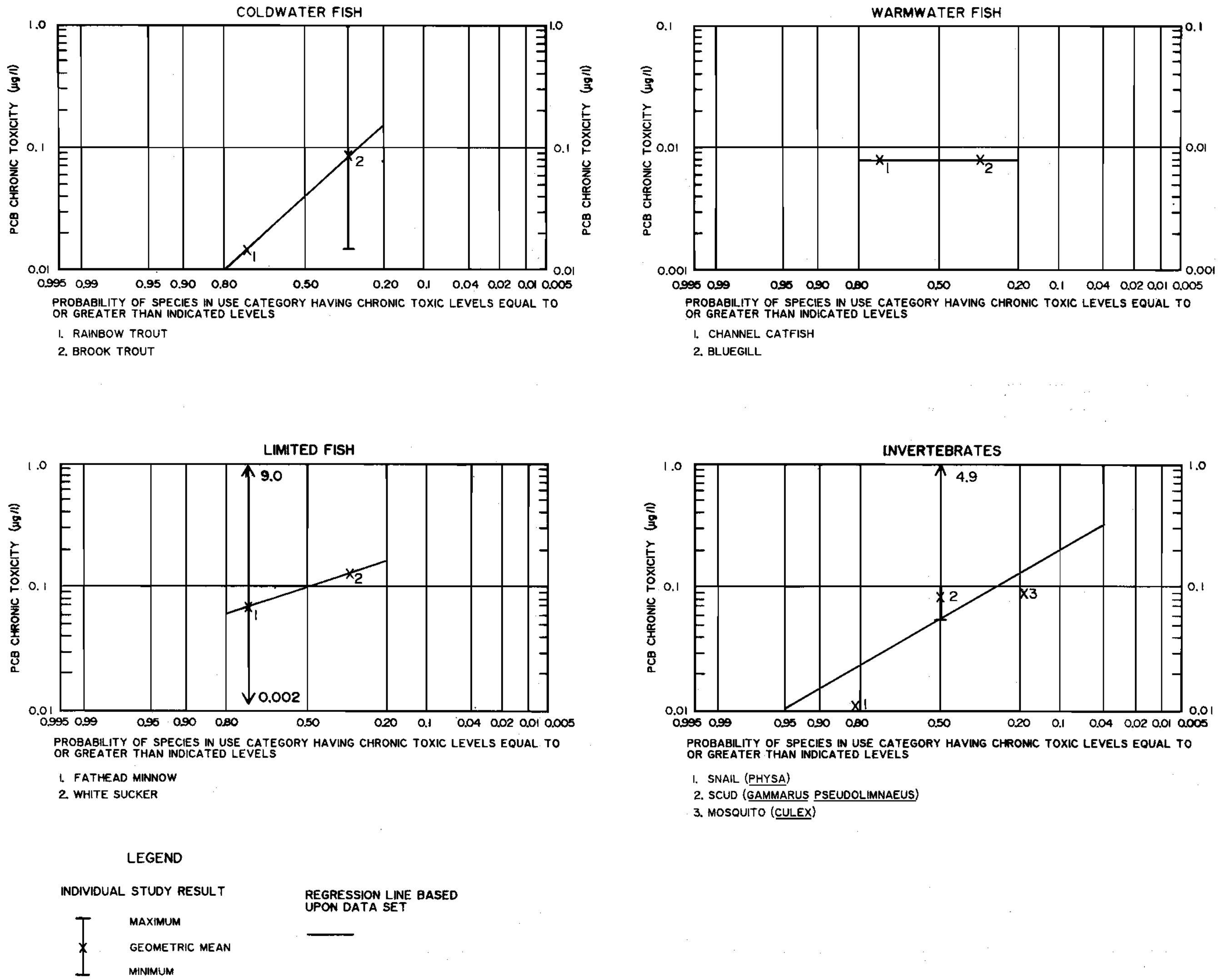
ACUTE TOXIC PCB LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 25

CHRONIC TOXIC PCB LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

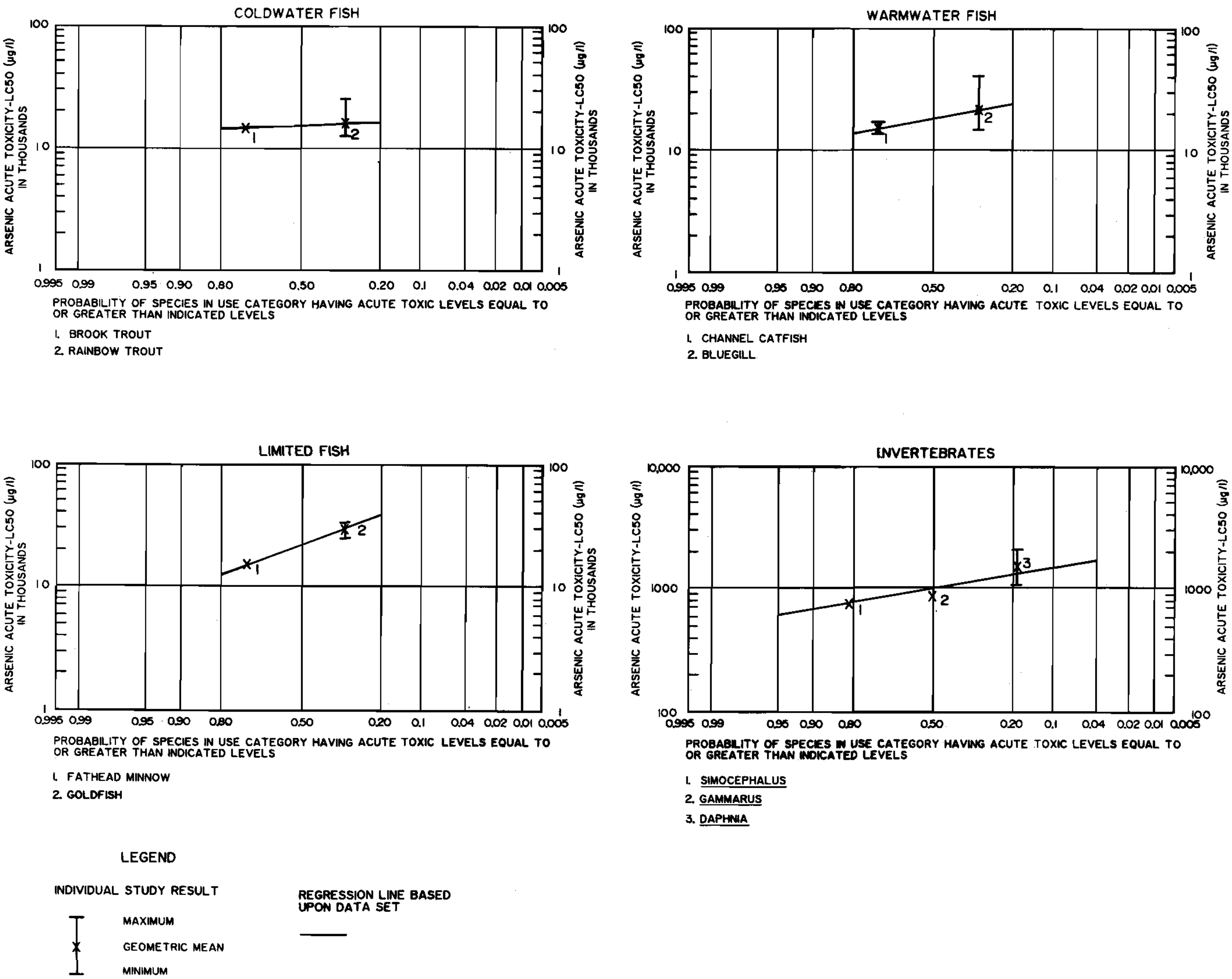
caddisfly. Chronic toxic levels of trivalent chromium are shown for two fish species and one invertebrate species in Figure 32. The chronic toxic levels are highly variable, ranging from 24 µg/l for rainbow trout to 1,020 µg/l for fathead minnow.

Copper: Acute toxic levels of copper are set forth in Figure 33 for fish and invertebrates. The mean species acute toxic levels for fish range from 32 µg/l for chinook salmon to 4,200 µg/l for American eel. For invertebrates, the mean species acute toxic levels range from 22 µg/l for a cladoceran to 8,300 µg/l for stonefly. Mean species chronic toxic levels of copper for fish, as set forth in Figure 34, range from 8.8 µg/l for bluntnose minnow to 60 µg/l for northern pike. Chronic toxic levels of copper are also shown for two invertebrate species: scud, with a chronic toxic level of 6.1 µg/l, and a snail, with a level of 10.9 µg/l.

Lead: Figure 35 sets forth acute toxic levels of lead for fish and invertebrate species. The mean species acute toxic levels for fish range from 5,200 µg/l for fathead minnow to 103,500 µg/l for bluegill. An invertebrate species—a scud—has the lowest mean acute level of 132 µg/l, although other invertebrates have relatively high acute levels, such as a rotifer with a mean acute level of 40,800 µg/l.

Figure 26

ACUTE TOXIC ARSENIC LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Mean chronic toxic levels of lead, as set forth in Figure 36, range from 25 μg/l for a snail to 350 μg/l for northern pike.

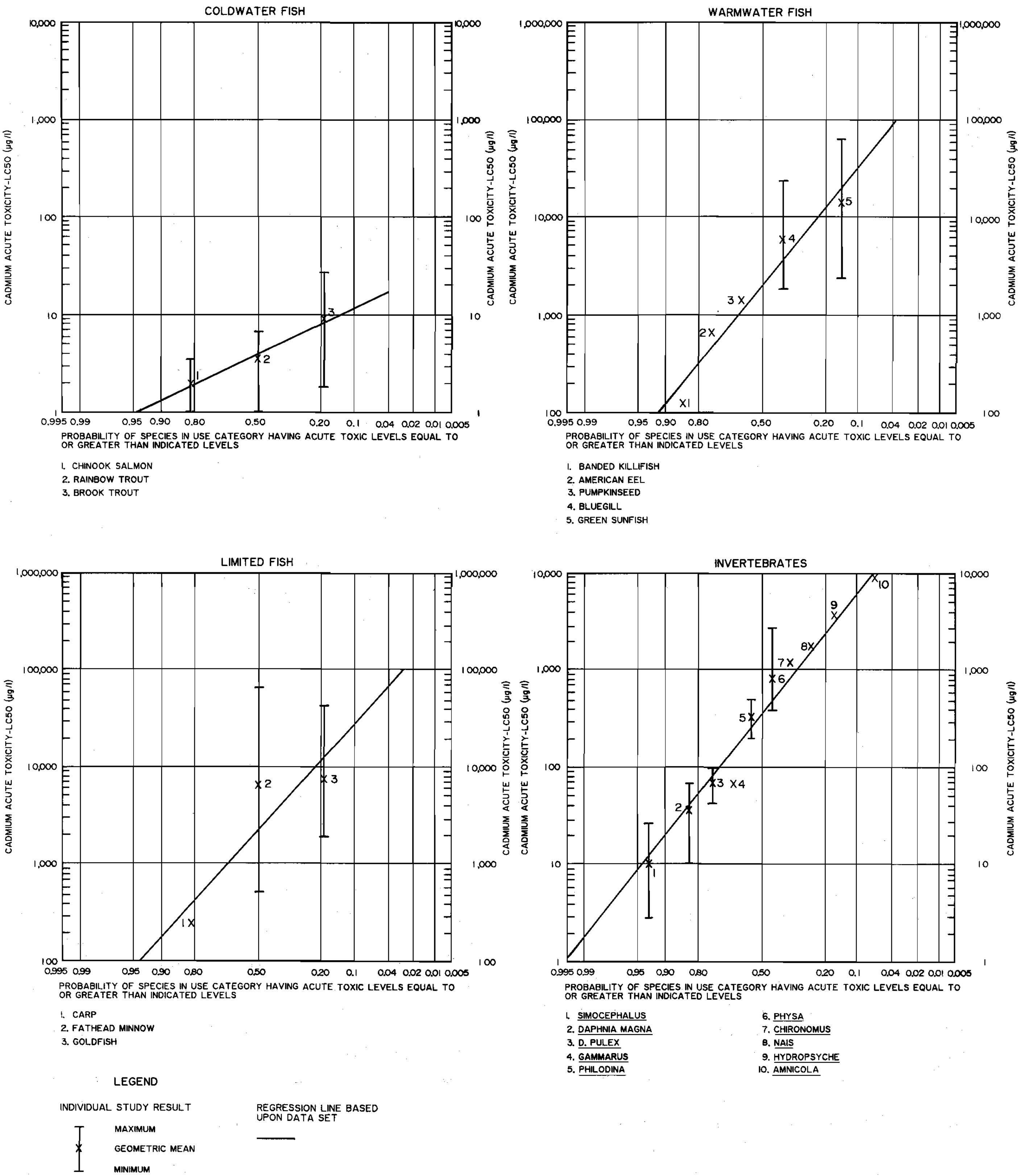
Mercury: Figure 37 sets forth acute toxic levels of mercury for fish and invertebrates. Mean species acute toxic levels for fish range from 160 μg/l for bluegill to 254 μg/l for rainbow trout. For invertebrates, the mean species acute toxic levels range from 2.4 μg/l for a cladoceran to 2,000 μg/l for both stonefly and mayfly. Chronic toxic levels of mercury are shown in Figure 38 for fathead minnow, with a mean toxic level of 1.2 μg/l, and for a cladoceran, with a mean toxic level of 1.3 μg/l.

Nickel: Figure 39 sets forth acute toxic levels of nickel for fish and invertebrate species. Mean species acute toxic levels for fish range from 2,500 μg/l for rock bass to 46,000 μg/l for banded killifish. For invertebrates, the mean acute toxic levels range from 2,300 μg/l for a cladoceran to 33,500 μg/l for stonefly. Chronic toxic levels of nickel are shown in Figure 40 for two fish species and one invertebrate species. The mean species chronic levels range from 86 μg/l for a cladoceran to 350 μg/l for rainbow trout.

Selenium: Acute toxic levels of selenium are set forth in Figure 41 for fish and invertebrates. The

Figure 27

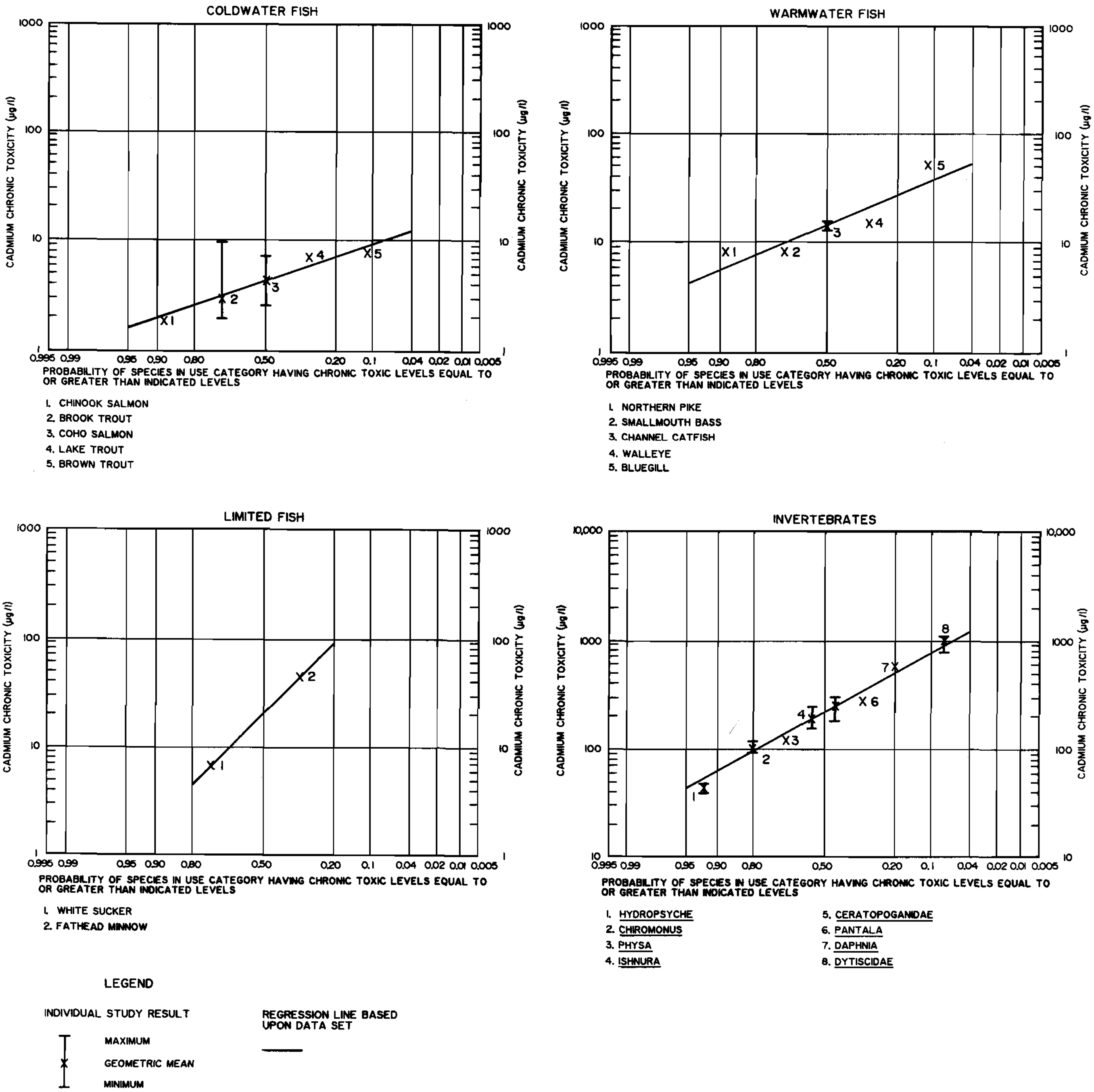
ACUTE TOXIC CADMIUM LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 28

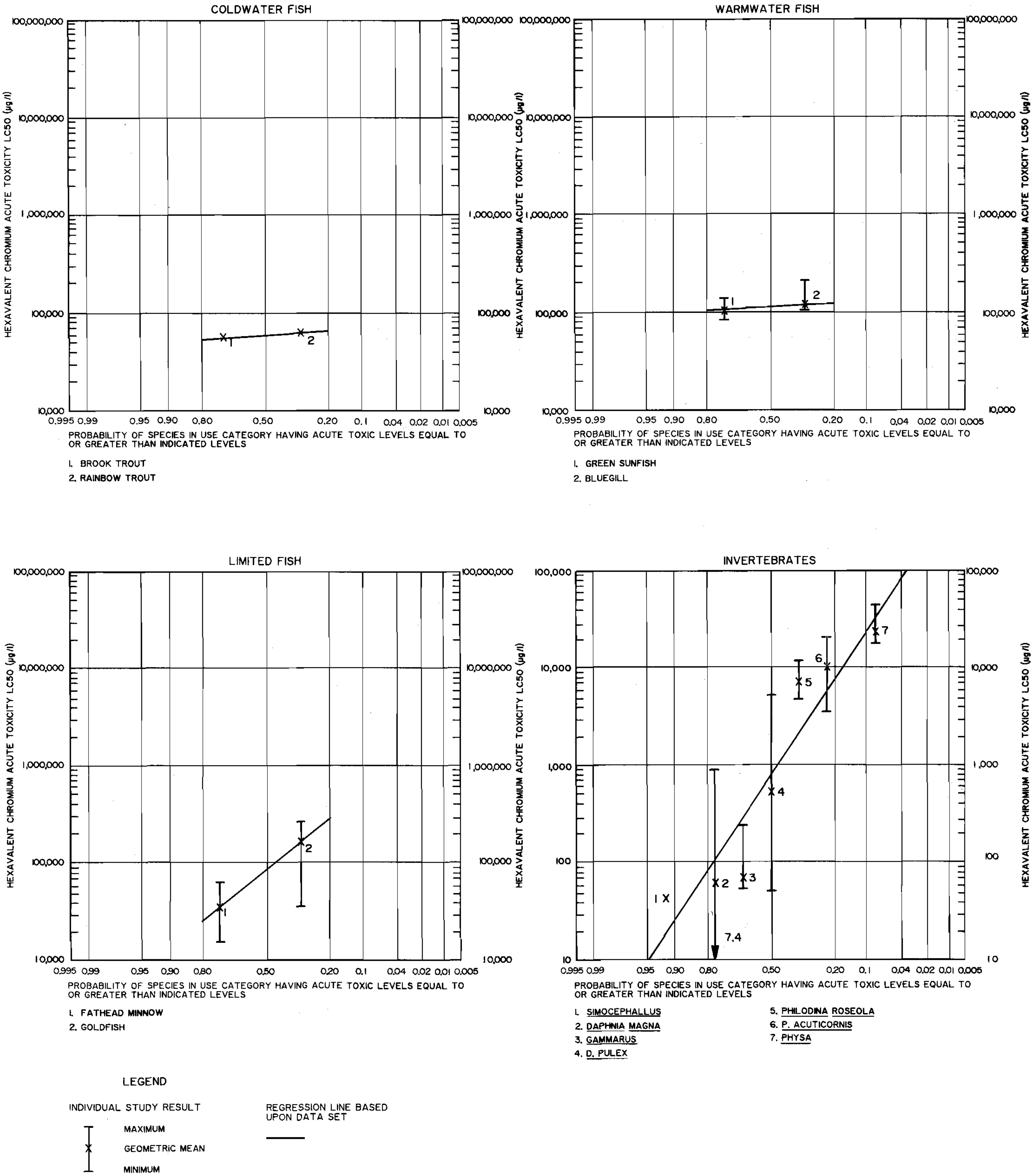
CHRONIC TOXIC CADMIUM LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 29

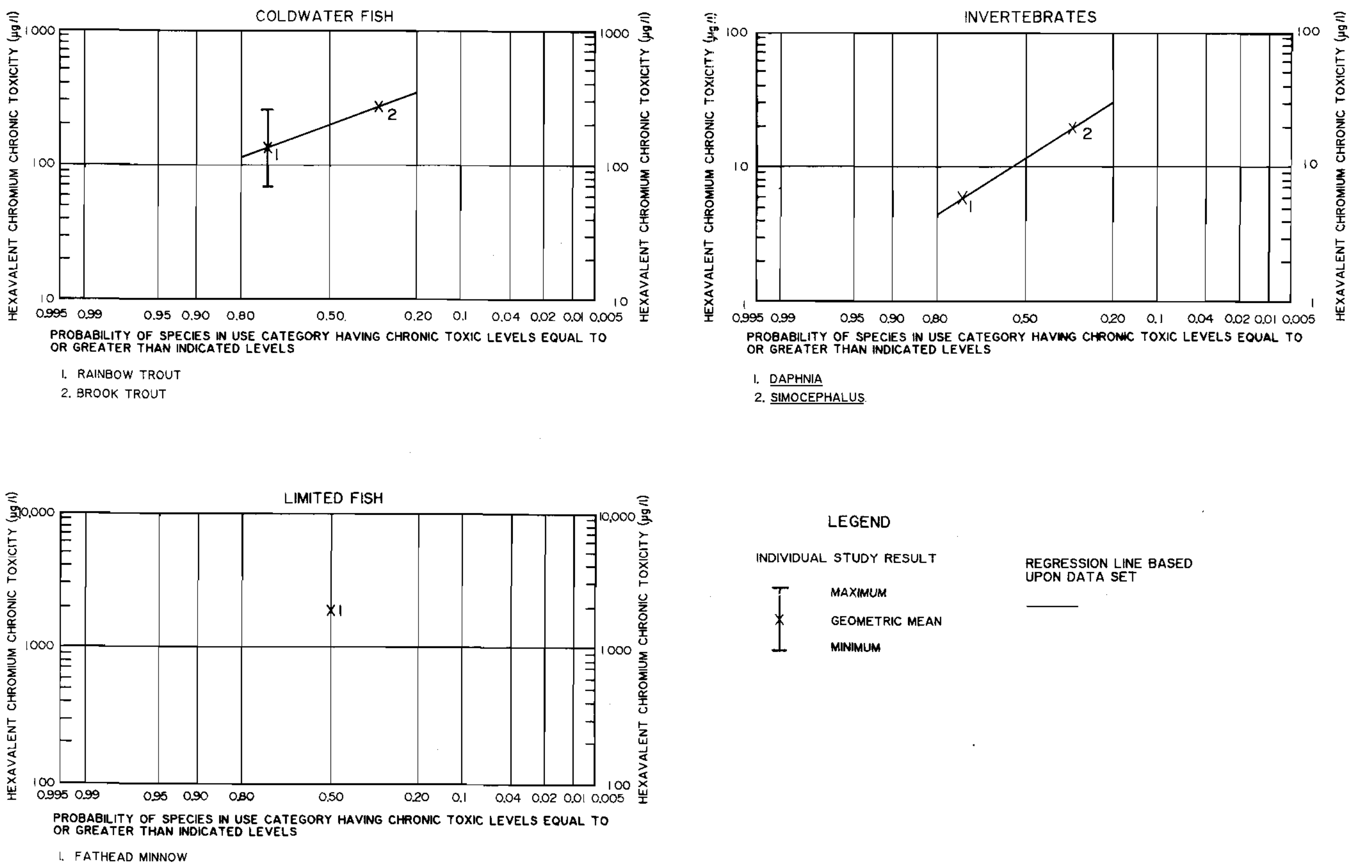
ACUTE TOXIC HEXAVALENT CHROMIUM LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 30

CHRONIC TOXIC HEXAVALENT CHROMIUM LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

mean species acute toxic levels for fish range from 3,100 μg/l for fathead minnow to 35,000 μg/l for carp. For invertebrates, the mean species acute toxic levels range from 340 μg/l for a scud to 24,100 μg/l for a snail. Chronic toxic levels of selenium are shown in Figure 42 for two fish species and two invertebrate species, ranging from 88 μg/l for rainbow trout to 690 μg/l for a cladoceran.

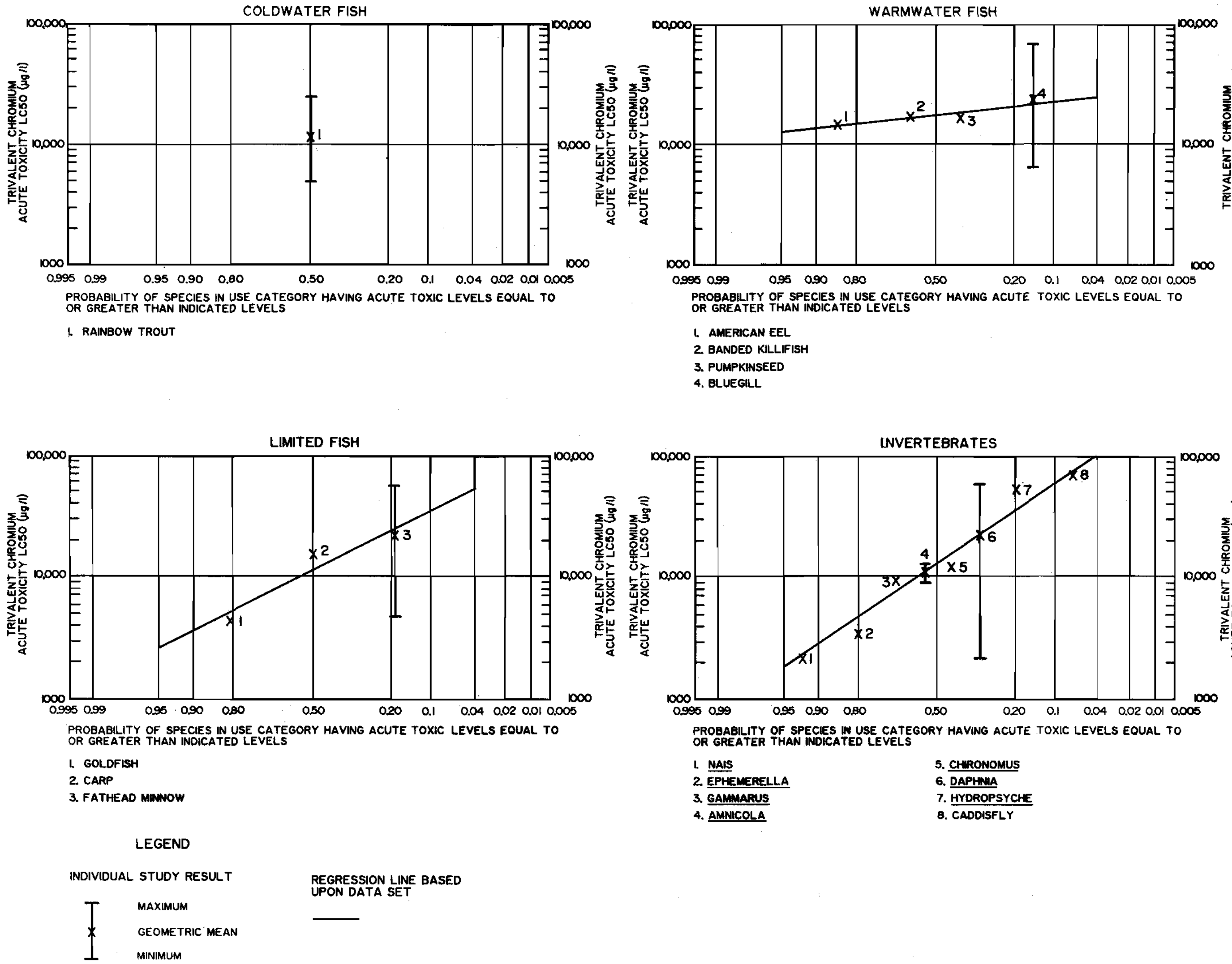
Silver: Acute toxic levels of silver are set forth in Figure 43 for fish and invertebrates. The mean species acute toxic levels for fish range from 3.8 μg/l for carp to 64 μg/l for bluegill. For invertebrates, the mean species acute toxic levels vary substantially, ranging from 2.3 μg/l for a cladoceran to 4,500 μg/l for a scud. Chronic toxic levels of silver are shown in Figure 44 for rainbow trout, with a mean chronic toxic level of 12 μg/l, and for a cladoceran, with a mean chronic toxic level of 7.9 μg/l.

Zinc: Acute toxic levels of zinc are set forth in Figure 45 for fish and invertebrates. The mean species acute toxic levels for fish range from 72 μg/l for chinook salmon to 20,000 μg/l for pumpkinseed. For invertebrates, the mean species acute toxic levels range from 370 μg/l for a cladoceran to 58,000 μg/l for caddisfly. Mean species chronic toxic criteria for zinc, as shown in Figure 46, range from 71 μg/l for a cladoceran to 850 μg/l for brook trout.

Application of Recommended Water Quality Standards: Historically, water quality standards were applied based upon the belief that water pollution was essentially a dry-weather, low-streamflow problem. This belief was based on analyses of streamwater quality conditions affected by sewage treatment plant discharges. Such plants normally discharge sewage effluent at a relatively constant rate and quality, thereby causing the most severe water quality problems when receiving

Figure 31

ACUTE TOXIC TRIVALENT CHROMIUM LEVELS FOR FISH AND INVERTEBRATES



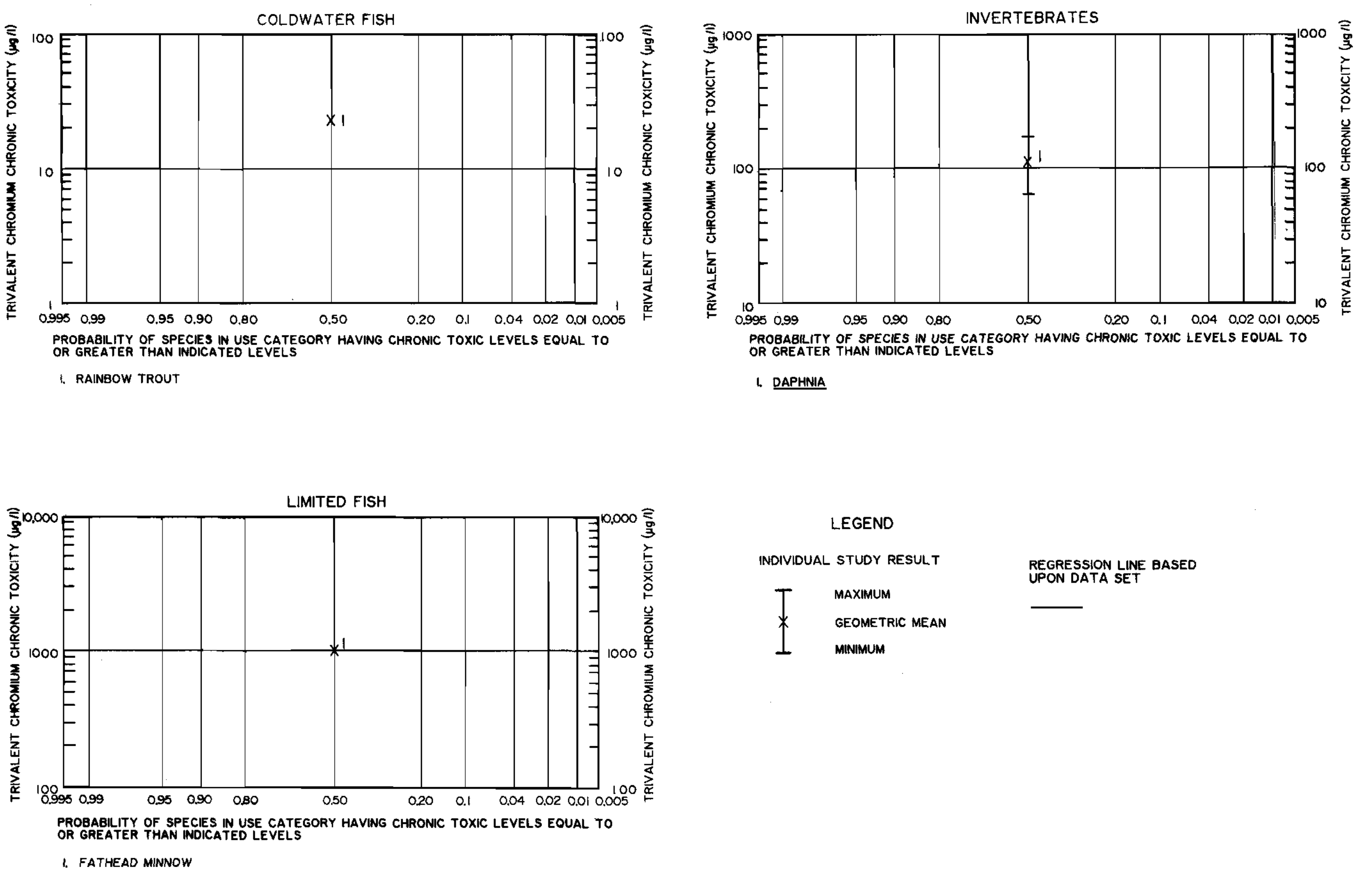
Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

streamflows are low. The Wisconsin Department of Natural Resources currently requires that all instream water quality standards be met during all but the very lowest flow conditions, such conditions being defined as flows less than the 7-day average, 1-in-10-year recurrence interval low flow.

Under the Commission regional water quality management planning program, however, it was determined that a probabilistic approach to the application of certain water quality standards, whereby the percent of time a given standard should be allowed to be violated would be specified, would allow the assessment and resolution of water quality problems during high-flow as well as low-flow conditions. Accordingly, analyses were conducted to determine the percent of the time certain standards should be allowed to be violated except under specified conditions. A 95 percent compliance level was selected as the criterion for meeting the water quality standards for some parameters which directly affect desirable forms of aquatic life; namely, dissolved oxygen, temperature, and pH. A 90 percent compliance level was

Figure 32

CHRONIC TOXIC TRIVALENT CHROMIUM LEVELS FOR FISH AND INVERTEBRATES



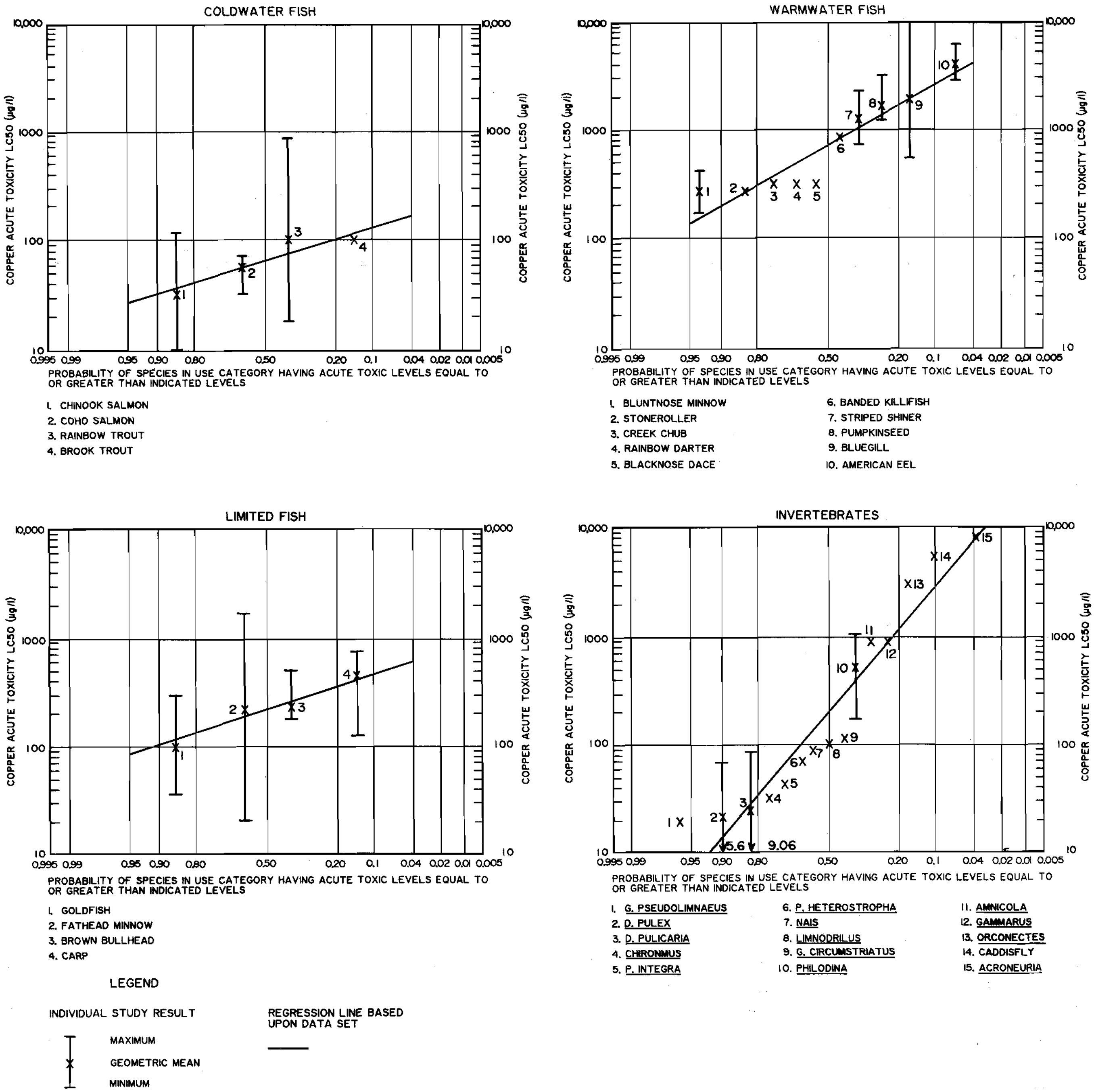
Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

selected as the criterion for parameters which do not directly affect desirable forms of aquatic life; namely, phosphorus and fecal coliform organisms. The analyses indicated that if these compliance levels were always met other than during periods of extreme low-flow conditions, the duration of the violation could be expected to be relatively short and the intensity of the violation to be relatively low, so that desirable uses and forms of aquatic life should not be adversely affected. Furthermore, the analyses indicated that even those surface waters which currently support full recreational uses and healthy fish and aquatic life communities often do not meet applicable water quality standards at all times. Thus, some level of violation of the standards was considered acceptable.

This probabilistic approach to water quality standards application was also used in the preparation of the Milwaukee Harbor estuary plan as a supplement to the current exemption in the standards for flow conditions lower than the 7-day average, 1-in-10-year recurrence interval low flow. The probabilistic compliance level approach was not applied to those parameters for which seasonal standards or standards based on acute and chronic toxic criteria were developed. For dissolved oxygen, 30-day mean, 7-day mean, 1-day mean, and absolute minimum standards are presented, some of which are applicable on a seasonal basis. For residual chlorine and un-ionized ammonia nitrogen, as well as for the 13 parameters set forth in Table 9, 30-day mean maximum values—based on chronic toxicity—and absolute maximum

Figure 33

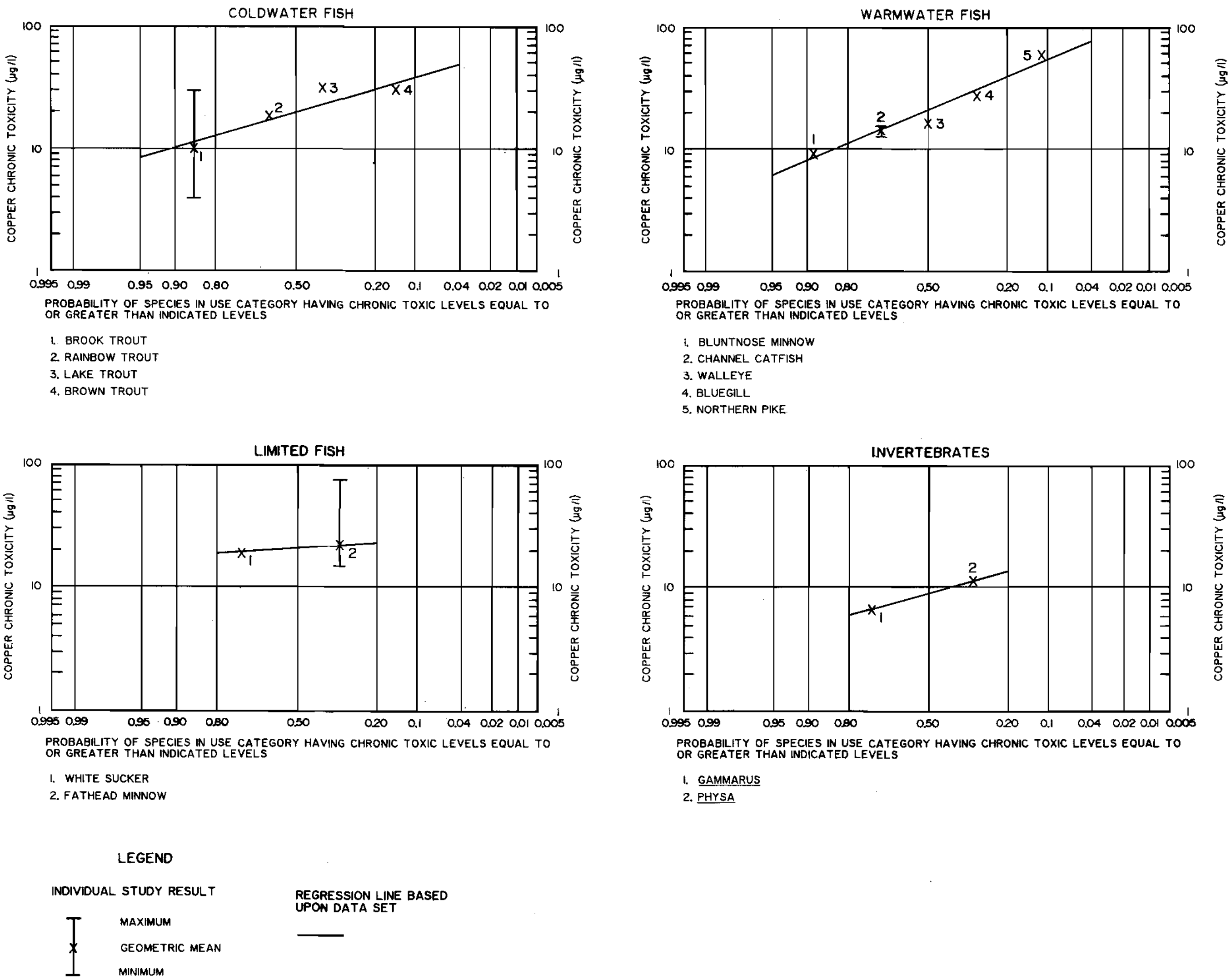
ACUTE TOXIC COPPER LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 34

CHRONIC TOXIC COPPER LEVELS FOR FISH AND INVERTEBRATES



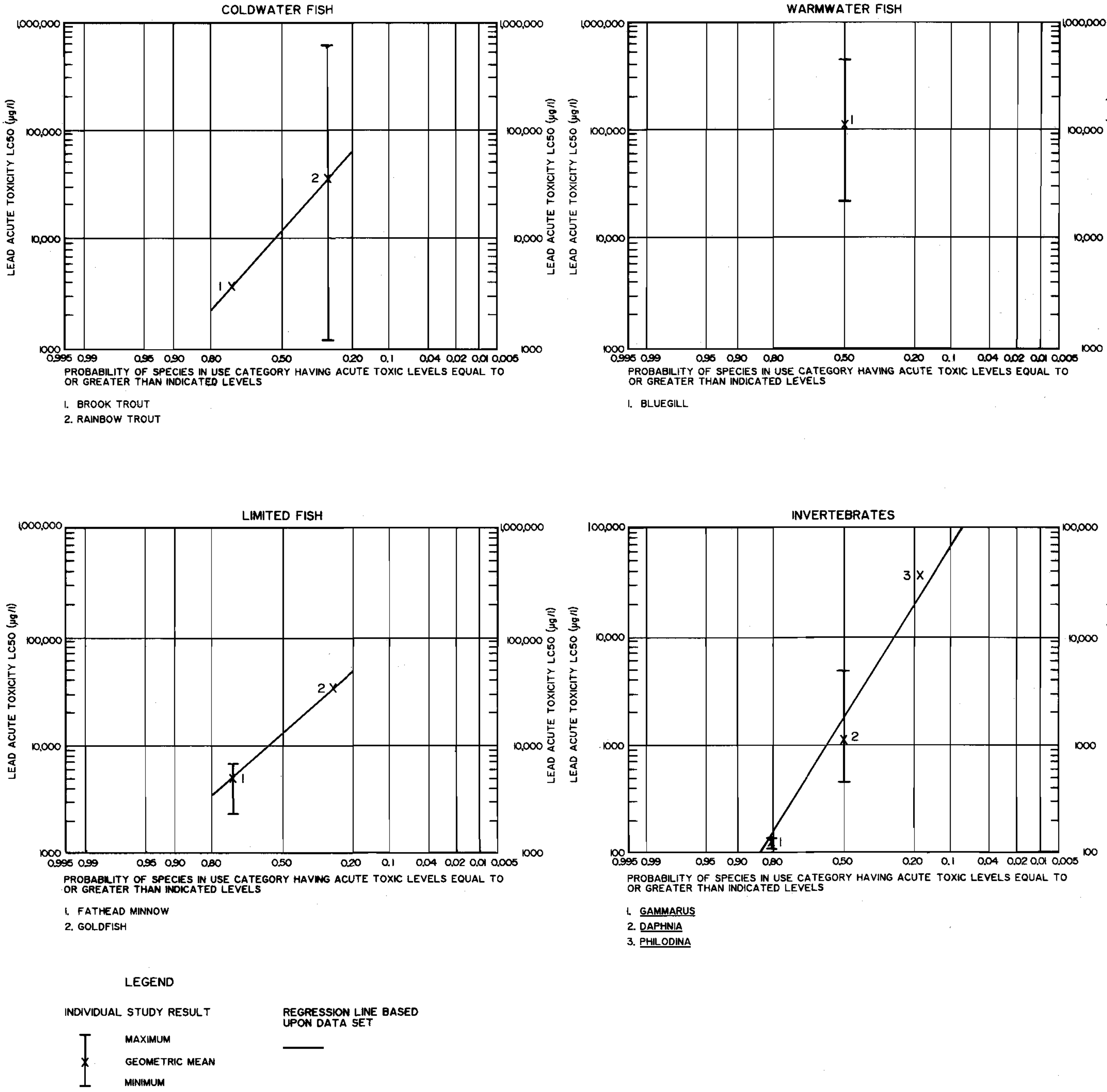
Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

values—based on acute toxicity—are presented. The application of such standards and criteria is specified in Tables 5 and 9, and no further probabilistic compliance level procedure is necessary.

Planning Standards: It should be noted that the planning standards herein recommended for adoption fall into two groups: comparative and absolute. The comparative standards, by their very 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 as aids not only in the development, test, and evaluation of water quality management, water control facility, and recreation and park and open space plans, but also in the development, test, and evaluation of local water resource management plans and in the development of plan implementation policies and programs.

Figure 35

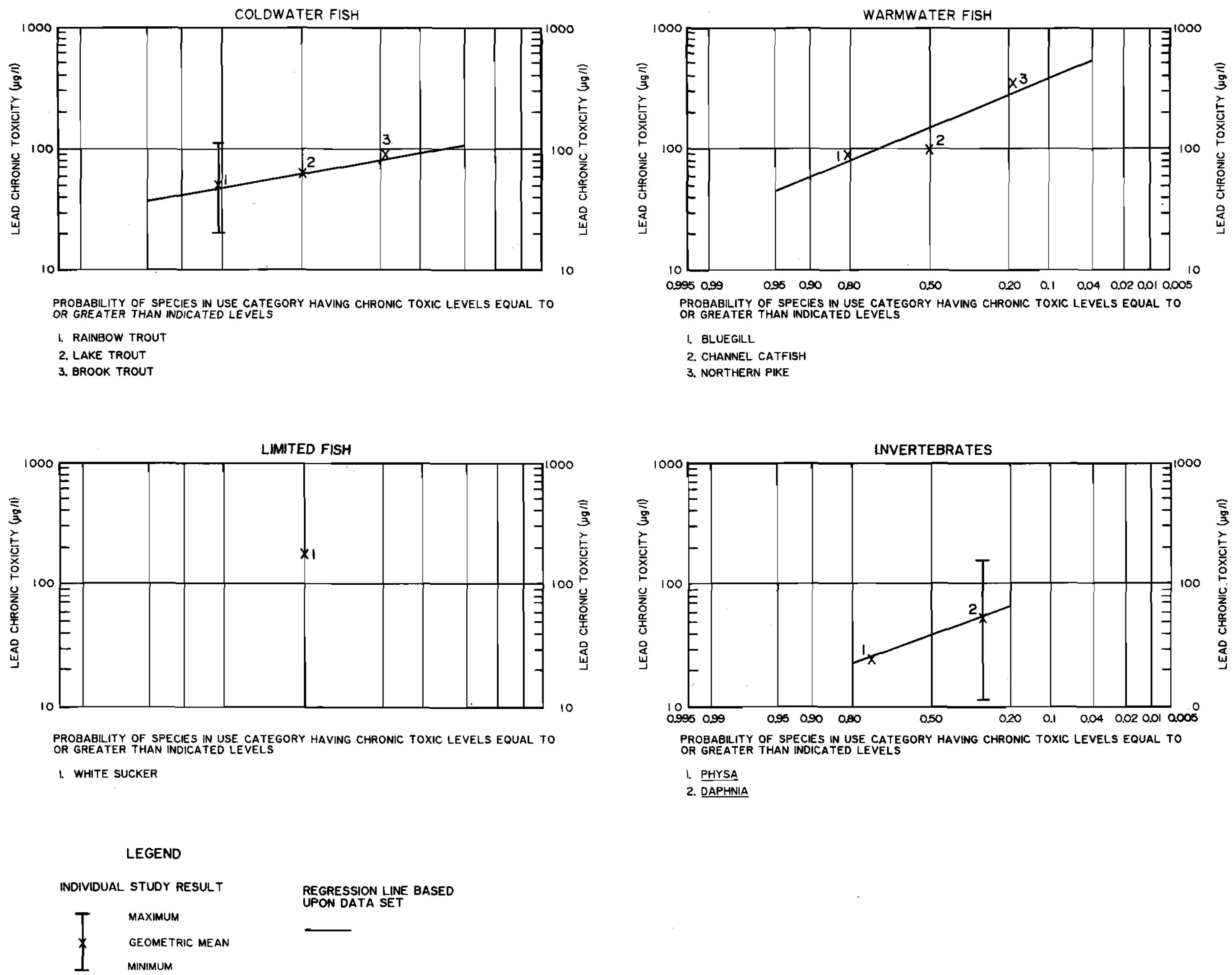
ACUTE TOXIC LEAD LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 36

CHRONIC TOXIC LEAD LEVELS FOR FISH AND INVERTEBRATES

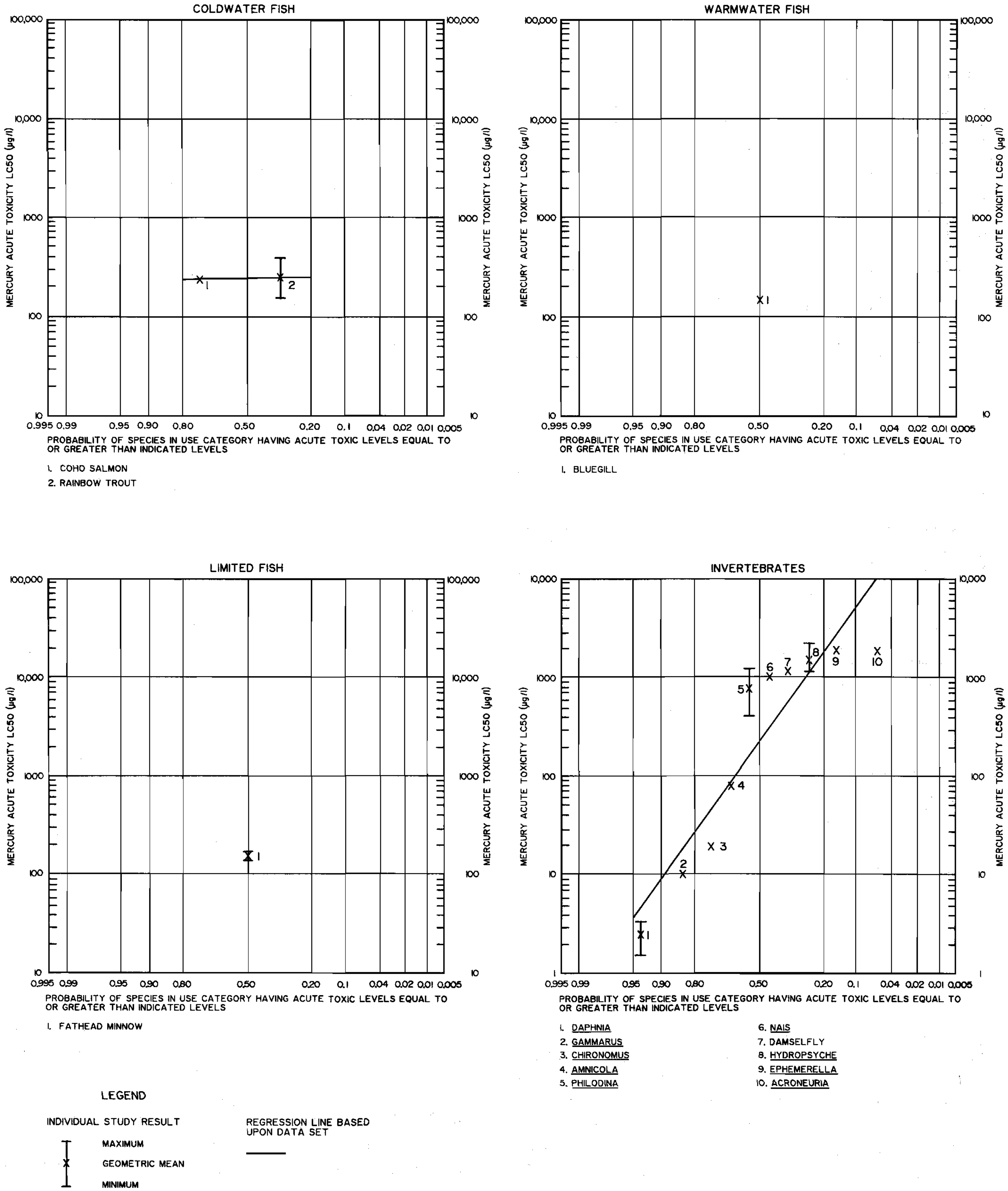


Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Overriding Considerations: When applying the water resource management objectives, principles, and standards to the plan elements, 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 through application of these objectives and standards alone, however, to assure such system integration, since the objectives and 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 planning and engineering techniques developed for this purpose—such as hydrologic, hydraulic, and water quality simulation—to quantitatively test the potential performance of the proposed facilities as part of a total system. Second, it must be recognized that it is unlikely that any one plan proposal will meet all the standards completely. Thus, the extent to which each standard is met, exceeded, or violated must serve as a

Figure 37

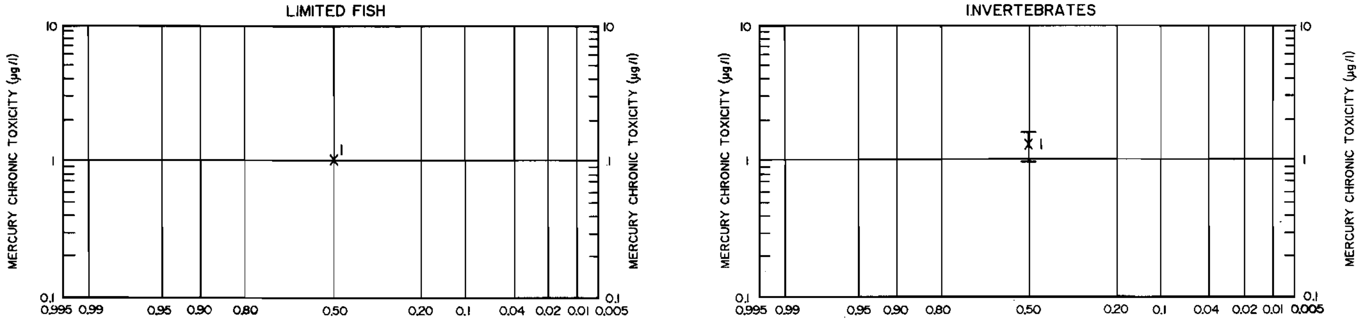
ACUTE TOXIC MERCURY LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 38

CHRONIC TOXIC MERCURY LEVELS FOR FISH AND INVERTEBRATES



Limited fish:
1. FATHEAD MINNOW

Invertebrates:
1. DAPHNIA

LEGEND

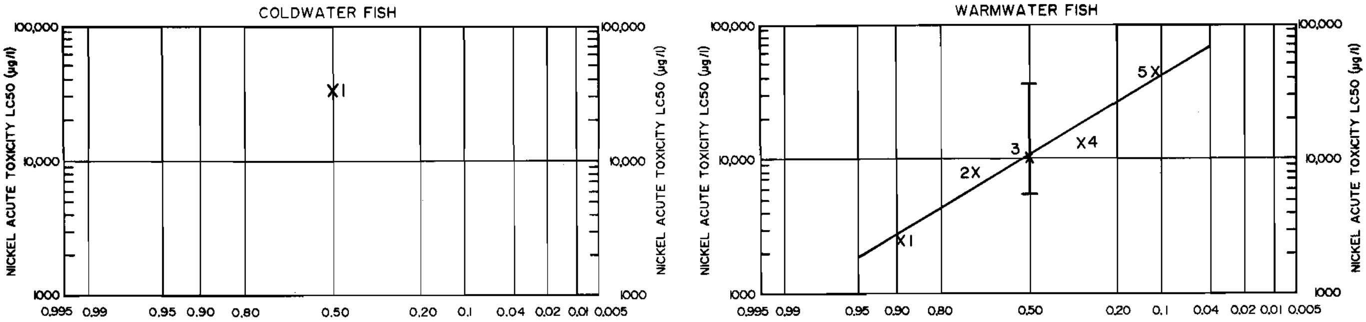
INDIVIDUAL STUDY RESULT: MAXIMUM, GEOMETRIC MEAN, MINIMUM

REGRESSION LINE BASED UPON DATA SET

Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

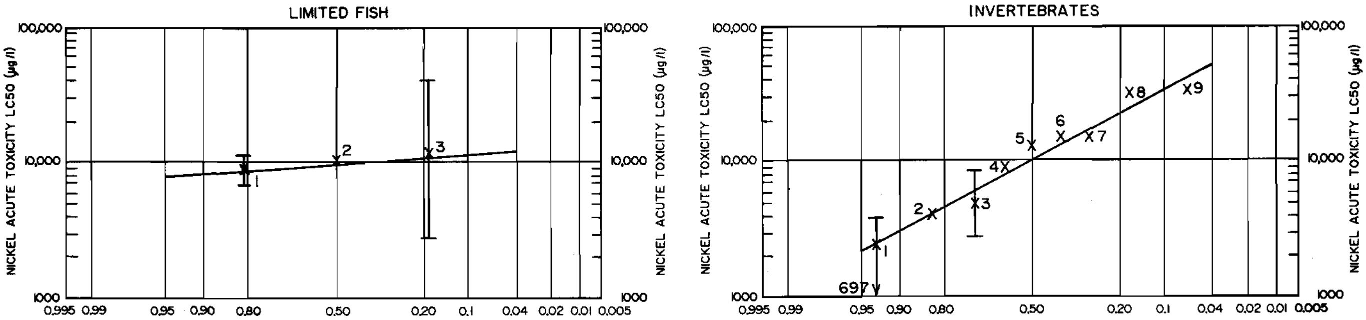
Figure 39

ACUTE TOXIC NICKEL LEVELS FOR FISH AND INVERTEBRATES



Coldwater fish:
1. RAINBOW TROUT

Warmwater fish:
1. ROCK BASS
2. PUMPKINSEED
3. BLUEGILL
4. AMERICAN EEL
5. BANDED KILLIFISH



Limited fish:
1. CARP
2. GOLDFISH
3. FATHEAD MINNOW

Invertebrates:
1. DAPHNIA
2. EPHEMERELLA
3. PHILODINA
4. CHIRONOMUS
5. GAMMARUS
6. NAIS
7. AMNICOLA
8. CADDISFLY
9. ACRONEURIA

LEGEND

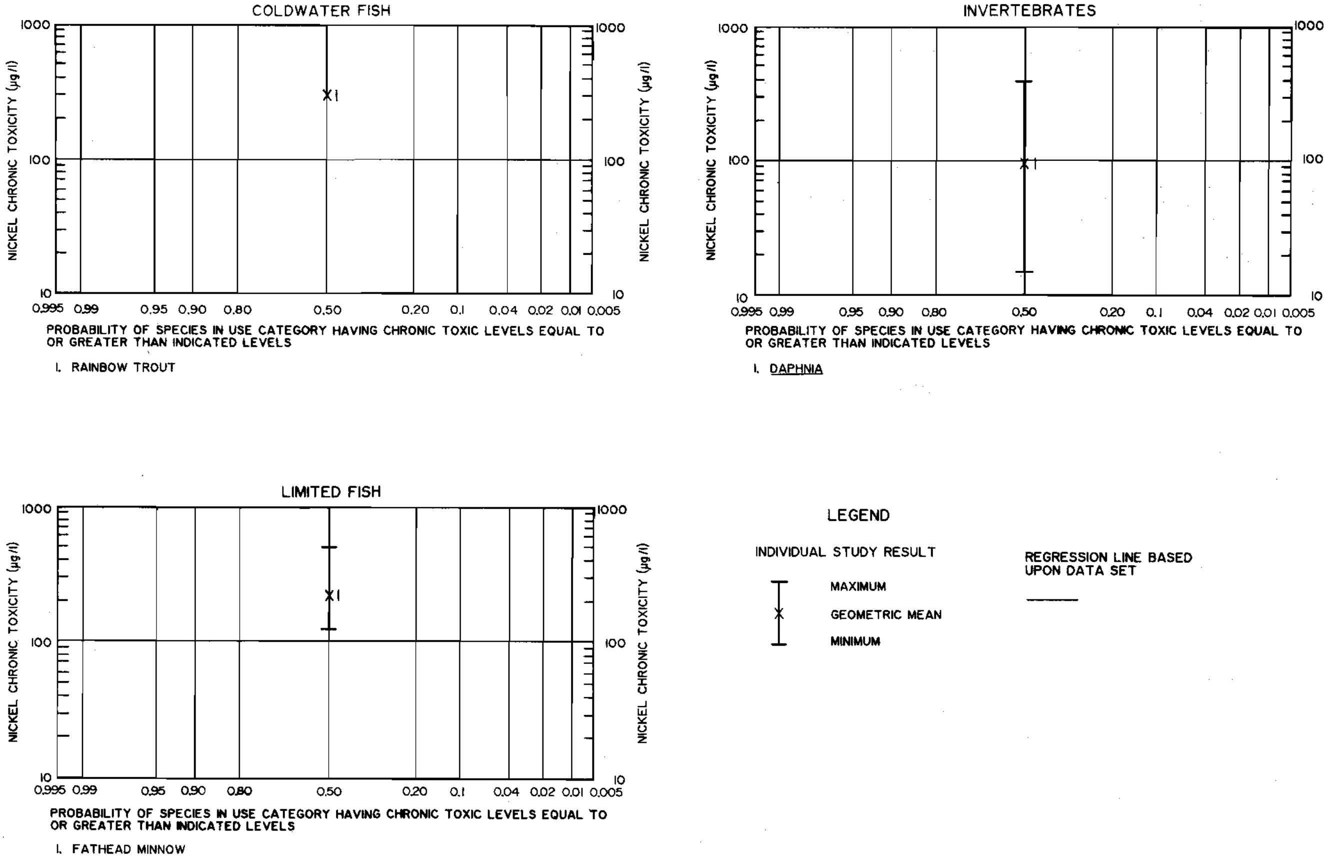
INDIVIDUAL STUDY RESULT: MAXIMUM, GEOMETRIC MEAN, MINIMUM

REGRESSION LINE BASED UPON DATA SET

Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 40

CHRONIC TOXIC NICKEL LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

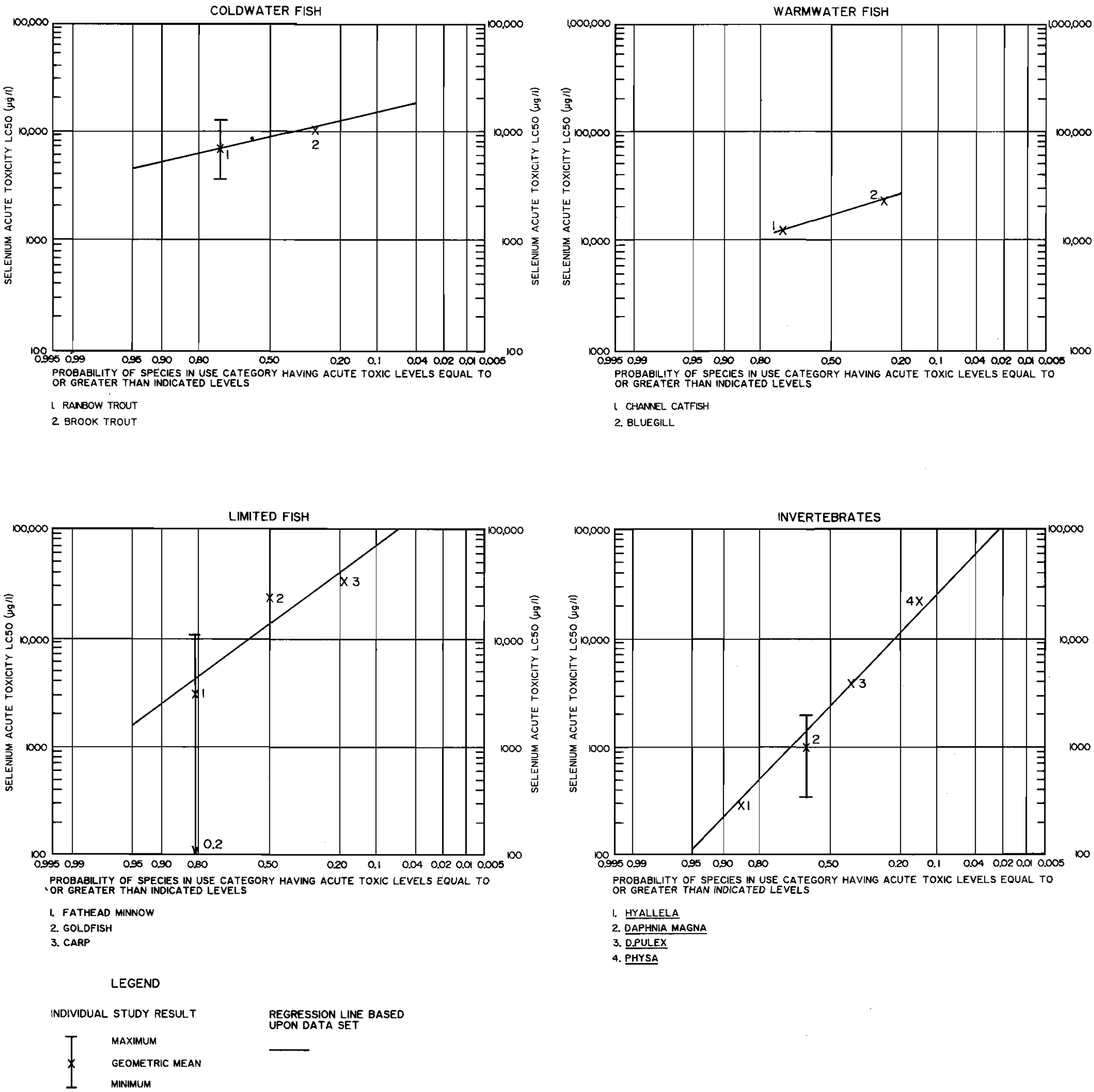
measure of the ability of each alternative plan proposal to achieve the specific objective which the given standard complements. Third, it must be recognized that certain objectives may be in conflict and that such conflict will require resolution through compromise. Such compromise is an essential part of any design effort. The degree to which the recommended Milwaukee Harbor estuary water resource management plan meets the adopted objectives and standards is discussed in Chapter VII of this volume.

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 this Milwaukee Harbor estuary plan must advance water resources management proposals that are technically effective, physically feasible, economically sound, and conducive to the achievement of water use objectives. Agreement on water resource management

Figure 41

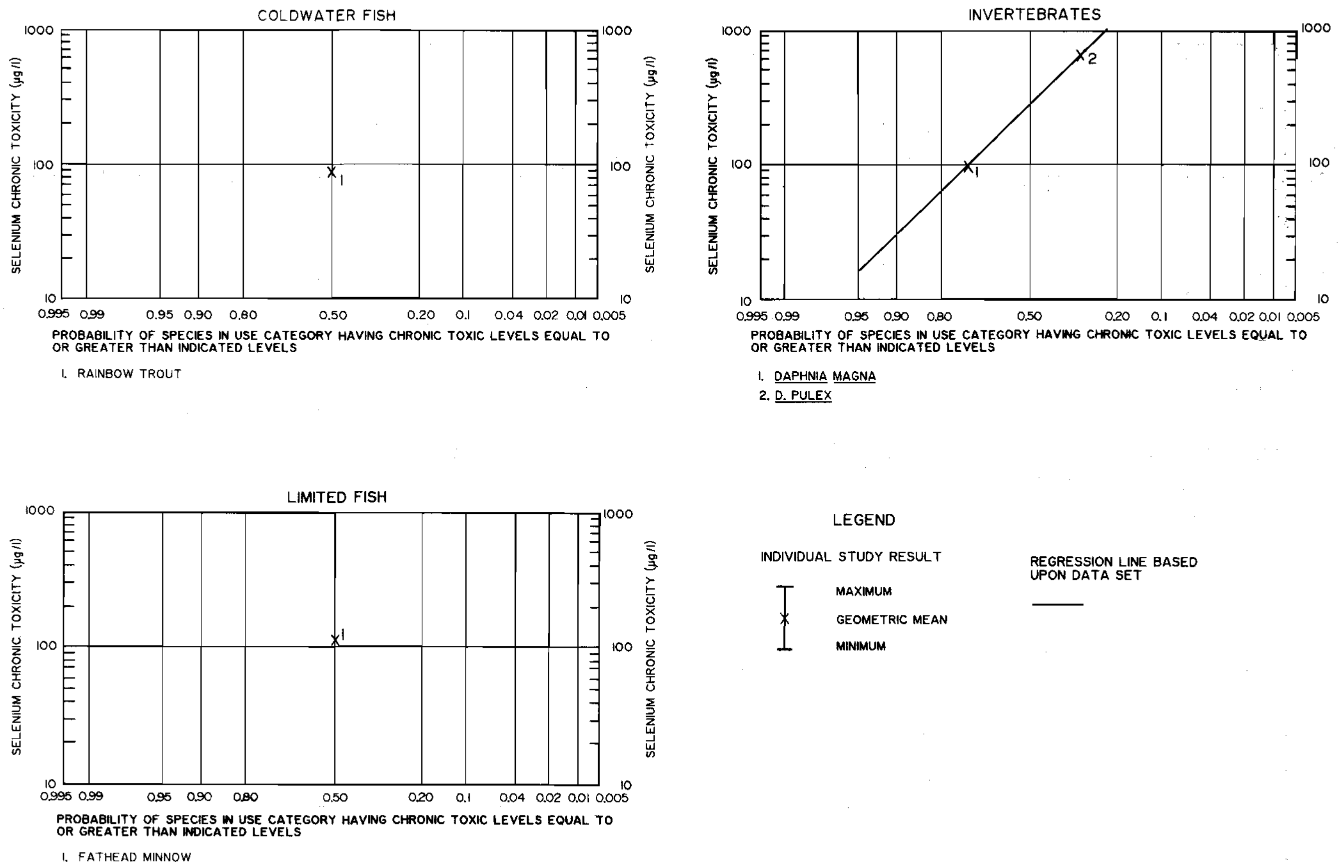
ACUTE TOXIC SELENIUM LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 42

CHRONIC TOXIC SELENIUM LEVELS FOR FISH AND INVERTEBRATES



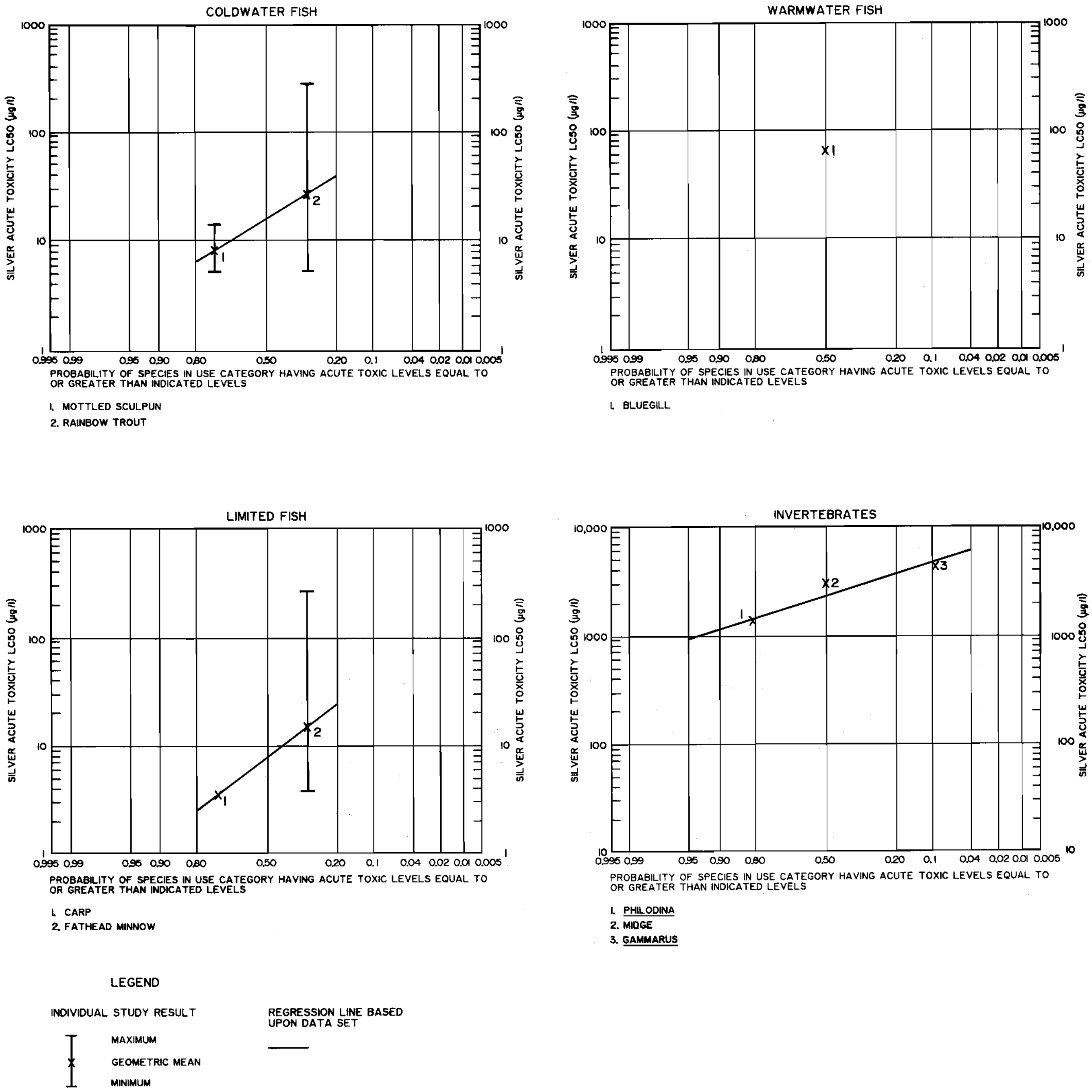
Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

objectives beyond such generalities, however, becomes more difficult to achieve because the definition of specific management objectives and supporting standards inevitably involves value judgments. Nevertheless, it is essential to state such objectives for the management of water resources, and to quantify them, insofar as possible, through standards in order to provide the framework within which water resource management plans for the Milwaukee Harbor estuary can be prepared.

Moreover, so that the Milwaukee Harbor estuary plans will form an integral part of the overall long-range plans for the physical development of the Region, the water resource management objectives for the estuary must be compatible with, and dependent upon, those regional development objectives which affect the Milwaukee Harbor estuary direct drainage area. Therefore, the water resource management objectives and supporting principles and standards set forth herein are based upon, and

Figure 43

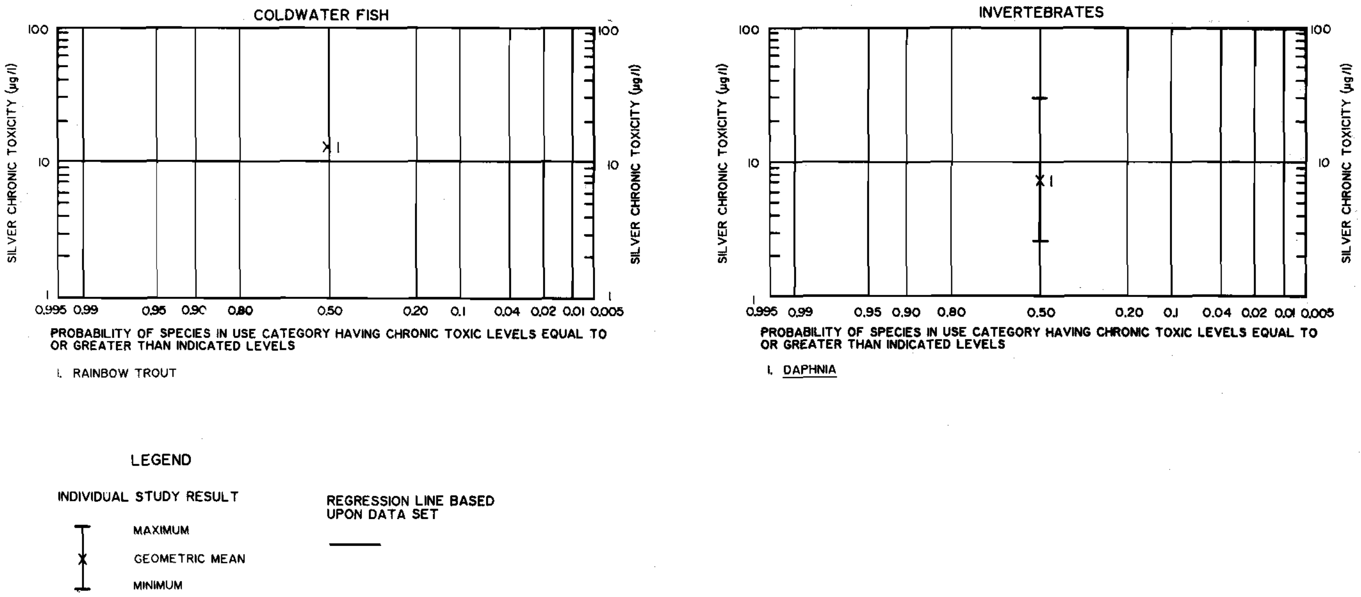
ACUTE TOXIC SILVER LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 44

CHRONIC TOXIC SILVER LEVELS FOR FISH AND INVERTEBRATES



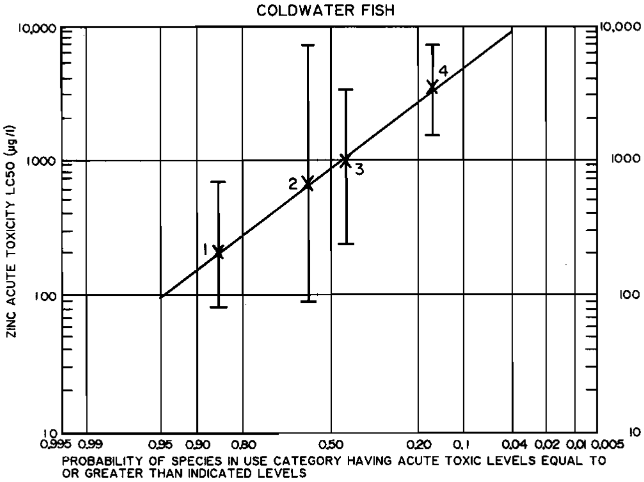
Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

incorporated into, certain previously adopted regional development objectives, supplementing these as required to meet the specific needs of the Milwaukee Harbor estuary planning program.

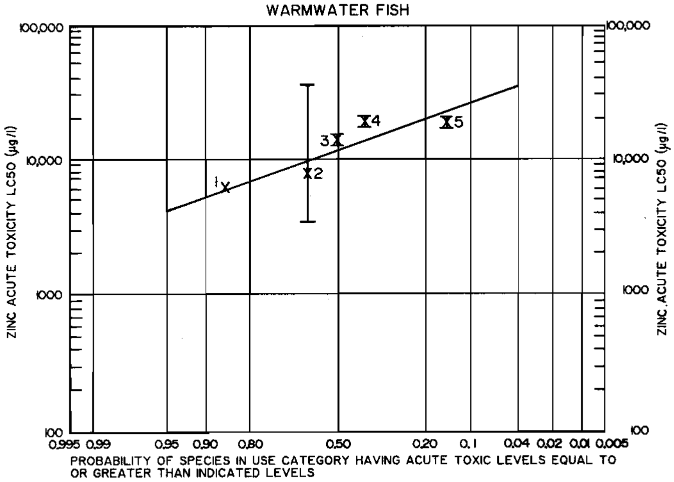
The adopted water resource management objectives for the Milwaukee Harbor estuary plan consist of all five of the water quality management objectives adopted by the Commission under its regional water quality management planning program; one recreation objective adopted by the Commission under its regional park and open space planning program; and one water control facility development objective adopted by the Commission under its comprehensive watershed planning programs. These regional objectives are directly applicable to water resource management in the Milwaukee Harbor estuary. In addition, two new water control facility development objectives were formulated under the Milwaukee Harbor estuary planning program. Together, these objectives and supporting principles and standards provided the basic framework within which alternative water resource management plans were formulated and evaluated and a recommended water resource management plan synthesized.

Figure 45

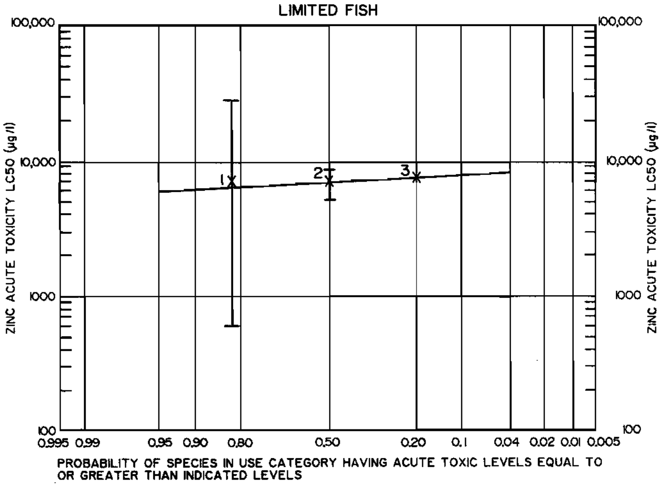
ACUTE TOXIC ZINC LEVELS FOR FISH AND INVERTEBRATES



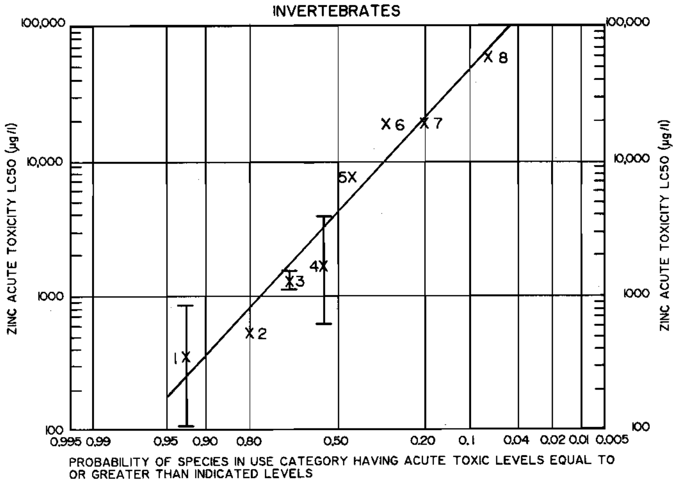
1. CHINOOK SALMON
2. RAINBOW TROUT
3. COHO SALMON
4. BROOK TROUT



1. GOLDEN SHINER
2. BLUEGILL
3. AMERICAN EEL
4. BANDED KILLIFISH
5. PUMPKINSEED



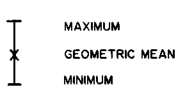
1. FATHEAD MINNOW
2. GOLDFISH
3. CARP



1. DAPHNIA MAGNA
2. D. PULEX
3. PHILODINA
4. PHYSA
5. GAMMARUS
6. CHIRONOMUS
7. NAIS
8. CADDISFLY

LEGEND

INDIVIDUAL STUDY RESULT

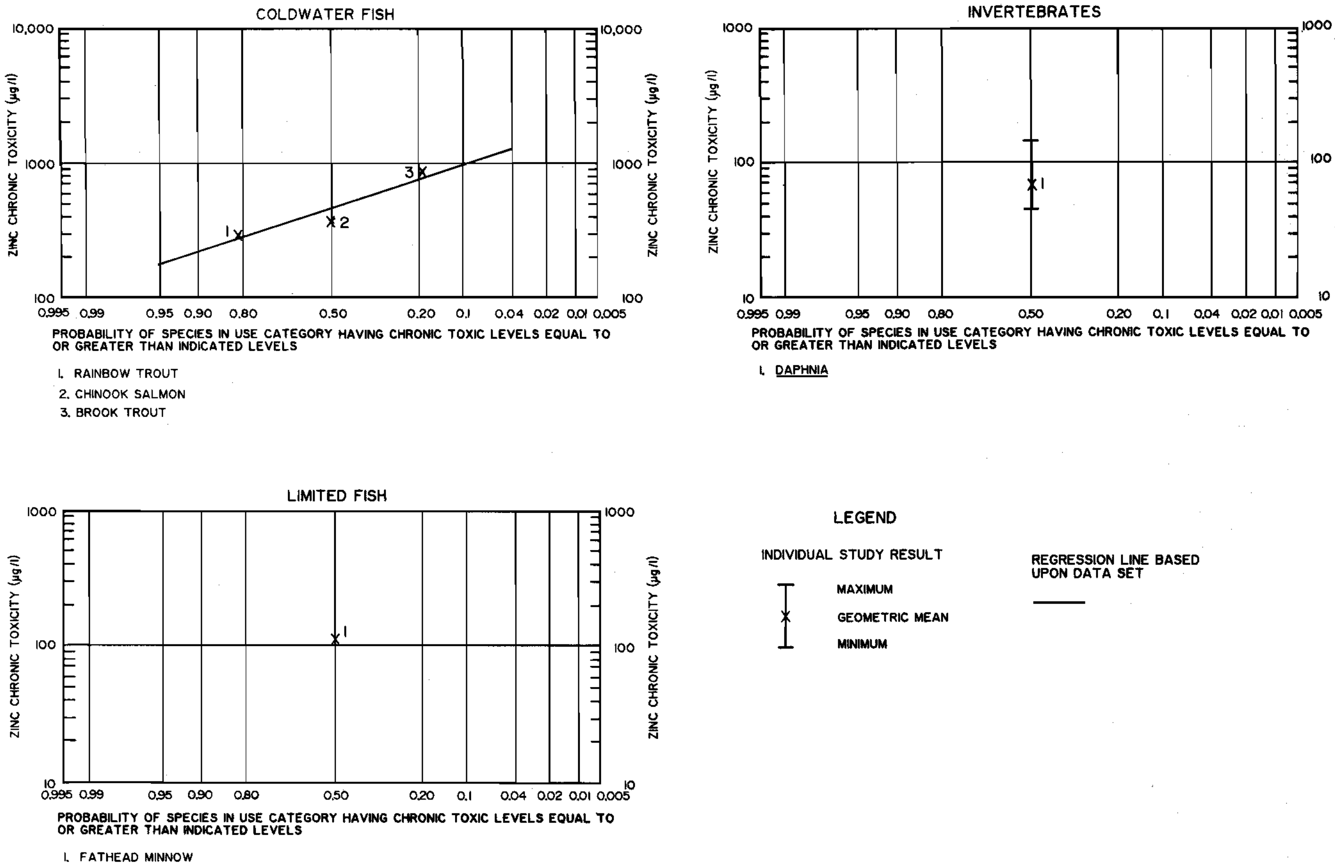


REGRESSION LINE BASED UPON DATA SET

Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 46

CHRONIC TOXIC ZINC LEVELS FOR FISH AND INVERTEBRATES



Source: U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

Chapter III

ANTICIPATED GROWTH AND CHANGE

INTRODUCTION

In any comprehensive planning effort, forecasts are required of all future events and conditions which are considered to lie outside the scope of the plans to be prepared, but which affect either the design of the plans or their implementation. Normally, the future demand for the natural resources in a planning area is determined primarily by the size and spatial distribution of future population and employment levels. In the study concerned, the issues involved are further complicated by the influx of a large number of daily commuters and, intermittently, of participants in and spectators of special entertainment events held in the portion of the planning area of primary concern—the Milwaukee estuary direct drainage area. Although the spatial distribution of future population and employment levels can be influenced by public land use regulation, control of changes in population and economic activity levels per se lies largely outside the scope of governmental activity at the regional and local levels. In the preparation of a comprehensive water resource and water resource-related plan, therefore, future population and economic activity levels must be forecast. These forecasts can then be converted to future demand for water resources in the study area, and a plan devised to meet this demand.

POPULATION AND ECONOMIC ACTIVITY

Because of factors operating largely external to the Region, the magnitude and character of future development in the Southeastern Wisconsin Region are uncertain. Therefore, the Commission has examined alternative future scenarios of the development of the Region based upon consideration of a range of conditions which may be expected to influence such development.[1] The principal factors considered in the development of these alternative future scenarios were energy cost and availability, technology and conservation, population lifestyles, and economic conditions. Based on a careful analysis of these external factors, two alternative future scenarios for the Region were postulated. Centralized and decentralized land use development patterns were considered under each scenario, resulting in a total of four alternative futures. The two alternative future scenarios and the four alternative futures are set forth in Table 11.

The two alternative future scenarios represent consistent and reasonable extremes of future development conditions in the Region. One alternative future scenario—the moderate growth scenario—was developed to represent the most optimistic conditions for future development in the Region. The moderate growth scenario assumes a severe energy situation, limited success in energy conservation, and moderate growth in regional population and employment levels. This scenario envisions a continuation of the types of population change experienced in the Region during the 1960's and early 1970's. Under this scenario, fertility rates continue at below-replacement levels into the 1980's, followed by a slight increase to replacement level by the year 2000. In addition, there is a balance between in- and out-migration of the population between 1970 and the year 2000. Anticipated fertility rates, together with a general aging of the population, are expected to create significant shifts in the age composition of the resident population, with a small decrease in the number of school age children and increases in the numbers of people in the work force and retirement age groups. Low fertility, coupled with some continuation in the trend of increasing numbers of one- and two-person households, is expected to lead to an average household size in the Region of between 2.9 and 3.1 persons by the year 2000. The total number of households in the Region is expected to range between 680,000 and 740,000, as compared to the 1980 level of 628,000. Under the moderate growth scenario, the resident population of the Region is expected to increase by about 454,400 persons, or about 26 percent, between 1980 and 2000—from about 1,764,900 persons in 1980 to about 2,219,300 persons in the year 2000.

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[1]*See SEWRPC Technical Report No. 25, Alternative Futures for Southeastern Wisconsin, December 1980.*

Table 11

ALTERNATIVE FUTURES: KEY EXTERNAL FACTORS, ATTENDANT REGIONAL CHANGE, AND LAND USE PLANS

Key External Factor	Moderate Growth Scenario	Stable or Declining Growth Scenario
Energy		
The future cost and availability of energy, particularly of petroleum	Oil price to converge with world oil price, which will increase at 5 percent annual rate to $72 per barrel in the year 2000 (1979 dollars) Petroleum-based motor fuel to increase to $2.30 per gallon by the year 2000 (1979 dollars) Assumes some potential for major and continuing disruptions in oil supply	Oil price to converge with world oil price, which will increase at 2 percent annual rate to $39 per barrel in the year 2000 (1979 dollars) Petroleum-based motor fuel to increase to $1.50 per gallon by the year 2000 (1979 dollars) Assumes no major or continued disruptions in oil supply
The degree to which energy conservation measures are implemented, particularly with respect to the automobile	Low degree of conservation in all sectors, resulting in increase in energy use of 3 percent Automobile fuel efficiency of 27.5 miles per gallon	High degree of conservation in all sectors, resulting in increase in energy use of 2 percent or less Automobile fuel efficiency of 32 miles per gallon
Population Lifestyles		
The degree to which the changing role of women affects the composition of the labor force	Female labor force increases to 50 to 55 percent and total labor force participation is 60 to 65 percent	Female labor force increases to 65 to 70 percent and total labor force participation is 70 to 75 percent
The future change in fertility rates	A continuation of below-replacement-level fertility rates during the next decade, followed by an increase to replacement level by the year 2000	A continuation of below-replacement-level fertility rates to the year 2000
The future change in household sizes	Average household size stabilizes	Average household size continues to decline
Economic Conditions		
The degree to which the Region will be able to compete with other areas of the nation for the reservation and expansion of its economic base	Region is considered to have relatively high attractiveness and competitiveness	Region is considered to have relatively low attractiveness and competitiveness
The future change of real income	Per capita and household income increase envisioned as a result of the attractiveness and competitiveness of the Region, an increased proportion of the population being of work force age, and increased population labor force participation	Per capita increase likely but no household income increase envisioned as a result of the lack of attractiveness and competitiveness of Region, but increased proportion of the population is of work force age, and there is increased population labor force participation
Attendant Regional Change	**Moderate Growth Scenario**	**Stable or Declining Growth Scenario**
Population of the Region in Year 2000		
Size	2,219,300 persons	1,688,400 persons
Age Distribution	29.2 percent—0-19 years of age 58.5 percent—20-64 years of age 12.3 percent—65 years of age or older	26.8 percent—0-19 years of age 60.6 percent—20-64 years of age 12.6 percent—65 years of age or older
Number of Households	681,100 to 739,400	673,600 to 750,600
Household Size	Average of 2.9 to 3.1 persons	Average of 2.2 to 2.5 persons

Table 11 (continued)

Attendant Regional Change	Moderate Growth Scenario	Stable or Declining Growth Scenario
Economic Activity of Region in Year 2000		
Employment	1,016,000 jobs	887,000 jobs
Structure	Manufacturing . . . . 32 percent Services . . . . 40 percent Other. . . . . 28 percent	Manufacturing . . . . 30 percent Services . . . . 41 percent Other. . . . . 29 percent
Personal Income	$29,600 to $32,000 per household in 1979 dollars (38 to 50 percent increase over 1970, or a 1.1 to 1.4 percent annual rate of increase) $10,000 per capita in 1979 dollars (54 percent increase over 1970, or a 1.4 percent annual rate of increase)	$21,400 to $23,700 per household in 1979 dollars (0 to 11 percent increase over 1970, or a 0.0 to 0.3 percent annual rate of increase) $9,500 per capita in 1979 dollars (46 percent increase over 1970, or a 1.3 percent annual rate of increase)

Land Use Development Characteristics	Moderate Growth Scenario		Stable or Declining Growth Scenario	
	Centralized	Decentralized	Centralized	Decentralized
Urban Growth and Density				
New Urban Residential Land	Occurs primarily at medium residential densities along the periphery of, and outward from, existing urban centers	Occurs primarily at suburban residential densities in a diffused pattern in areas proximate to, and removed from, existing urban centers	Occurs primarily at medium residential densities along the periphery of, and outward from, existing urban centers	Occurs primarily at suburban residential densities in a diffused pattern in areas proximate to, and removed from, existing urban centers
Urban Density	Existing developed portions of Milwaukee County generally maintain residential density existing in 1970	Existing developed portions of Milwaukee may decrease in residential density between 1970 and 2000	Existing developed portions of Milwaukee County generally maintain residential density existing in 1970	Existing developed portions of Milwaukee may decrease in residential density between 1970 and 2000

Land Use Plan Characteristics	Moderate Growth Scenario: Centralized Plan	Moderate Growth Scenario: Decentralized Plan	Stable or Declining Growth Scenario: Centralized Plan	Stable or Declining Growth Scenario: Decentralized Plan
Year 2000 Population				
Region	2,219,300	2,219,300	1,690,000	1,690,000
Direct Drainage Area	238,685	194,439	183,325	162,191
Kinnickinnic River Watershed	113,261	105,746	88,423	74,092
Menomonee River Watershed	343,147	317,113	256,235	253,450
Milwaukee River Watershed	426,206	449,627	330,032	322,581
Total Study Area	1,121,299	1,066,925	858,015	812,314
Year 2000 Households				
Region	739,400	681,100	750,600	673,600
Direct Drainage Area	104,830	77,763	105,700	74,190
Kinnickinnic River Watershed	41,899	35,540	40,325	32,933
Menomonee River Watershed	110,939	96,235	110,172	98,867
Milwaukee River Watershed	141,205	141,484	143,057	127,804
Total Study Area	398,873	351,022	399,254	333,794
Year 2000 Employment				
Region	1,016,000	1,016,000	887,000	887,000
Direct Drainage Area	217,023	185,489	210,249	188,850
Kinnickinnic River Watershed	53,903	49,633	51,534	50,013
Menomonee River Watershed	117,085	163,841	158,608	156,071
Milwaukee River Watershed	172,359	181,292	154,159	158,555
Total Study Area	620,370	580,255	574,550	553,489

Source: SEWRPC.

The economic changes that may be expected to occur under the moderate growth scenario represent a continuation of the changes that have occurred historically in the regional economy—that is, long-term economic growth at a rate equivalent to or slightly below national averages. An increased proportion of the population will be of work force age, and there will be increased female labor force participation. Under the moderate growth scenario, the number of jobs available in the Region will increase by about 141,300, or about 16 percent, between 1980 and 2000—from a 1980 level of 874,700 jobs to about 1,016,000 jobs in the year 2000.

The second alternative future scenario—the stable or declining growth scenario—assumes ample petroleum supplies, a high degree of conservation in all sectors of the economy, and little growth in population or economic activity. Fertility rates at below-replacement levels are assumed to continue through the year 2000. This assumption, combined with a rate of net out-migration sufficiently large to offset all natural increases in regional population, will produce a slight population decrease in the Region by the year 2000. It is also assumed under this scenario that the Region will be unable to compete effectively with other regions of the country for economic development, and that persons presently in their twenties and thirties will continue to have a low rate of family formation. Continued low fertility rates in concert with the general aging of the population, and high levels of regional out-migration in the age groups below 45 years of age, will create significant shifts in the age composition of the resident population, with major decreases in school age population and slight increases in the work force age group and retirement age population. Lower fertility rates, coupled with a continuation of nonfamily-oriented household formation patterns, will also lead to a major decrease in average household size to between 2.2 and 2.5 persons in the year 2000, and an increase in the total number of households to between 674,000 and 750,000, as compared with the 1980 level of 628,000. Population under this scenario will decline to 1,690,000 persons in the year 2000, a loss of about 74,900 persons, or about 4 percent, from the 1980 level. The difference in total regional population in the year 2000 between the moderate growth scenario and the stable or no growth scenario is about 529,000 persons.

The economic changes that may be expected to occur under the stable or declining growth scenario represent a departure from existing long-term regional trends. This departure is based on a decline in population level, along with the assumed inability of the Region to compete with other regions of the nation economically. As a result, employment levels may be expected to show only a moderate increase between 1980 and the year 2000. It is assumed that the rate of increase in regional employment will be significantly below the national rates of increase. Employment growth that does occur is assumed to be accommodated by increases in the labor force participation rate and by a slight increase in the size of the population in labor force age groups. Under this scenario, the number of jobs in the Region may be expected to increase over the 1980 level by about 12,300 jobs, or slightly more than 1 percent, to about 887,000 jobs in the year 2000. The difference in total regional employment between the moderate growth scenario and the stable or declining growth scenario is about 129,000 jobs.

As indicated in Table 11, population levels in the Milwaukee Harbor estuary direct drainage area and in the total study area in the year 2000 are generally the highest under the moderate growth scenario, centralized land use plan and the lowest under the stable or declining growth scenario, decentralized land use plan. Although the regional levels of population, households, and employment are the same within the two scenarios, the distribution of population and economic activity throughout the Region is affected by the land use pattern considered. As shown in Table 11, the centralized land use pattern would concentrate new urban development in a concentric fashion around the periphery of existing urban centers, while urban development in the decentralized land use pattern would occur primarily at lower densities in areas both proximate to and removed from existing urban centers. The distribution of population and economic activity within the study area, as shown in Table 11, would therefore vary according to the alternative land use pattern that is assumed to develop.

Following review of these four sets of potential future conditions, the Advisory Committee concluded that the alternative water resource management plans for the Milwaukee Harbor estuary should be developed based upon the moderate growth scenario, centralized land use plan. The Advisory Committee based its recommendation on the fact that population levels in the Milwaukee Harbor estuary direct drainage area and its tributary river watersheds may be expected to be higher under the moderate growth scenario than under the stable or declining growth scenario, and thus,

Table 12

EXISTING AND FORECAST POPULATION IN THE MILWAUKEE HARBOR ESTUARY DIRECT DRAINAGE AREA, ITS TRIBUTARY RIVER WATERSHEDS, AND THE REGION: 1980 AND 2000—MODERATE GROWTH SCENARIO, CENTRALIZED LAND USE PLAN

Watershed	Population			
	1980	2000	Increment	Percent Change
Milwaukee Harbor Estuary Direct Drainage Area	255,171	238,685	-16,486	-6.5
Kinnickinnic River Watershed[a].	102,171	113,261	11,090	10.9
Menomonee River Watershed[a].	271,917	343,147	71,230	26.2
Milwaukee River Watershed[a].	340,968[b]	426,206[c]	85,238	25.0
Total Study Area	970,227	1,121,299	151,072	15.6
Region	1,764,919	2,219,300	454,381	25.7

[a]*Excluding that portion of the watershed lying within the Milwaukee Harbor estuary direct drainage area.*

[b]*Includes 326,228 persons residing in the Region and 14,740 persons residing outside the Region.*

[c]*Includes 406,204 persons forecast to reside in the Region, and 20,002 persons projected to reside outside the Region based on population growth rates observed between 1970 and 1980.*

Source: SEWRPC.

the demand on the water resources in the estuary would be greater. The Advisory Committee also considered the fact that the centralized land use pattern would have the greatest potential impact on the water resources of the estuary because of its assumed concentration of population around existing urbanized areas, including the Milwaukee Harbor estuary direct drainage area and the cities and villages generally located along the main stem of the tributary rivers. From the standpoint of water resources management, then, the future conditions represented by the moderate growth, centralized land use plan may be expected to result in a conservative approach to forecasting the impacts of land use development on the water resources of the Milwaukee Harbor estuary.

Resident Population

Table 12 sets forth the forecast year 2000 population levels for the Milwaukee Harbor estuary direct drainage area, its tributary river watersheds, and the Region under the moderate growth scenario, centralized land use plan. As may be seen in this table, the population of the direct drainage area is forecast to decrease by about 16,500 persons, or about 7 percent—from about 255,200 persons in 1980 to about 238,700 persons in the year 2000. Population within the total study area, however, is forecast to increase by about 151,100 persons, or nearly 16 percent—from about 970,200 persons in 1980 to about 1,121,300 persons in the year 2000. The largest absolute gain in population is expected to occur in the Milwaukee River watershed, which

Table 13

NUMBER OF HOUSEHOLDS AND AVERAGE HOUSEHOLD SIZE IN THE MILWAUKEE HARBOR ESTUARY DIRECT DRAINAGE AREA, ITS TRIBUTARY RIVER WATERSHEDS, AND THE REGION: 1980 AND 2000–MODERATE GROWTH SCENARIO, CENTRALIZED LAND USE PLAN

Watershed	Number of Households				Average Household Size			
	Year		Change		Year		Change	
	1980	2000	Absolute	Percent	1980	2000	Absolute	Percent
Milwaukee Harbor Estuary Direct Drainage Area	103,957	104,830	873	0.8	2.33	2.16	-0.17	-7.3
Kinnickinnic River Watershed[a].	41,343	41,899	556	1.3	2.45	2.68	0.23	9.4
Menomonee River Watershed[a].	101,999	110,939	8,940	8.8	2.60	3.00	0.40	15.4
Milwaukee River Watershed[a,b]	127,249	141,205	13,956	11.0	2.65	2.96	0.31	11.7
Total Study Area	374,548	398,873	24,325	6.5	2.52	2.73	0.21	8.3
Region	627,955	739,400	111,445	17.7	2.75	2.90	0.40	13.8

[a]*Excluding that portion of the watershed lying within the Milwaukee Harbor estuary direct drainage area.*

[b]*Assumes that households in the portion of the watershed outside the Region increase at the same rate as do households within the in-Region portion of the watershed.*

Source: SEWRPC.

is forecast to increase in resident population by about 85,200 persons, or about 25 percent, between 1980 and the year 2000—from 341,000 persons in 1980 to 426,200 persons in 2000. The largest relative gain in population is expected to occur in the Menomonee River watershed, where the resident population is forecast to increase by more than 26 percent, or by about 71,200 persons—from a 1980 population level of about 271,900 persons to a year 2000 population level of 343,100 persons.

Household and Employment Levels

Along with an increase in population within the study area will come an increase in the number of households. As shown in Table 13, the number of households within the total study area is forecast to increase by more than 24,300 units, or by about 7 percent—from about 374,500 households in 1980 to about 398,900 households in the year 2000. The greatest absolute and relative increases in households are expected to occur within the Milwaukee River watershed, which is forecast to gain about 14,000 units—from 127,200 households in 1980 to 141,200 households in the year 2000—for an increase of about 11 percent. The lowest absolute increase in households is expected within the Kinnickinnic River watershed, which is forecast to increase by fewer than 600 units, or by slightly more than 1 percent—from about 41,300 households in 1970 to about 41,900 households in the year 2000. The lowest relative increase is expected in the Milwaukee Harbor estuary direct drainage area, which is expected to increase by fewer than 900 units, or by slightly less than 1 percent—from about 104,000 households in 1980 to about 104,900 households in the year 2000.

Table 14

EXISTING AND FORECAST EMPLOYMENT WITHIN THE MILWAUKEE HARBOR ESTUARY DIRECT DRAINAGE AREA, ITS TRIBUTARY RIVER WATERSHEDS, AND THE REGION: 1980 AND 2000—MODERATE GROWTH SCENARIO, CENTRALIZED LAND USE PLAN

Watershed	Employment			
	1980	2000	Increment	Percent Change
Milwaukee Harbor Estuary Direct Drainage Area	184,664	217,023	32,359	17.5
Kinnickinnic River Watershed[a].	46,958	53,903	6,945	14.8
Menomonee River Watershed[a].	158,092	177,085	18,993	12.0
Milwaukee River Watershed[a,b]	133,245	172,359	39,114	29.4
Total Study Area	522,959	620,370	97,411	18.6
Region	815,530	1,016,000	200,470	24.6

[a]*Excluding that portion of the watershed lying within the Milwaukee Harbor estuary direct drainage area.*

[b]*Assumes that employment in that portion of the watershed outside the Region increases at the same rate as does the employment within the in-Region portion of the watershed.*

Source: SEWRPC.

Although the direct drainage area may be expected to exhibit only a small increase in households, the attendant forecast decrease in the resident population of the area, as is indicated in Table 12, means that the average household size may also be expected to decrease. With an anticipated population decrease of about 16,500 persons between 1980 and 2000, and with an increase of about 900 households over this same period, the average household size in the Milwaukee Harbor estuary direct drainage area may be expected to decrease from about 2.33 persons in 1980 to about 2.16 persons in the year 2000, as shown in Table 13. As also indicated in this table, average household size in the individual tributary river watersheds, in the total study area, and in the Region are all expected to increase between 1980 and the year 2000.

The forecast change in employment in the Milwaukee Harbor estuary direct drainage area and its tributary river watersheds and in the Region between 1980 and the year 2000 is shown in Table 14. As indicated in this table, under the moderate growth scenario employment in the total study area is forecast to increase by about 97,400 jobs, or by about 19 percent—from 523,000 jobs in 1980 to about 620,400 jobs in the year 2000. A comparison of the relative change in population levels, as shown in Table 12, indicates that the rate of employment increase is higher than the rate of population change within each watershed except the Menomonee River watershed. Most notably, such a comparison indicates that although the Milwaukee Harbor estuary direct drainage area is forecast to exhibit about a 7 percent decrease in resident population between 1980 and the year 2000, total employment in the area is forecast to increase by slightly less than 18 percent over this same period. One underlying factor supporting this projection is the anticipated shift in age composition, with fewer persons in the school-age and younger age groups and a greater number of persons in the labor force age groups. The general aging of the resident population within the direct drainage area is, in turn, supported by the forecast decrease in average household size, as shown in Table 13. The decrease from an average of 2.33 persons per household in 1980 to 2.16 persons in the year 2000 means that there will be fewer younger residents in the direct drainage area and a greater number of persons in labor force age groups. Also contributing to the higher rate of employment growth as compared with population change is the anticipated increase in the number of females in the labor force. Moreover, an increased rate of commuting into the direct drainage area by nonresidents of the area for work purposes may also contribute to the increase in employment, although the resident population of the direct drainage area is forecast to decline. This daily influx is estimated to represent more than a 50 percent increase in the resident population of the direct drainage area. The commuting population, which was estimated to be 130,000 persons in 1972 and just over 140,000 persons in 1980, is expected to increase further as major development projects in the downtown business area create employment opportunities. Such ongoing projects are discussed in the following section on land use.

In addition to the daily influx of people to the estuary direct drainage area, it is estimated that 1,500,000 persons attend special entertainment events at the Summerfest grounds and in the downtown area annually. This influx of people is also expected to continue and to increase.

LAND USE

As noted earlier in this chapter, two alternative land use plans—a centralized plan and a decentralized plan—were developed by the Commission for each of the two alternative future scenarios—the moderate growth scenario and the stable or declining growth scenario. Under the centralized land use plan, future urban growth would occur primarily at medium residential densities along the periphery of, and outward from, existing urban centers. Under the decentralized land use plan, future urban development would occur primarily at suburban residential densities in a diffused pattern in areas both proximate to and removed from existing urban centers. The pattern of future land use development in the Region is particularly important to water resources planning for the Milwaukee Harbor estuary, since the decentralized plan would place greater emphasis on the use of onsite soil absorption sewage disposal systems (septic tanks) and on private water supply wells, while the centralized plan would emphasize the provision of public sanitary sewer service and public water supply.

As noted earlier in this chapter, after review of both the centralized plan and the decentralized plan, the Advisory Committee concluded that the development of alternative water resource management plans for the Milwaukee Harbor estuary should be based on the centralized land use plan. Use of this alternative would result in a plan based upon sound densities of urban development, with an attendant increase in the demand for public sanitary sewer service and public water supply as such development occurs in a concentric fashion around existing urban centers. This land use pattern would also result in higher population levels in the Milwaukee Harbor estuary direct drainage area and in the cities and villages generally located along the main stem of the tributary rivers, and would have the greatest potential impact on the water resources of the estuary. Thus, as already noted, the use of the centralized land use pattern, like the use of the moderate growth scenario, may be expected to result in a conservative approach to the forecast of the impacts of land use development on the water resources of the Milwaukee Harbor estuary.

Table 15 presents a summary of the existing and forecast land use in the Milwaukee Harbor estuary direct drainage area and its tributary river watersheds for the years 1980 and 2000 under the moderate growth scenario, centralized land use plan. As indicated in the table, future development within the total study area will require the conversion of about 27 square miles of rural land to urban uses by the year 2000. Land devoted to urban uses within the study area would therefore increase from about 219.2 square miles in 1980, or about 26 percent of the total area within the watersheds, to about 246.4 square miles in the year 2000, or about 29 percent of the total area within the watersheds. Table 15 also indicates that, owing to the present intensive urban development, little change in existing land use within the Milwaukee

Table 15

EXISTING AND FORECAST LAND USE IN THE MILWAUKEE HARBOR ESTUARY DIRECT DRAINAGE AREA AND ITS TRIBUTARY RIVER WATERSHEDS: 1980 AND 2000—MODERATE GROWTH SCENARIO, CENTRALIZED LAND USE PLAN

Land Use Category	Kinnickinnic River Watershed[a]					
	Existing 1980		Planned Increment		Year 2000	
	Area (square miles)	Percent of Watershed	Area (square miles)	Percent Change	Area (square miles)	Percent of Watershed
Urban						
Residential	6.93	34.68	0.70	10.1	7.63	38.19
Commercial	0.57	2.85	--	3.5	0.59	2.95
Industrial	1.07	5.36	0.11	10.3	1.18	5.91
Transportation and Utilities	7.10	35.54	0.10	1.4	7.20	36.04
Governmental and Institutional	1.59	7.96	0.06	3.8	1.65	8.26
Recreational	0.78	3.90	0.21	26.9	0.99	4.95
Total Urban Land Use	18.04	90.29	1.20	6.7	19.24	96.30
Rural						
Agricultural	0.18	0.90	-0.11	-61.1	0.07	0.35
Open Land and Surface Water	1.76	8.81	-1.09	-61.9	0.67	3.35
Total Rural Land Use	1.94	9.71	-1.20	-61.9	0.74	3.70
Total Land Use	19.98	100.00	--	--	19.98	100.00

Land Use Category	Menomonee River Watershed[a]					
	Existing 1980		Planned Increment		Year 2000	
	Area (square miles)	Percent of Watershed	Area (square miles)	Percent Change	Area (square miles)	Percent of Watershed
Urban						
Residential	34.62	26.48	6.38	18.43	41.00	31.36
Commercial	1.99	1.52	0.26	13.1	2.25	1.72
Industrial	3.13	2.39	2.13	68.1	5.26	4.02
Transportation and Utilities	21.68	16.59	2.26	10.4	23.94	18.31
Governmental and Institutional	4.85	3.71	0.48	9.9	5.33	4.08
Recreational	4.33	3.32	1.60	37.0	5.93	4.54
Total Urban Land Use	70.60	54.01	13.11	18.6	83.71	64.03
Rural						
Agricultural	35.90	27.46	-5.88	-16.4	30.02	22.97
Open Land and Surface Water	24.22	18.53	-7.23	-29.9	16.99	13.00
Total Rural Land Use	60.12	45.99	-13.11	-21.8	47.01	35.97
Total Land Use	130.72	100.00	--	--	130.72	100.00

Table 15 (continued)

Land Use Category	Milwaukee River Watershed[a,b]					
	Existing 1980		Planned Increment		Year 2000	
	Area (square miles)	Percent of Watershed	Area (square miles)	Percent Change	Area (square miles)	Percent of Watershed
Urban						
Residential	51.71	7.54	5.59	10.8	57.30	8.36
Commercial	2.28	0.33	0.39	17.1	2.67	0.39
Industrial	3.88	0.56	1.20	30.9	5.08	0.74
Transportation and Utilities	39.71	5.79	4.08	10.3	43.79	6.39
Governmental and Institutional	4.86	0.71	0.53	10.9	5.39	0.79
Recreational	7.63	1.12	0.88	11.5	8.51	1.24
Total Urban Land Use	110.07	16.05	12.67	11.5	122.74	17.91
Rural						
Agricultural	370.68	54.09	13.28	3.6	383.96	56.02
Open Land and Surface Water	204.63	29.86	-25.95	-12.8	178.68	26.07
Total Rural Land Use	575.31	83.95	-12.67	-2.2	562.64	82.09
Total Land Use	685.38	100.00	- -	- -	685.38	100.00

Land Use Category	Milwaukee Harbor Estuary Direct Drainage Area					
	Existing 1980		Planned Increment		Year 2000	
	Area (square miles)	Percent of Watershed	Area (square miles)	Percent Change	Area (square miles)	Percent of Watershed
Urban						
Residential	7.74	35.10	-0.06	-0.8	7.68	34.83
Commercial	1.14	5.17	0.18	15.8	1.32	5.99
Industrial	1.34	6.07	0.04	3.0	1.38	6.26
Transportation and Utilities	8.10	36.74	0.05	0.6	8.15	37.00
Governmental and Institutional	1.30	5.90	- -	- -	1.30	5.85
Recreational	0.82	3.72	0.08	9.8	0.90	4.08
Total Urban Land Use	20.44	92.70	0.29	1.4	20.73	94.01
Rural						
Agricultural	- -	- -	- -	- -	- -	- -
Open Land and Surface Water	1.61	7.30	-0.29	-18.0	1.32	5.99
Total Rural Land Use	1.61	7.30	-0.29	-18.0	1.32	5.99
Total Land Use	22.05	100.00	- -	- -	22.05	100.00

Table 15 (continued)

Land Use Category	Total Study Area					
	Existing 1980		Planned Increment		Year 2000	
	Area (square miles)	Percent of Watershed	Area (square miles)	Percent Change	Area (square miles)	Percent of Watershed
Urban						
Residential	101.00	11.77	12.61	12.5	113.61	13.24
Commercial	5.98	0.70	0.85	14.2	6.83	0.80
Industrial	9.42	1.10	3.48	36.9	12.90	1.50
Transportation and Utilities	76.59	8.93	6.49	8.5	83.08	9.69
Governmental and Institutional	12.60	1.47	1.07	8.5	13.67	1.59
Recreational	13.56	1.58	2.77	20.4	16.33	1.90
Total Urban Land Use	219.15	25.53	27.27	12.4	246.42	28.72
Rural						
Agricultural	406.76	47.40	7.29	1.8	414.05	48.25
Open Land and Surface Water	232.22	27.07	-34.56	-1.3	197.66	23.03
Total Rural Land Use	638.98	74.47	-27.27	-4.2	611.71	71.28
Total Land Use	858.13	100.00	- -	- -	858.13	100.00

NOTE: These figures represent the areas determined by approximating the boundaries of the study area by U. S. Public Land Survey quarter section and summing the quarter-section totals.

[a]Excluding that portion of the watershed lying within the Milwaukee Harbor estuary direct drainage area.

[b]Since detailed land use inventories and forecasts are not available for the portions of the Milwaukee River watershed lying outside the Region for the years 1980 and 2000, it was assumed that the 1967 land use inventory conducted by the Commission for these areas remained constant over the period of study.

Source: SEWRPC.

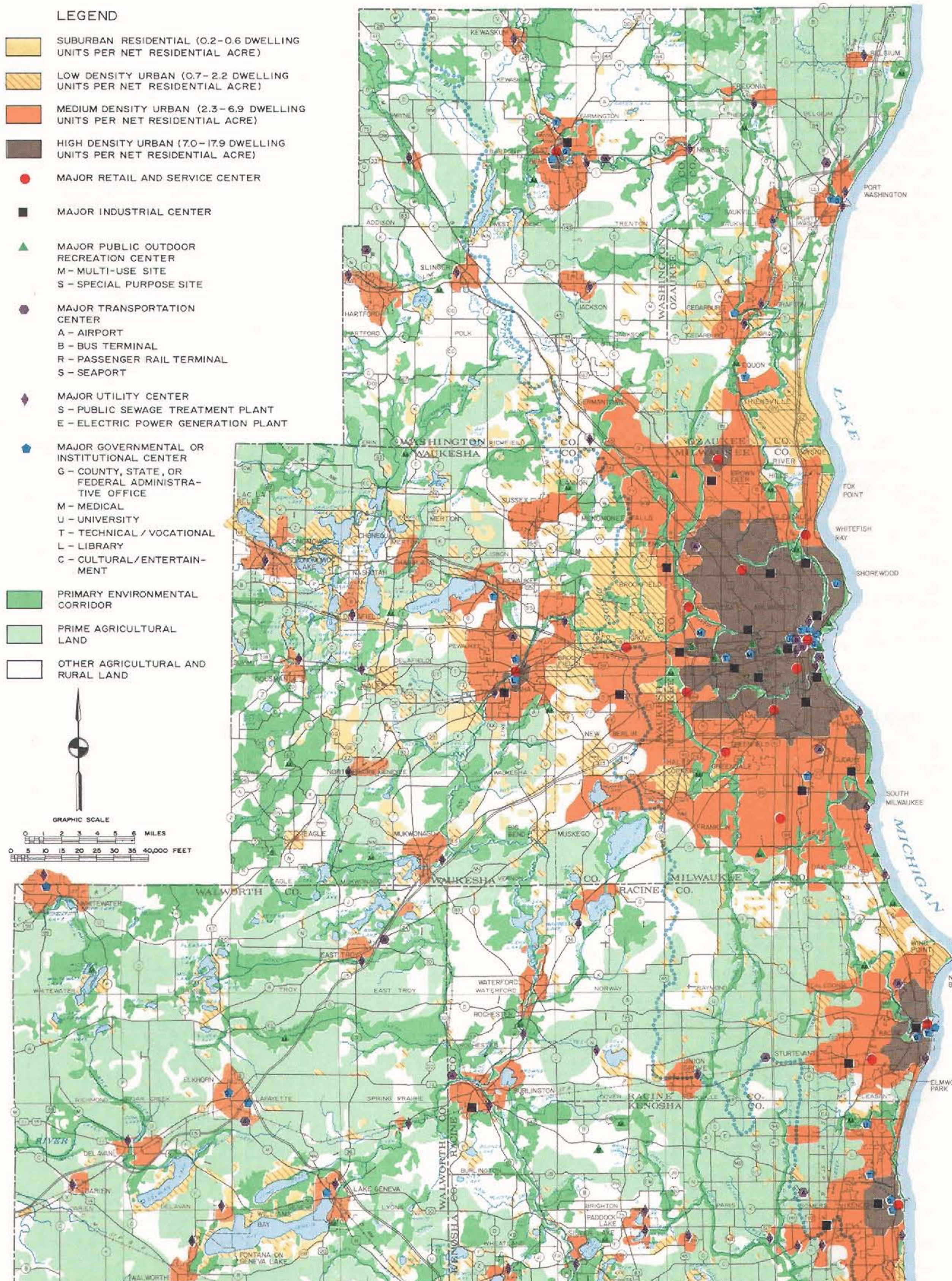
Harbor estuary direct drainage area may be expected by the year 2000. The land use pattern of the Region that would be expected in the year 2000 under the moderate growth scenario, centralized land use plan is depicted on Map 3.

While the land use pattern in the estuary direct drainage area is not expected to change significantly, substantial redevelopment is expected to occur. As reported in Chapter III of Volume One, as of 1986 there were 50 public and private development projects reported by the City of Milwaukee Department of Development which could be influenced by improved water quality in the estuary. These projects, which are described further in Chapter III of Volume One, include two public works projects, 12 commercial projects, 13 recreational projects, 10 residential projects, 1 industrial project, 3 institutional projects, and 9 mixed use and miscellaneous projects. Since these projects and others that are expected to develop are considered to be potentially influenced by improved water quality, they can be an important factor in considering water use objectives for the estuary.

SUMMARY

Because of the uncertainty about how future changes in social and economic conditions will affect water quality in the Milwaukee Harbor estuary, an alternative futures approach was used as the basis for estimating future demand on the water resources of the estuary and of the tributary watersheds. The principal factors considered in the development of the alternative futures were energy

Map 3
ADOPTED REGIONAL LAND USE PLAN FOR SOUTHEASTERN WISCONSIN: 2000



Under the moderate growth scenario, centralized land use plan for southeastern Wisconsin, new urban development would occur only in those areas which are covered by soils suitable for such development, which are not subject to special hazards such as flooding, and which can be readily provided with such urban services as sanitary sewer, water supply, and mass transit. These areas are indicated by the yellow, orange, and brown areas on the map. Under this scenario, all of the remaining primary environmental corridors—the dark green areas on the map—would be preserved in essentially natural, open uses, thus protecting the best remaining woodlands, wetlands, and wildlife habitat areas, as well as the undeveloped shorelands and floodlands, surface waters, and groundwater discharge and recharge areas, from incompatible development. Finally, under this scenario, almost all of the remaining prime agricultural areas of the Region—the light green areas on the map—would be preserved in agricultural use. Within the Milwaukee Harbor Estuary direct drainage area and its tributary watersheds, future development will require the conversion of about 27 square miles from rural to urban uses between 1980 and the year 2000. Within the Milwaukee Harbor estuary direct drainage area itself, presently in intensive urban use, little change in land use is expected.

Source: SEWRPC.

cost and availability, technology and conservation, population lifestyles, and economic conditions. Based on a careful review of these factors, two alternative futures having quite different implications for the development of the Region were devised. The scenarios were developed to represent consistent and reasonable extremes of future conditions in the Region. One scenario, termed the moderate growth scenario, envisions moderate population and economic growth in the Region. The other scenario, termed the stable or declining growth scenario, envisions stable or slightly declining population and economic activity levels in the Region. Under each of these scenarios, two different alternative futures were developed for the Region—one based upon a centralized land use pattern and one upon a decentralized land use pattern. Following review of these four sets of potential future conditions, the Advisory Committee concluded that the alternative water resource management plans for the Milwaukee Harbor estuary should be developed based upon the moderate growth scenario, centralized land use plan.

Under the moderate growth scenario, centralized land use plan, the resident population in the Milwaukee Harbor estuary direct drainage area may be expected to decline by about 16,500 persons, or nearly 7 percent—from about 255,200 persons in 1980 to about 238,700 persons by the year 2000. Population levels in the total study area, however, may be expected to increase by about 151,100 persons, or nearly 16 percent—from about 970,200 persons in 1980 to about 1,121,300 persons by the year 2000. More than 51 percent of this increase in population is expected to occur within the Milwaukee and Menomonee River watersheds.

The number of households within the study area will also increase between 1980 and the year 2000. The combined number of households within the Milwaukee Harbor estuary direct drainage area and its tributary river watersheds may be expected to increase by about 24,300 units, or about 7 percent—from about 374,500 households in 1980 to about 398,900 households by the year 2000. Average household size is forecast to decrease in the direct drainage area—from 2.33 persons per houshold in 1980 to 2.16 persons per household in 2000—but is expected to increase within the individual tributary river watersheds. Overall, average household size within the total study area may be expected to increase from 2.52 persons in 1980 to 2.73 persons in the year 2000.

Under the moderate growth scenario, centralized land use plan, employment in the study area may be expected to increase by about 97,400 jobs, or by nearly 19 percent—from about 523,000 jobs in 1980 to about 620,400 jobs in the year 2000. The Milwaukee Harbor estuary direct drainage area itself may be expected to gain almost 32,400 jobs, or about 18 percent—from about 184,700 jobs in 1980 to about 217,000 jobs in the year 2000.

In order to accommodate the population levels and economic activity envisioned under the moderate growth, centralized land use plan, it is envisioned that approximately 27 square miles of rural land will be converted to urban uses within the study area by the year 2000. Because of the existing level of intensive urbanization in the Milwaukee Harbor estuary direct drainage area, however, very little change in land use may be expected in the area between 1980 and the year 2000.

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Chapter IV

ALTERNATIVE WATER QUALITY MANAGEMENT MEASURES

INTRODUCTION

The inventory and analysis phases of the Milwaukee Harbor estuary comprehensive water resources planning program identified certain water resource problems, including water pollution from combined sewer overflows, other point sources, nonpoint sources, and in-place pollutants. The development of a plan for the abatement of these problems was the primary objective of the Milwaukee Harbor estuary planning program. The purpose of this chapter is to present alternative plans for water pollution abatement, and to evaluate those plans in order to provide a basis for the selection of the best water quality management plans for incorporation into the comprehensive water resources management plan for the Milwaukee Harbor estuary. More specifically, this chapter analyzes the extent to which various alternative water pollution abatement measures may be expected to mitigate the combined sewer overflow, other point source, nonpoint source, and in-place pollution problems that exist within the study area, and, based on evaluation of the technical, economic, and environmental performance of the alternatives considered, recommends an integrated set of water quality management measures for incorporation into the water resource management plan for the Milwaukee Harbor estuary.

In the planning process used by the Commission, the formulation of a set of water resources management objectives, including water use objectives and supporting water quality standards, provides an important basis for alternative plan design and evaluation. A set of water use objectives and supporting water quality standards was presented in Chapter II of this volume, together with other water resource management objectives and standards. The Commission has always recognized that the formulation of objectives and standards is an iterative process in which, as a result of the findings of the plan design and evaluation process, certain objectives initially proposed may have to be revised or discarded because their satisfaction has been proven unrealistic, and in which new objectives may be suggested and conflicts between inconsistent objectives may be balanced out. Thus, the formulation of objectives and standards must proceed in concert with plan design and evaluation.

The water quality management plans prepared under other Commission studies include recommendations which should contribute to the resolution of the water quality problems within the Milwaukee Harbor estuary; namely, recommendations for the abatement of the point and nonpoint sources of pollution such as sewage treatment plant discharges, separate sanitary and combined sanitary and storm sewer overflows, industrial wastewater discharges, malfunctioning septic tank system discharges, stormwater runoff from rural and urban lands, soil erosion, and livestock waste runoff. These previous Commission studies include the comprehensive plans for the Milwaukee, Menomonee, and Kinnickinnic River watersheds and the areawide water quality management plan. The water quality management plan for the Milwaukee Harbor estuary is accordingly set within the context of these other Commission plans.

The water quality management plan element for the Milwaukee Harbor estuary, as described herein, is a systems level plan, and as such has three primary functions:

1. Identification of the type and source of existing and probable future water pollution problems.

2. Determination of the pollutant reductions required to achieve desired levels of water quality; and formulation and evaluation of alternative combined sewer overflow and other point source, nonpoint source, and in-place pollution abatement measures for achieving the desired levels of water quality.

3. Identification of the best means for abating identified water pollution problems and achieving established water use objectives and supporting water quality standards considering technical practicality, economic feasibility, and environmental impact.

The material presented in this chapter is organized as follows. First, the relationships between the Milwaukee Harbor estuary water quality management plan and the Regional Planning Commission's adopted areawide water quality management plan, the Milwaukee Metropolitan Sewerage District's adopted water pollution abatement program, and the Wisconsin Department of Natural Resources' Milwaukee River Priority Watersheds Program are described. Next, plan design criteria and procedures are presented. Alternative combined sewer overflow, other point source, nonpoint source, and in-place pollution abatement alternatives are then advanced and evaluated. Based upon the evaluation of these alternatives, a recommended plan is presented. Finally, a summary of the chapter is provided.

RELATIONSHIP TO AREAWIDE WATER QUALITY MANAGEMENT PLAN

As noted in Chapter I of Volume One of this report, the areawide water quality management plan for southeastern Wisconsin was completed by the Regional Planning Commission in 1979. The adopted plan consists of five major plan elements: a land use element, a point source pollution abatement element, a nonpoint source pollution abatement element, a sludge management element, and a water quality monitoring element. The findings and recommendations of the areawide water quality management plan are set forth in SEWRPC Planning Report No. 29, A Regional Wastewater Sludge Management Plan for Southeastern Wisconsin, and in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000.

Sewerage facilities and local level nonpoint source abatement planning efforts were recommended in the areawide water quality management plan to refine that plan and to help implement it. These local level planning efforts were to be based on specific knowledge of identified water quality problems; the sources and causes of these problems; alternative designs for abating these problems; and evaluation of the technical, financial, social, managerial, and environmental considerations which affect the selection and implementation of a pollution abatement measure.

The water quality management elements of the Milwaukee Harbor estuary plan are thus intended to further refine and detail the areawide water quality management plan with respect to the water pollution abatement measures required to achieve recommended water use objectives and supporting water quality standards in the Milwaukee Harbor estuary. More specifically, the Milwaukee Harbor estuary plan refines and details the point source and nonpoint source recommendations set forth in the areawide plan and evaluates certain pollution abatement measures that were not specifically addressed in the areawide plan. The Milwaukee Harbor estuary study thus serves to implement, as well as extend, the areawide water quality management plan.

RELATIONSHIP TO MILWAUKEE METROPOLITAN SEWERAGE DISTRICT WATER POLLUTION ABATEMENT PROGRAM

The Milwaukee Metropolitan Sewerage District's water pollution abatement program and the planning and engineering studies underlying that program share objectives with the areawide water quality management plan and the Milwaukee Harbor estuary planning program. The important work elements of the District water pollution abatement program, as described in Chapter I of Volume One of this report, include: a sewer system evaluation survey; rehabilitation of the sanitary sewer system; construction of relief sewers; abatement of combined sewer overflows; improvement and expansion of the Jones Island and South Shore sewage treatment plants; provision of large subterranean conveyance and storage facilities to contain separate and combined sewer peak flows in excess of the capacity of the sewerage system and the sewage treatment plants; development of a solids management program; and provision of trunk sewers to serve the various communities comprising the District service area.

The water quality impacts of several elements of the water pollution abatement program—such as the abatement of pollution from sanitary sewer flow relief devices and combined sewer overflows—are directly addressed in the Milwaukee Harbor estuary study. As indicated in Chapter VIII of Volume One of this report, the harbor estuary study also addresses certain issues raised during the conduct of the District water pollution abatement program. These issues include the establishment of water use objectives and supporting water quality standards for the Milwaukee Harbor estuary, and a determination of 1) the reduction required in pollutant loadings from point and nonpoint sources discharged to the stream network upstream of the estuary, 2) whether toxic conditions are affecting desired uses of the estuary, 3) the level of protection needed for the abatement of pollution from combined sewer overflows, and 4) the need for, and methods of, abating in-place pollutants. The Milwaukee Harbor estuary study is thus closely related to certain aspects of the District water pollution abatement program, and the study findings and recommendations are intended to help shape and amend, as well as implement, that program.

RELATIONSHIP TO MILWAUKEE RIVER PRIORITY WATERSHEDS PROGRAM

On May 8, 1984, Governor Anthony S. Earl signed into law 1983 Wisconsin Senate Bill 548. This law directed the Wisconsin Department of Natural Resources (DNR) to undertake on an accelerated basis a nonpoint source water pollution abatement program throughout the Milwaukee and Menomonee River watersheds.[1] The goals of the program are to:

1. Achieve healthy and balanced aquatic communities in the near-shore waters of Lake Michigan, the harbor estuary, and the rivers, streams, and inland lakes of the watersheds concerned.

2. Provide increased opportunities for healthy outdoor recreation activities, such as swimming, fishing, and boating.

3. Implement nonpoint source water pollution abatement measures on a schedule coordinated with the Milwaukee Metropolitan Sewerage District's combined sewer overflow and point source water pollution abatement program schedule.

The implementation of urban and rural nonpoint source controls, and of related fish management activities, is intended to improve water quality conditions and help rehabilitate the fisheries and other aquatic resources throughout the watersheds concerned.

With respect to nonpoint source pollution abatement, the areawide water quality management plan provided systems level recommendations on the overall level of reductions in nonpoint water pollution loadings required to achieve the water use objectives and supporting water quality standards set forth in the plan for those surface waters located upstream of the estuary. The Milwaukee Harbor estuary study was intended to evaluate how reductions in nonpoint source pollutant loadings being discharged to the estuary would affect the water quality of the estuary itself. Accordingly, the levels of reduction in pollutant loadings to the estuary from upstream nonpoint sources needed to meet water quality standards within the estuary are identified in this chapter. The priority watersheds program should provide the more detailed, facilities level planning efforts needed to determine how best to achieve the needed pollutant loading reductions in a cost-effective manner. The resulting nonpoint source control plan is expected to be completed by the Department in 1987, and is to serve as a basis for the disbursement of the cost-share funding made available by the State Legislature to assist in the implementation of eligible nonpoint source abatement measures.

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[1] *On September 5, 1984, the Wisconsin Department of Natural Resources formally requested the Southeastern Wisconsin Regional Planning Commission to assist the Department in the preparation of a prospectus for the Milwaukee River Priority Watersheds Program. That prospectus, entitled, Milwaukee River Priority Watersheds Program Prospectus, was prepared and published jointly by the Department and the Commission in March 1985. Although the Kinnickinnic River watershed was not designated by the State Legislature as a priority watershed under Senate Bill 548, the prospectus recommended that the Kinnickinnic River watershed be so designated by the State Legislature and that the associated funding be provided by the Legislature. The prospectus also recommended that additional funds be provided by the State Legislature to support additional water quality sampling and the analytical work necessary to quantitatively determine the impacts of the recommended nonpoint source pollution abatement measures on instream water quality conditions. The Legislature, however, did not include those requested funds in the 1985-1986 biennium budget.*

On June 18, 1986, the Regional Planning Commission, in cooperation with the seven county land conservation committees within the Region, recommended to the State Nonpoint Source Coordinating Committee and the Wisconsin Department of Natural Resources that the Kinnickinnic River watershed be selected as a priority watershed under the state nonpoint source water pollution abatement program. Following consideration of 21 watersheds recommended by the regional watershed selection committees, the Committee and the Department subsequently declined to designate the Kinnickinnic River watershed as a priority watershed.

WATER QUALITY MANAGEMENT PLANNING CRITERIA AND ANALYTIC PROCEDURES

Certain planning criteria and analytic procedures were utilized in the design of alternative plan elements, in the test of the technical feasibility of those elements, and in the making of the necessary economic comparisons. The procedures used in the development of the combined sewer overflow control measures, other point source control measures, nonpoint source control measures, and instream management measures are described in the following sections of this chapter. Also described are the procedures used in the economic analyses.

Basis for the Development and Analysis of Alternative Water Quality Management Plans

The alternative water quality management plan elements presented in this chapter are based on the areawide water quality management plan adopted by the Commission in 1979, including the land use element of that plan. With respect to water quality conditions and pollution source analyses, however, this report incorporates the findings of the most recent data collection efforts, as described in Chapter VI, Volume One, of this report.

Surface water use objectives and supporting water quality standards were the primary basis for plan design and evaluation. For the purposes of the initial water quality analyses, the water use objectives and supporting standards used were those set forth in Chapter II of this volume. The water quality standards specify maximum or minimum levels for certain substances indicative of water quality conditions, including a broad range of toxic substances, that are required to support recreational uses in the water, and desired healthy populations of fish and other aquatic life. A reevaluation of the initially proposed water use objectives and supporting standards was conducted, based upon the findings of the biological, water quality, and sediment quality inventories, as set forth in Chapter VI of Volume One of this report, and the review of designated water use classifications and supporting water quality standards conducted by the Wisconsin Department of Natural Resources in 1984 and 1985.

The review conducted by the Wisconsin Department of Natural Resources included a determination of the potential uses of each river segment comprising the inner harbor and of the outer harbor; an assessment of the factors which may be impairing those uses; the identification of the degree to which available measures could mitigate or eliminate those impairing factors; and a determination of the economic feasibility and environmental consequences of attaining the desired uses. The review was conducted by the Department in order to meet the requirements of Section 24 of U. S. Public Law 97-117, the 1981 Municipal Wastewater Treatment Construction Grant Amendments. The findings of this review, together with the findings of the comparative analyses of the alternative water pollution abatement measures considered, as set forth in this chapter, were utilized in the development of the recommended water quality management plan for the Milwaukee Harbor estuary, and in the establishment of a final set of recommended water use objectives and supporting standards.

The types and levels of pollution abatement which are technically sound and economically feasible influence the extent to which the water use objectives can be achieved. Point source pollution abatement measures have historically been given high priority in the resolution of surface water quality problems. Point source pollution abatement measures represent a highly advanced, well-developed technology, and point sources of pollution and their effects on surface water quality conditions can be relatively accurately quantified because of the manner of introduction of the pollutants into the surface water systems. Nonpoint source pollution abatement measures represent a more recently developed technology, and nonpoint sources and their effects on surface water conditions cannot be quantified as readily, or as well, as point sources and their affects. Recent studies, however, have contributed greatly to the knowledge of the pollutant loading characteristics of various nonpoint sources; of the effectiveness of nonpoint source pollution abatement measures; and of the degree of pollution control that may be expected to be achieved by various measures.[2]

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[2] *U. S. Environmental Protection Agency, Great Lakes National Program Office, The IJC Menomonee River Watershed Study, 1979; Wisconsin Department of Natural Resources, Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin, 1983; and U. S. Environmental Protection Agency, Results of the Nationwide Urban Runoff Program, 1983.*

Combined Sewer Overflow Abatement Measures

The combined sewer overflow abatement plan originally proposed in the comprehensive plan for the Milwaukee River watershed prepared and adopted by the Regional Planning Commission in 1972,[3] and ultimately incorporated into the Milwaukee Metropolitan Sewerage District's advanced facility plan,[4] is herein summarized. That plan was used as a basis for determining probable future water quality conditions in the harbor estuary. The design criteria, cost estimating procedures, and cost-effectiveness analyses are set forth in the facility plan documents.[5] The primary design consideration evaluated in the harbor estuary study was the level of protection required to be provided by the combined sewer overflow abatement measure. As of February 1986, the Milwaukee Metropolitan Sewerage District estimated that the storage facilities designed to contain excess discharge from the separate sewered areas would also provide for combined sewer overflow abatement at a 0.7-year level of protection.

Other Point Source Abatement Measures

A major finding of the areawide water quality management planning effort was that more stringent control of point sources would be needed to meet water use objectives and supporting water quality standards for streams within the drainage area tributary to the Milwaukee Harbor estuary. The recommended levels of point source effluent quality were designed to achieve the water use objectives and supporting water quality standards in the receiving streams. The areawide water quality management plan did not determine whether water use objectives or supporting water quality standards should be met within the Milwaukee Harbor estuary itself, explicitly leaving that complex task to be accomplished under a special study of the estuary. The harbor estuary study, therefore, investigated whether or not the quality of upstream point source effluents, as recommended in the water quality management plan, should be changed in order to meet the recommended water use objectives and supporting water quality standards for the estuary. The locations of point sources and the attendant discharge volumes assumed in the harbor estuary study under future conditions are those set forth in the adopted areawide plan. The point source criteria and analytic procedures utilized in the preparation of the areawide plan are described on pages 50 through 60 of SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative Plans, February 1979. The design criteria and assumptions set forth in SEWRPC Planning Report No. 30 were also utilized in the harbor estuary study, although all costs were updated to 1986.

Nonpoint Source Abatement Measures

The areawide water quality management plan indicated that nonpoint source pollution abatement would be necessary to fully meet the water use objectives and supporting standards for the lakes and streams lying within the drainage area tributary to the Milwaukee Harbor estuary. That plan did not determine the level of nonpoint source abatement needed to meet the water quality standards within the estuary, again, explicitly leaving that task to be accomplished under a special study of the estuary. Water quality analyses were conducted under the harbor estuary study to determine the effect that a reduction in nonpoint source pollutant loadings would have on the achievement of the recommended water quality standards within the estuary. The nonpoint source criteria and analytic procedures utilized in the preparation of the areawide water quality management plan are set forth on pages 60 through 67 of SEWRPC Planning Report No. 30, Volume Two, Alternative Plans.

Instream Measures

Instream measures could be used to supplement point and nonpoint source pollution abatement measures and to thereby improve water quality conditions in the Milwaukee Harbor estuary. An

[3] *SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed, Volume One, Inventory Findings and Forecasts, December 1970; and Volume Two, Alternative Plans and Recommended Plan, October 1971.*

[4] *Milwaukee Metropolitan Sewerage District, Combined Sewer Overflow Advanced Facility Plan, December 1983.*

[5] *Milwaukee Metropolitan Sewerage District, Combined Sewer Overflow, Vol. 3, Part 2, June 1980, Appendix 6I—"Unit Cost Data," Appendix 6J—"Cost Estimating Procedures and Cost-Effectiveness Analysis," and Appendix 6M—"Level of Protection"; and Combined Sewer Overflow Advanced Facility Plan, Vol. 5, Part 2, December 1983, Appendix B—"Design Criteria—Sewer Systems," and Appendix C—"Instrumentation and Control Memorandum and and Design Instructions."*

instream treatment concept was considered in the preparation of the Milwaukee Metropolitan Sewerage District facility plan.[6] Several instream measures—chemical coagulation, sedimentation and solids removal by conventional mechanical means, and disinfection—were identified in the facility plan but eliminated from further consideration because of technical and environmental limitations. Three instream measures were evaluated in the District facility plan: flow augmentation, aeration, and dredging. Alternative dredging plans are set forth in Chapter V of this volume.

This chapter describes the development and evaluation of four water quality management plans which utilize instream measures: 1) continuous or intermittent use of the existing Milwaukee River and Kinnickinnic River flushing tunnels; 2) construction and continuous or intermittent use of a new flushing tunnel which would discharge to the Menomonee River estuary; 3) relocation and/or modification of the Wisconsin Electric Power Company valley power plant spent condenser cooling water outfall, which presently discharges to the South Menomonee Canal; and 4) instream aeration of the Menomonee River estuary. The existing flushing tunnels were assumed to be capable of operating at the full capacity of 600 cubic feet per second (cfs) to the Milwaukee River, and 350 cfs to the Kinnickinnic River. Instream aerators were designed using criteria and procedures set forth in the Milwaukee Metropolitan Sewerage District report entitled, Combined Sewer Overflow, Volume 3, Part 2, Appendix 6F, June 1980. The instream aerators were sized and located to help achieve the recommended dissolved oxygen standards in the Menomonee River estuary.

Economic Evaluation

The concepts of economic analysis and economic selection are vital to the public planning process. Sound economic analysis should be an important guide to planners and decision-makers in the selection of the most suitable plan from an array of alternatives. With respect to water quality management planning, the cost-effectiveness of a given control measure refers to the cost of that measure relative to the attendant water quality improvements that may be expected. Therefore, the most cost-effective measure provides the most water quality benefits at the lowest cost.

The costs presented in this report are sufficiently accurate for systems level planning, but should be refined during facilities planning and project engineering. At the systems level of planning, the cost information is used primarily to compare alternatives on a consistent basis.

Planning Period and Economic Life: The physical life of a facility is that period between its original construction and final disposal of the facility. The economic life is defined as the period after which the incremental benefits from continued use no longer exceed the incremental cost of operation. In the economic analyses conducted under the Milwaukee Harbor estuary study, the time period over which a facility is totally depreciated was made equal to the economic life.

Although the plan design year for the Milwaukee Harbor estuary study is 2000, the economic life of certain planned facilities will extend beyond this design year. Accordingly, a salvage value was assigned to those facilities with an economic life extending beyond the end of the economic analysis period. For purposes of the economic analyses, an economic life of 50 years was assumed for sewers, stormwater storage structures, major structural facilities, and land; an economic life of 25 years was assumed for pumps and other major electrical and mechanical equipment; and an economic life of 10 years was assumed for aerators. While the plan design period used was 15 years, from 1986 to 2000, the economic analysis period used was 1986 to 2035. All costs are expressed in 1986 dollars. An interest rate of 6 percent was used in all the economic analyses under the Milwaukee Harbor estuary planning program.

Following sound principles of engineering economic analyses, no escalation over time of construction, operation, maintenance, or replacement costs was considered. In the economic evaluations, provisions for the replacement of shorter-lived components were incorporated into the total economic costs through the selection of an economic life. The economic analyses of alternatives assume replacement of facilities at specific life intervals. As already noted, a salvage value was credited to facilities whose economic life extended beyond the year 2035.

Construction Capital Costs: The construction costs presented in the Milwaukee Metropolitan Sewerage District facility plan for those facilities that were evaluated during preparation of the plan were updated to 1986. Other construction costs were

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[6] *Milwaukee Metropolitan Sewerage District, Combined Sewer Overflow, Vol. 3, Part 2, Appendix 6F, "Instream Concept," June 1980.*

calculated using 1986 unit prices, which reflect the type and size of facility or control measure, location, and regional labor and material costs. These construction costs were multiplied in the economic analyses by a factor of 1.35 to obtain total capital costs. The 35 percent was added to account for contingencies, engineering and legal fees, administrative costs, and financing costs.

Present Worth and Annual Costs: Four terms are commonly used in preparing economic analyses of important engineering projects: the single payment present worth factor (PWF), the uniform series present worth factor (SPWF), the gradient present worth factor (GPWF), and the capital recovery factor (CRF).

The single payment present worth factor converts the cost of a single expenditure at some future time to an equivalent present value. The uniform series present worth factor converts a series of future uniform annual payments to equivalent present value. Where annual payments are increasing by a fixed amount, the gradient present worth factor is used to determine the equivalent present value of the series. The present worth of future single, uniform, or nonuniform annual series payments is always less than the absolute value of the single payment or the sum of the annual payments. The capital recovery factor converts a lump payment at the beginning of a period into a series of uniform annual payments over the length of the period. The sum of these uniform annual payments is always greater than the lump payment. The uniform annual payments—or annual costs—allow alternatives with nonuniform series of costs to be compared.

It should be noted that, given the same interest rate and the same estimated series of costs, comparisons by annual cost lead to the same conclusions as comparisons by present worth. The economic analysis utilizing present worth and annual costs allows alternatives to be compared in monetary terms. This enables public officials to evaluate more objectively and explicitly the benefits and costs of alternative plans to assure that the public will receive the greatest possible benefits from limited monetary resources.

DESCRIPTION OF WATER QUALITY MANAGEMENT ALTERNATIVES

To abate the existing water quality problems described in Chapter VI of Volume One of this report, and to meet the water use objectives and supporting water quality standards presented in Chapter II of this volume, several water quality management measures were considered:

1. Committed action to abate pollution of the Milwaukee Harbor estuary, including abatement of combined sewer overflows at a 0.7-year level of protection.

2. Abatement of combined sewer overflows at higher levels of protection.

3. Low-flow augmentation of the inner harbor using the existing flushing tunnels that discharge to the Milwaukee River and Kinnickinnic River.

4. Low-flow augmentation of the inner harbor using the existing flushing tunnels plus a new flushing tunnel that would discharge to the Menomonee River.

5. Instream aeration of the Menomonee River estuary and low-flow augmentation using the existing flushing tunnels.

6. Abatement of nonpoint sources of pollution located upstream of the combined sewer service area.

7. Reduction in phosphorus loadings from point sources of pollution located upstream of the combined sewer service area.

8. Modifications to, or relocation of, the condenser cooling water outfalls of the Wisconsin Electric Power Company valley power plant and low-flow augmentation using the existing flushing tunnels.

9. Dredging of the bottom sediments in the inner harbor and outer harbor to improve water quality conditions.

10. Modifications to the operation of the North Avenue and Estabrook Park dams on the Milwaukee River.

11. Relocation of the Jones Island sewage treatment plant outfall.

Alternatives 1 through 8 were found to provide some water quality benefits and to be technically feasible. These alternatives were considered further. Alternatives 9 through 11 were not considered to be effective, or technically feasible, and therefore were not considered further in the evaluation. Dredging and disposal alternatives are discussed in Chapter V. That chapter concludes that while maintenance dredging for navigation purposes would have to be continued, no additional dredging for water quality improvement purposes is required. The data currently available regarding conventional pollutants indicate that dredging the bottom sediments would not result in substantial improvements in water quality conditions with respect to dissolved oxygen, fecal coliform, ammonia, or phosphorus. Accordingly, dredging was not considered further as a water quality management measure in this evaluation, which was directed toward conventional pollutants.

The intent of the revised operation of the Milwaukee River dams would be to reduce the supply of algae, which may grow rapidly in the upstream impoundments, and the volume of oxygen-depleted waters which may form in the bottom layers of the impoundments owing to organic sediment decomposition, and then flow into the Milwaukee River estuary. Statistical analysis of water quality data collected both upstream and downstream of the impoundments, however, indicated that the downstream levels of chlorophyll-a and dissolved oxygen were not significantly different from those found upstream of the impoundments. It was concluded, therefore, that revised operation of the Milwaukee River dams would not result in significant water quality improvement in the harbor estuary. Accordingly, this alternative was not considered further. It should be noted that actual removal of the dams, while not providing water quality benefits, could improve aquatic habitat conditions, including cover, spawning, and feeding areas. The removal of these dams may be controversial, however, because of the intensive recreational use and aesthetic value of the associated impoundments. Modifications of the Milwaukee River dams may be considered for purposes other than water quality enhancement in the estuary, but would require detailed evaluation and public review.

Relocation of the Jones Island sewage treatment plant outfall would substantially reduce the loadings of pollutants—the most important of which are phosphorus and ammonia—to the outer harbor. However, the analyses indicated that these pollutant loadings to the outer harbor, while significant, do not preclude the attainment of desired water use objectives within the outer harbor. Furthermore, relocation of the plant outfall to Lake Michigan would have a serious adverse effect on the water quality of a localized area of the lake.

Each of the eight technically feasible water quality management alternatives is described in greater detail below. For each alternative, the technical effectiveness, applicability, and estimated costs are presented.

All of the alternatives, including the committed action alternative, assume the implementation of committed measures. Such measures include the abatement of combined sewer overflows at a level of protection of 0.7 year, the elimination of discharges from separate sanitary sewer flow relief devices, and continued dredging of the bottom sediments in the inner and outer harbors in order to maintain navigation. The costs of these committed actions are included in the cost of the water quality element of this plan.

Although the information presented in this chapter is intended to provide a basis for the comparative evaluation of the eight alternative plans, it must be recognized that not all of the alternatives considered equally abate the water quality problems of the Milwaukee Harbor estuary. Therefore, a simple cost comparison cannot be used to determine the most economically efficient alternative. Following the evaluation of the alternative plans, a recommended plan was selected on the basis of its practicality, cost, and ability to meet the water use objectives for the harbor estuary.

Committed Action Alternative

The committed action alternative includes the implementation of the following previously committed measures:

1. Abatement of combined sewer overflows at a 0.7-year level of protection.

2. Elimination of separate sanitary sewer flow relief devices.

3. Continued dredging of bottom sediments for maintenance of navigation.

No other water quality management actions, including continued operation of the Milwaukee and Kinnickinnic River flushing tunnels, would be undertaken. Continued operation of the flushing tunnels was not considered to be a committed decision under this alternative.

Abatement of Combined Sewer Overflows: The committed action alternative includes the abatement of combined sewer overflows using the measures recommended in the Commission's adopted Milwaukee River watershed plan and areawide water quality management plan as those plan recommendations were refined and detailed in the facility planning efforts conducted by the Milwaukee Metropolitan Sewerage District. During dry-weather conditions, the combined sewers convey up to 68 million gallons per day, including clearwater infiltration, to the Jones Island sewage treatment plant. During intense storm events, combined sewer flows can exceed 60 times the daily capacity of the sewage treatment plant. Overflows of combined stormwater runoff and untreated sanitary sewage occur at 109 outfalls within the combined sewer service area. These overflows occur on an average of 50 times each year, with a total annual duration of about 150 hours. The combined sewer service area and the location of the existing outfalls are shown on Map 4.

In the preparation of the system and facility plans, a wide range of alternatives for the abatement of combined sewer overflows was considered. These alternatives included the provision of centralized tunnel storage, decentralized near-surface storage, sewer separation, and combinations of these measures. These alternatives were documented in a series of District reports, including Combined Sewer Overflows, June 1980; Inline Storage Facilities Plan, February 1982; and Combined Sewer Overflows Advanced Facility Plan, December 1983. The District's facility plan recommended that a deep tunnel inline storage system be constructed to abate excessive infiltration and inflow problems in the separately sewered area and to help relieve the metropolitan interceptor sewer system during wet weather, as well as to provide storage for combined sewer overflows.

Approximately 470 bypasses or relief pumping facilities have been constructed in the District conveyance system to relieve surcharging of separate sanitary sewers and attendant basement flooding. The inline storage system is intended to abate these separate sewer discharges, as well as to reduce the occurrence of combined sewer overflows to about once every eight months.

It is important to recognize that the inline storage system is related to other committed actions to improve the sewerage system, including removal of clearwater infiltration and inflow, treatment plant rehabilitation and expansion, interceptor sewer rehabilitation, and new interceptor sewer construction. A sewer system evaluation survey conducted by the District established separately sewered area storage requirements and provided flow data used for sizing the storage facilities. Advanced facility planning and design for the sewage treatment plants furnished data on storage facility pumpout rates, storage volumes, solids handling and treatment requirements, and sizing of force mains.

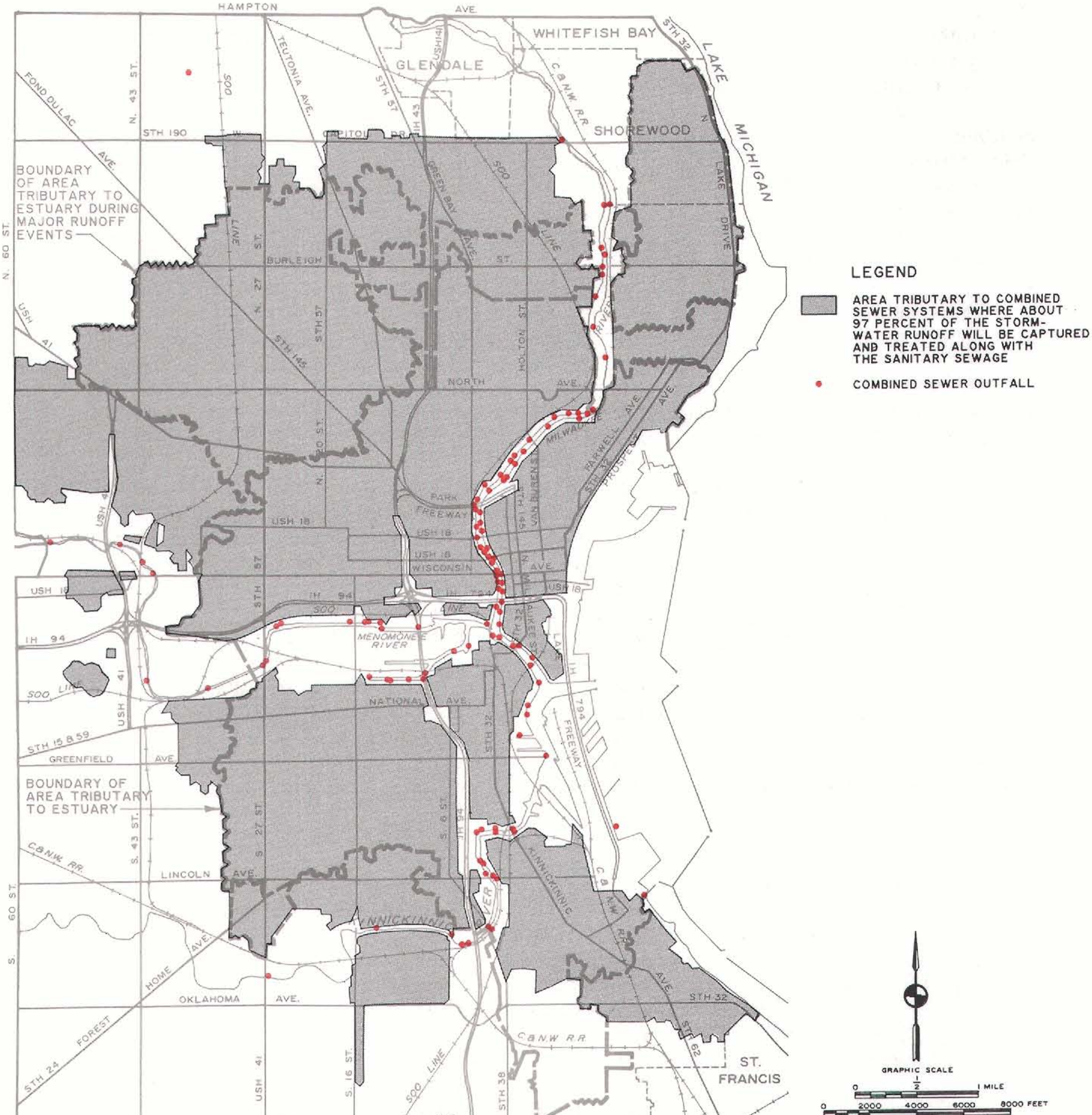
One function of the inline storage system is the temporary storage of combined sewer overflows until the Jones Island or South Shore sewage treatment plants can accept and treat the wastewater. The inline storage facilities, which are designed and sized to convey and store flows from the separately sewered areas, will also provide for storage of combined sewer overflows at an approximately 0.7-year level of protection. If additional storage capacity is required for the overflows in order to meet water quality objectives for the Milwaukee Harbor estuary, the deep tunnel inline storage and conveyance capacities would need to be increased by excavating additional storage capacity.

Approximately 1,140 acre-feet of storage are to be provided for combined sewer overflows and excessive flows from the separately sewered area. A mathematical flow control and storage routing simulation model was used to estimate the volume, duration, and frequency of overflows which may be expected to occur after the storage facilities are constructed. The simulation model applications, using rainfall records from 1940 through 1979, indicated that overflows may be expected to occur on the average of once every 0.7 year. The minimum, mean, and maximum volume of overflows occurring over this 40-year period would be 4 and 832 and 4,313 acre-feet, respectively. The mean duration of an overflow would be about 12 hours. About 51 percent of the overflows would occur during the summer months of June, July, and August; about 24 percent during the spring months of March, April, and May; about 18 percent during the fall months of September, October, and November; and about 7 percent during the winter months of December, January, and February. Even during major storm events, the initial runoff, which may be expected to contain the highest levels of pollutants, would be captured before the system overflowed. The overflows would be discharged through the existing combined sewer outfalls.

The combined sewer overflow abatement facilities recommended in the advanced facility plan have an estimated capital cost of $204 million in 1986 dollars, and an annual operation and maintenance cost of $617,000.

Map 4

COMBINED SEWER SERVICE AREA AND OUTFALLS: 1979



The central area of the City of Milwaukee and portions of the Village of Shorewood are served by a combined sanitary and storm sewer system. Intercepting sewers paralleling the rivers are designed to carry the dry-weather sanitary sewage from the combined sewers and a small portion of the wet-weather flow to the Jones Island treatment plant, with excess wet-weather flows discharged directly to the estuary through combined sewer outfalls. Overflows of combined storm runoff and untreated sanitary sewage occur at 109 outfalls within the combined sewer service area. Of these 109 outfalls, 87 discharge to the harbor estuary and to Lake Michigan. Overflow from these outfalls occurs an average of 50 times each year, with a total annual duration of about 150 hours.

Source: Milwaukee Metropolitan Sewerage District.

Elimination of Discharges from Separate Sanitary Sewer Flow Relief Devices: The Commission's areawide water quality management plan recommended the abatement of discharges from separate sanitary sewer flow relief devices within the entire drainage area tributary to the Milwaukee Harbor estuary. These flow relief devices include bypasses, crossovers, pumping stations, and combined sewers which discharge untreated sanitary waste to surface waters. Elimination of the flow relief devices would be accomplished by expansion of wastewater treatment plants, construction of new trunk sewers, and other sewerage system improvements. Emergency bypass structures would need to be retained to protect sewerage facilities and prevent backups in the event of severe flooding, power outage, equipment failure, or insufficient pumping capacity. These bypasses, however, would be used only in extreme emergencies, and therefore very infrequently. Within the Milwaukee Metropolitan Sewerage District service area, flow relief devices would be abated by the expansion and upgrading of the Jones Island and South Shore sewage treatment plants, new sewer construction, and the construction of the deep tunnel inline storage system.

The abatement of separate sanitary sewer flow relief devices would entail a capital cost of about $134.4 million, and an annual operation and maintenance cost of about $923,000.

Continued Dredging of Bottom Sediments for Maintenance of Navigation: As set forth in Chapter V of this volume, continued dredging of the portions of the estuary used for waterborne commerce is recommended to maintain navigation. Dredged areas are recommended to be maintained at the project water depths established by the U. S. Army Corps of Engineers. Such dredging is expected to require the removal of between 65,000 and 130,000 cubic yards of dredge spoils per year. It is also recommended that the dredge spoils be deposited in the existing outer harbor confined disposal facility, or in a new disposal facility recommended to be constructed just north of the existing facility. Over the 15-year period from 1986 through 2000, the recommended maintenance dredging plan would have an estimated capital cost of $11.9 million, and an average annual operation and maintenance cost of about $600,000.

The findings of the water quality analyses reported in Chapter V indicate that it is not necessary to dredge the bottom sediments to abate dissolved oxygen and other conventional pollutant problems in the estuary. Dredging was also not recommended as a means of improving aquatic habitat for fish and other aquatic life. Further study of the sources, fate, and transport of certain toxic substances—especially metals—in the bottom sediments was recommended to determine whether dredging beyond that required to maintain navigation is needed to abate pollution by toxic substances.

Elimination of Combined Sewer Overflows Alternative

Virtual elimination of combined sewer overflows would require the provision of additional storage volume to accommodate an interval event of approximately 100 years. The inline storage system, designed to provide a 0.7-year level of protection for combined sewer overflow abatement, would result in overflow volumes as large as 4,313 acre-feet being discharged to surface waters. Thus, an additional 4,300 acre-feet of storage volume would be necessary to store the largest expected overflow volume, based on 40 years of precipitation records—during which an event having an 85-year recurrence interval was experienced. To accommodate this additional overflow, it was assumed that a cavern would be mined in Niagara dolomite beneath the inner harbor. For the purpose of analyzing the water quality effects of this alternative, it was assumed that no combined sewer overflows would occur.

This alternative would have a capital cost of about $350 million and an annual operation and maintenance cost of about $1.0 million. These costs are in addition to the cost of abatement of combined sewer overflows at a 0.7-year level of protection.

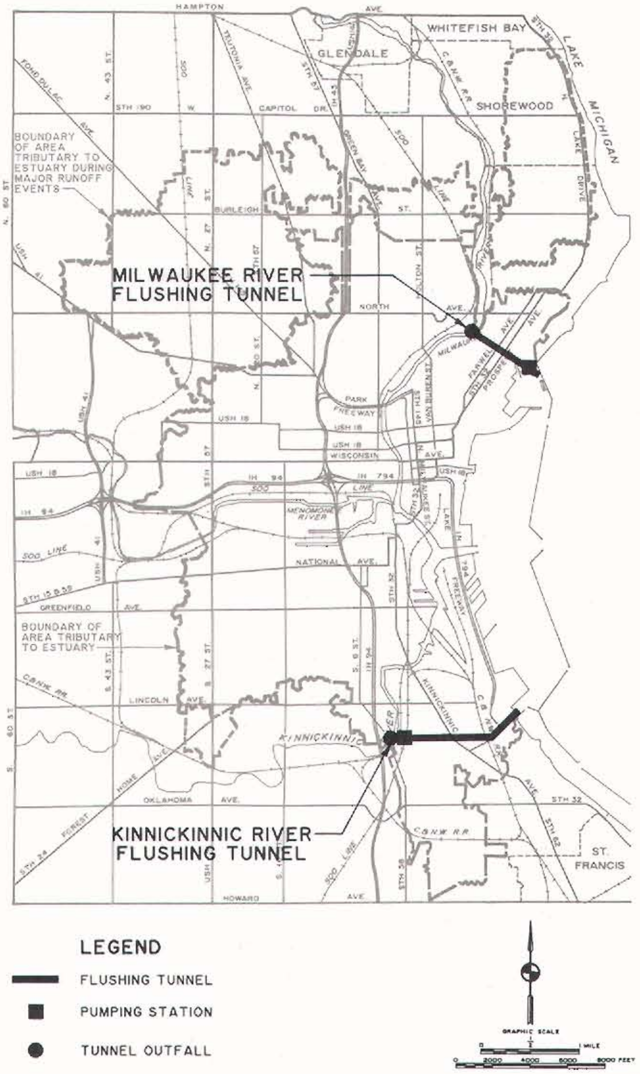
Low-Flow Augmentation Alternative

This alternative consists of two subalternatives. The first subalternative—referred to as the existing flushing tunnels subalternative—would include the continued operation of the Milwaukee and Kinnickinnic River flushing tunnels. The existing pump capacities and equipment would be retained, but the frequency and duration of tunnel operation would be modified to provide optimal water quality benefits. This subalternative would not include the construction of a new flushing tunnel to discharge water to the Menomonee River estuary.

The existing flushing tunnels augment flows in the Milwaukee and Kinnickinnic Rivers by pumping water from the outer harbor into the Milwaukee River just downstream of the North Avenue dam, and to the Kinnickinnic River just downstream of S. Chase Avenue, as shown on Map 5. The Milwau-

Map 5

EXISTING MILWAUKEE AND KINNICKINNIC RIVER FLUSHING TUNNELS



The Milwaukee River flushing tunnel, constructed in 1888, has a capacity of about 600 cubic feet per second (cfs) and discharges water from the outer harbor to the Milwaukee River just downstream of the North Avenue dam. The Kinnickinnic River flushing tunnel, constructed in 1907, has a capacity of about 350 cfs and discharges water from the outer harbor to the Kinnickinnic River just downstream of S. Chase Avenue. Under this alternative, the flushing tunnels would continue to operate, although the frequency and duration of operation would be modified to provide optimal water quality benefits. Operation of the tunnels substantially increases low dissolved oxygen levels in the Milwaukee and Kinnickinnic River estuaries. Relatively minor benefits are provided for the Menomonee River estuary.

Source: SEWRPC.

kee River flushing tunnel, constructed in 1888, has a diameter of 12 feet, is about 2,500 feet in length, and has a capacity of about 600 cubic feet per second. The tunnel intake is located in the outer harbor near the Milwaukee Yacht Club. The Kinnickinnic River flushing tunnel, constructed in 1907, also has a diameter of 12 feet, is approximately 7,200 feet in length, and has a capacity of about 350 cfs. The tunnel intake is located in the outer harbor near the U. S. Coast Guard Station at E. Russell Avenue extended. When the tunnels are operated during low streamflow conditions, the resulting flow velocities in the Milwaukee and Kinnickinnic Rivers exceed 0.1 foot per second. Milwaukee Metropolitan Sewerage District studies indicate that this flow velocity is sufficient to keep flocculent material in suspension and effectively flush suspended solids and debris out of the inner harbor. Over the period 1982 through 1984, the Milwaukee River flushing tunnel was operated for a total of 500 hours, or an average of 167 hours per year; the Kinnickinnic River flushing tunnel was operated for a total of 1,236 hours, or an average of 412 hours per year. As indicated in Chapter VI of Volume One of this report, dissolved oxygen levels in the Milwaukee and Kinnickinnic River estuaries can be substantially increased by operation of the tunnels.

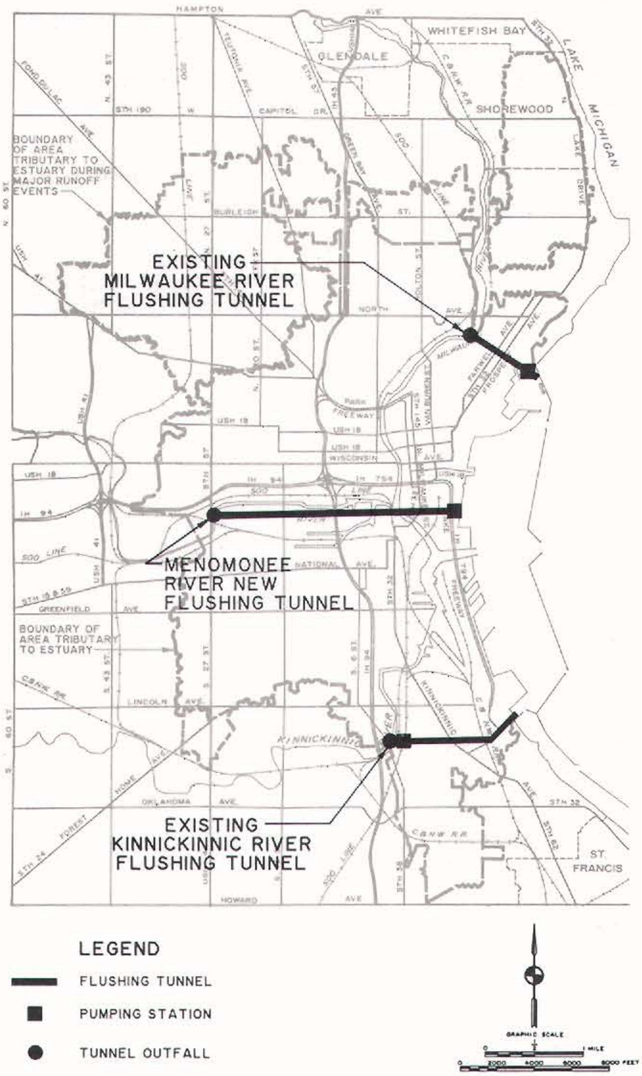
Under the existing flushing tunnels subalternative, the tunnels would be operated at full capacity about 20 percent of the time from May through September, an average of about 34 hours per week, or about 740 hours per year.

Continued operation of the tunnels would entail a capital expenditure of about $300,000 prior to the year 2000. Replacement of the pumps, which would be required around 2010, would entail a capital cost of about $1,460,000 for the Milwaukee River tunnel, and about $850,000 for the Kinnickinnic River tunnel. The existing flushing tunnels subalternative would have an annual operation and maintenance cost of about $70,000.

Under the second subalternative, referred to as the Menomonee River new flushing tunnel subalternative, the existing Milwaukee and Kinnickinnic River flushing tunnels would be operated as under the first subalternative. In addition, a new flushing tunnel would be constructed to discharge outer harbor water to the Menomonee River just upstream of N. 25th Street, as shown on Map 6. The new tunnel would be eight feet in diameter and have a capacity of about 350 cfs. The tunnel would be operated about 30 percent of the time from May through September, an average of about 50 hours per week, or about 1,090 hours per year.

Map 6

LOCATION OF FLUSHING TUNNELS UNDER THE NEW MENOMONEE RIVER FLUSHING TUNNEL SUBALTERNATIVE



Under this alternative, the existing Milwaukee and Kinnickinnic River flushing tunnels would continue to operate at a modified duration and frequency. In addition, a new flushing tunnel, with a discharge capacity of about 350 cfs, would be constructed to discharge outer harbor water to the Menomonee River just upstream of S. 25th Street. This alternative would substantially improve dissolved oxygen levels throughout the inner harbor.

Source: SEWRPC.

The Menomonee River new flushing tunnel subalternative would require a capital cost of about \$24.3 million, and an annual operation and maintenance cost of about \$95,000. About \$24 million, or nearly 99 percent, of the capital cost, and \$25,000, or 26 percent, of the operation and maintenance cost would be required for construction and operation of the new Menomonee River flushing tunnel.

An option that could be considered under the Menomonee River new flushing tunnel subalternative to reduce the capital cost is the installation of an eight-foot-diameter steel pipe within the inline storage system presently being constructed. This would reduce the length of the new flushing tunnel to be constructed in-ground and could reduce the capital cost of this alternative by about 50 percent. Although technically feasible, further study would be required to determine the impact of this alternative on the functioning of the inline storage system being constructed.

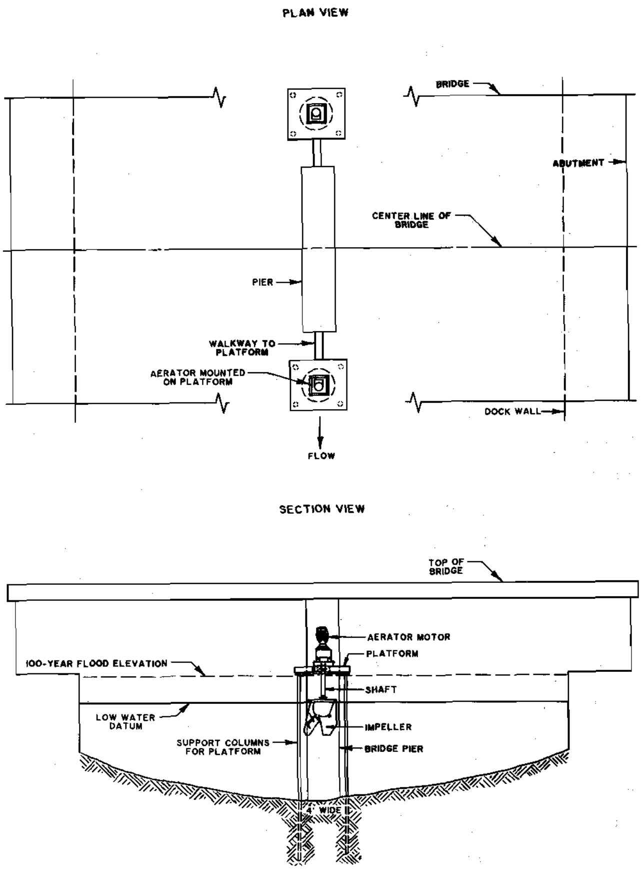
Menomonee River Instream Aeration Alternative

Under this alternative, instream aeration techniques would be used in the Menomonee River estuary to increase levels of dissolved oxygen. The existing flushing tunnels would continue to discharge to the Milwaukee and Kinnickinnic River estuaries. Two commonly used methods of instream aeration are diffusion aeration and mechanical surface aeration. Diffusion aeration involves the injection of pure oxygen or air into the water through porous diffusers or diffuser pipes located on the bottom of the river. As the oxygen or air rises toward the surface, some oxygen is dissolved into the water, thereby providing aeration. Mechanical surface aeration involves the use of an electric motor-powered impeller mounted on a vertical shaft and submerged below the water surface. As the impeller rotates, vertical mixing of the water column increases, which increases the transfer of oxygen from the air to the water.

The Milwaukee Metropolitan Sewerage District evaluated alternative instream aeration techniques for the entire inner harbor in its facilities planning effort. The District concluded that the use of mechanical surface aerators would be feasible in the inner harbor, and that the aerators could be anchored to bridge piers, thereby minimizing interference with navigation. A typical locational drawing of a mechanical surface aeration system attached to a bridge pier on the Menomonee River estuary is shown in Figure 47. The District study noted that mechanical surface aerators could be readily installed and maintained, and should provide high oxygen transfer efficiencies. The air diffusion technique was found to be less practical for use in the inner harbor. Coarse bubble diffusers, which would be required to prevent clogging, were found to have high initial costs and low oxygen-transfer efficiencies. Diffusion aerators would also interfere with dredging activities needed to maintain navigation.

Figure 47

TYPICAL LOCATIONAL ARRANGEMENT
OF AN INSTREAM AERATION SYSTEM



Source: SEWRPC.

The use of a diffused pure oxygen system can greatly reduce the piping and diffusion equipment needed, since the transfer of pure oxygen under pressure is substantially greater than the transfer of air. The main disadvantage is the need to purchase liquid oxygen for the process. However, installations using pure oxygen have been successfully installed in river systems. The use of such a system could minimize the facilities and maintenance needed and would eliminate navigation interference.

For costing purposes, it was assumed that low-speed surface aerators would be utilized. However, prior to implementation of this alternative, it is recommended that the options of a pure oxygen diffuser system and of other types of surface aerators, including rotating discs, be considered in the detailed facility planning phase.

Following the abatement of combined sewer overflows, it is estimated that under seven-day, 10-year recurrence interval ($Q_{7,10}$) low-flow conditions, the dissolved oxygen level in the Menomonee River at N. 25th Street would be 3 milligrams per liter (mg/l). To provide sufficient oxygen during critical low-flow summer periods, as well as during higher flow periods, it was estimated that 2,000 pounds per day of dissolved oxygen would need to be provided to the upstream end of the Menomonee River estuary.

In order to supply the amount of dissolved oxygen necessary to achieve the dissolved oxygen standards, this alternative would provide four 25-horsepower low-speed mechanical surface aerators in the Menomonee River estuary at the locations shown on Map 7. One aerator would be located at the Soo Line—former Chicago, Milwaukee, St. Paul & Pacific Railroad Company—bridge, just upstream of S. 25th Street; one aerator would be located at the S. 25th Street bridge; and two aerators would be located at the N. 16th Street bridge. With an assumed oxygen transfer efficiency of two pounds of dissolved oxygen per horsepower-hour, the aerators would be capable of providing up to 180 pounds of dissolved oxygen per hour of operation. It is estimated that the aerators would be operated for 1,200 hours annually.

The Menomonee River instream aeration alternative would have a capital cost of about $600,000, of which $300,000, or 50 percent, would be for the aeration system and $300,000, or 50 percent, would be for a major renovation of the existing flushing tunnels; and an annual operation and maintenance cost of about $80,000, of which about $10,000, or about 12 percent, would be for the aeration system, and $70,000, or 88 percent, would be for the operation of the existing flushing tunnels.

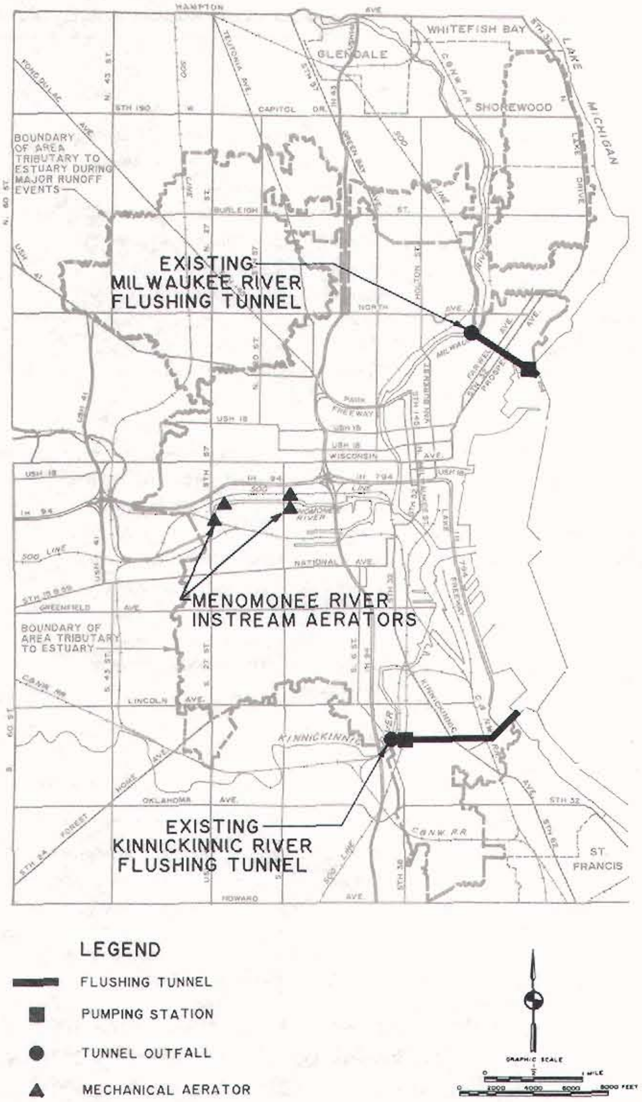
Abatement of Nonpoint Sources of Pollution Alternative

The nonpoint source alternative includes the implementation of the committed measures described for the committed action alternative, and the control of nonpoint sources of pollution upstream of the combined sewer service area. The control of nonpoint sources of pollution was recommended in the areawide water quality management plan for southeastern Wisconsin. The nonpoint source control measures, the anticipated levels of reduction in pollutant loadings, and the estimated costs of nonpoint source control are being refined in the priority watershed program for the Milwaukee River basin being conducted by the Wisconsin Department of Natural Resources.

The areawide water quality management plan indicated that many of the streams within the Milwaukee Harbor estuary drainage area were

Map 7

MENOMONEE RIVER INSTREAM AERATION ALTERNATIVE



Under this alternative, four 25-horsepower mechanical surface aerators would be placed in the Menomonee River estuary: one at the Soo Line bridge upstream of S. 25th Street; one at the S. 25th Street bridge; and two at the N. 16th Street bridge. The existing Milwaukee and Kinnickinnic River flushing tunnels would continue to operate at a modified duration and frequency. A similar alternative would provide for the diffusion of pure oxygen to the Menomonee River at about the same location, but would not require the mechanical aerator system. This alternative would substantially improve dissolved oxygen levels throughout the inner harbor.

Source: SEWRPC.

polluted by oxygen-demanding organic substances, phosphorus, fecal coliform organisms, and ammonia nitrogen contributed by nonpoint sources. To meet the water use objectives and supporting water quality standards set forth in the plan, categories of nonpoint source control measures were recommended to be implemented. Alternative categories of control measures and the approximate level of pollution control expected to be achieved are shown in Table 16.

The systems level, areawide water quality management plan provided overall goals for nonpoint source pollutant reductions and recommended sets of control measures for implementation. The plans recommended more detailed, second level planning efforts to determine how best to achieve the recommended pollutant reduction goals.

For the entire Milwaukee Harbor estuary study area—except the direct drainage area to Lake Twelve in Washington County—the minimum nonpoint source control measures were recommended to abate pollution from both urban and rural nonpoint sources. While the level of pollution control achieved by these minimum measures was expected to vary, depending upon the specific pollutant and the types and severity of pollution sources, these measures were expected to achieve a reduction of approximately 25 percent in pollutant loadings. Additional nonpoint source control measures were recommended for the direct drainage area to Lake Twelve to achieve more than a 50 percent reduction in nonpoint source pollutants. In the areawide water quality management plan it was estimated that implementation of the recommended nonpoint source control measures within the Milwaukee Harbor estuary drainage area would entail a capital cost of $86 million in 1986 dollars, with an annual operation and maintenance cost of about $2.7 million. At the completion of the areawide plan, it was believed that more effective, and costly, nonpoint source control measures would not be needed to meet the recommended water use objectives within the surface waters tributary to the Milwaukee Harbor estuary.

The priority watersheds program for the Milwaukee River basin is intended to refine, and build upon, the abatement levels and measures recommended in the adopted systems level plans by identifying the most cost-effective nonpoint source abatement measures needed to achieve water use objectives throughout the basin. The priority watersheds program will utilize and incorporate the results of studies on nonpoint source control measures completed since the adoption of the areawide water quality management plan in order to refine the selection of control measures within each watershed. Specifically, the Nationwide Urban

Table 16

ALTERNATIVE CATEGORIES OF NONPOINT SOURCE CONTROL MEASURES PROPOSED IN THE AREAWIDE WATER QUALITY MANAGEMENT PLAN

Nonpoint Source Pollution Control Category	Approximate Level of Pollutant Loading Reduction	Measures to Control Nonpoint Source Pollution from Urban Areas	Measures to Control Nonpoint Source Pollution from Rural Areas
Minimum Nonpoint Source Control Measures	25 percent	Public education programs; litter and pet waste control; retricted use of fertilizers and pesticides; construction erosion control; septic tank system management; critical area protection; improved timing and efficiency of street sweeping, leaf collection, and catch basin cleaning; and industrial and commercial material storage facilities and runoff control	Public education programs, fertilizer and pesticide management, critical area protection, crop residue management, chisel tillage, pasture management, contour plowing, livestock waste runoff control, construction erosion control
Additional Nonpoint Source Control Measures	50 percent	Above, plus: Increased street sweeping, improved street maintenance and refuse collection and disposal, increased catch basin cleaning, stream protection, increased leaf and vegetation debris collection and disposal	Above, plus: Crop rotation, contour strip-cropping, grassed waterways, diversions, wind erosion controls, terraces, stream protection, livestock waste storage
	More than 50 percent	Above, plus: An additional increase in street sweeping, use of onsite stormwater storage measures in residential areas, parking lot stormwater runoff storage and treatment, use of urban stormwater storage and treatment facilities	Above, plus: Stormwater storage systems

NOTE: The minimum nonpoint source control measures were recommended in the areawide water quality management plan for the entire Milwaukee Harbor estuary study area upstream of the combined sewer service area except the drainage area to Lake Twelve, where additional measures required to achieve more than a 50 percent reduction in pollutants from rural nonpoint sources were recommended.

Source: SEWRPC.

Runoff Program (NURP) studies, the International Joint Commission Pollution from Land Use Activities Reference Group (PLUARG) studies, the Washington County Project, the small-scale nonpoint source projects, and implementation programs conducted under the Wisconsin Nonpoint Source Water Pollution Abatement Program all provide information on the effectiveness, applicability, and cost of various nonpoint source control measures. These studies and programs are described in Table 17.

Although the nonpoint source abatement plan being prepared under the priority watershed program is not expected to be completed until 1988, some estimates were made of the maximum level of nonpoint source control which is technically achievable, of the types of control measures which are likely to be implemented under the program, and of the effectiveness and costs of these control measures. These nonpoint source control estimates, based on the results of priority watershed plans prepared for other watersheds as well as the other studies described in Table 17, served as the basis for the design of the abatement of nonpoint sources of pollution alternative. This alternative is designed to achieve reductions in nonpoint source pollutant loadings that are similar to those recommended in the areawide water quality management plan for the lakes and streams in the study area upstream of the estuary.

Table 18 sets forth the recommended rural nonpoint source control measures, the maximum level of reduction in phosphorus loadings achievable, the reduction expected to be achieved under the priority watersheds program, and the attendant costs of rural nonpoint source control. The primary nonpoint source control measures are those that are likely to be the most commonly needed,

Table 17

MAJOR NONPOINT SOURCE STUDIES CONDUCTED SINCE COMPLETION OF THE AREAWIDE WATER QUALITY MANAGEMENT PLAN

Study or Program	Date	Description
International Joint Commission Menomonee River Watershed Study	1974-1979	The purpose of this study, funded by the U. S. Environmental Protection Agency, was to investigate the effects of land runoff on the pollution input to Lake Michigan and develop a predictive capacity for the sources, forms, and amounts of pollutants reaching Lake Michigan. The study was carried out by the Wisconsin Department of Natural Resources, the University of Wisconsin, and the Southeastern Wisconsin Regional Planning Commission
Washington County Project	1976-1982	The purposes of the Washington County Project, a nonpoint source control demonstration project sponsored by the U. S. Environmental Protection Agency, were to evaluate 1) land use and water quality effects with emphasis on urbanizing areas; and 2) the institutional arrangements for cities, villages, and counties. The interagency project involved the Washington County Soil and Water Conservation District, the Board of Soil and Water Conservation Districts, the University of Wisconsin, the Wisconsin Department of Natural Resources, the U. S. Soil Conservation Service, and the Southeastern Wisconsin Regional Planning Commission
Small-Scale Nonpoint Source Projects	1979-1980	A number of small-scale nonpoint source implementation projects were conducted by the Wisconsin Department of Natural Resources in Washington County. The Cedar Lake Inland Lake Renewal Project, using state inland lake program funds, installed a number of nonpoint source controls at critical locations tributary to the lake. In addition, two DNR Nonpoint Source Water Pollution Abatement Program Local Priority Projects, both barnyard runoff control systems, were completed—one in the Town of Germantown, Washington County, in the Menomonee River watershed, and one in the Town of Trenton, Washington County, in the Milwaukee River watershed
Nationwide Urban Runoff Program Study in Milwaukee County	1978-1984	The purposes of the Nationwide Urban Runoff Program study conducted in the Milwaukee area were to characterize the quality of urban stormwater runoff and evaluate the effectiveness of specific urban management practices, especially street sweeping. The study was largely sponsored by the U. S. Environmental Protection Agency and conducted by the Wisconsin Department of Natural Resources, the U. S. Geological Survey, and the Southeastern Wisconsin Regional Planning Commission

Source: SEWRPC.

Table 18

RURAL NONPOINT SOURCE POLLUTION ABATEMENT MEASURES: 1986-2000

Rural Pollution Source	Primary Abatement Measures	Secondary Abatement Measures	Maximum Technically Achievable			Expected Implementation of Priority Watershed Program[a]		
			Reduction in Phosphorus Loadings (percent)	Capital Cost (millions)	Average Annual Operation and Maintenance Cost	Reduction in Phosphorus Loadings (percent)	Capital Cost (millions)	Average Annual Operation and Maintenance Cost
Livestock Waste	Barnyard Runoff Control Manure Spreading Management Manure Storage	Livestock Fencing Livestock Crossings	60	$22	$ 800,000	30	$11	$400,000
Agricultural Land Runoff	Conservation Tillage Contour Plowing Contour Strip-cropping Grassed Waterways Crop Rotation	Public Education Proper Use of Fertilizers and Pesticides Terracing, Diversions Critical Area Stabilization Grade Stabilization Structures Stream Bank Stabilization Settling Basins	30	$ 9	$ 500,000	15	$ 4.5	$250,000
			Total Cost	$31	$1,300.000	--	$15.5	$650,000

[a]*It was assumed that implementation of the Milwaukee River Priority Watersheds Program would achieve about 50 percent of the maximum achievable level of control.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

cost-effective, and applied measures in the study area. The list of primary abatement measures includes some measures, such as manure storage, contour strip cropping, and grassed waterways, that have a substantial capital cost and that were not specifically recommended in the areawide plan. The studies and local level planning efforts completed since the areawide plan have indicated that these measures should be applied in order to effectively reduce rural nonpoint source pollutant loadings. The secondary control measures are additional measures which may also be eligible for cost-share funding under the priority watersheds program. It is estimated that livestock waste control measures, if implemented throughout the tributary drainage area, could reduce phosphorus loadings to surface waters from livestock by up to 60 percent, while complete implementation of the agricultural land management measures could reduce phosphorus loadings from agricultural land runoff by about 30 percent. Similar reductions could be expected for sediment loadings. For the purpose of evaluating the abatement of nonpoint sources of pollution alternative, it was assumed that implementation of the priority watersheds program would achieve about 50 percent of the maximum achievable level of control. Thus, it was assumed that program implementation would result in reductions in phosphorus loadings of approximately 30 percent and 15 percent from livestock waste and agricultural land runoff, respectively.

The rural nonpoint source control measures expected to be implemented under the priority watersheds program would have an estimated capital cost of $15.5 million, of which $11 million, or 71 percent, would be for livestock waste control, and $4.5 million, or 29 percent, would be for agricultural land management. The annual operation and maintenance cost for rural nonpoint source control would be about $650,000, of which about $400,000, or 62 percent, would be for livestock waste control, and about $250,000, or 38 percent, would be for agricultural land management.

Table 19 sets forth the recommended urban nonpoint source control measures, the maximum achievable level of pollutant loading reductions, the reductions expected to be achieved under the priority watersheds program, and the attendant costs of urban nonpoint source control. The most cost-effective urban nonpoint source control measures should be determined by locally prepared stormwater management system plans. These plans should address existing and probable future water quantity and quality problems. The plans should evaluate alternative stormwater collection, conveyance, storage, diversion, and infiltration systems, as well as nonpoint source pollution abatement measures, designed to resolve flooding, drainage, and water pollution problems. These stormwater management system plans should serve as a basis for the design and implementation of stormwater management measures.

Table 19

URBAN NONPOINT SOURCE POLLUTION ABATEMENT MEASURES: 1986-2000

Primary Abatement Measures	Secondary Abatement Measures	Level of Abatement	Expected Reduction in Urban Pollutant Loadings (percent)					Capital Cost (millions)	Annual Operation and Maintenance Cost
			Suspended Solids	Total Phosphorus	Lead	Chemical Oxygen Demand	Fecal Coliform		
Wet Detention Basins Infiltration Systems (grass roadside swales, disconnection of rooftop runoff from storm sewer systems, and infiltration sites for runoff from large paved areas and rooftops)	Public Education Catch Basin Cleaning Street Sweeping Leaf Collection Proper Use of Fertilizers and Pesticides Proper Oil and Grease Disposal Septic Tank System Management	Maximum Technically Achievable[a]	25	20	30	25	5	$340	$6,000,000
		Expected Implementation of Priority Watersheds Program[b]	15	10	15	15	5	$170	$3,000,000

[a] *For purposes of calculating the maximum achievable pollutant removal rates and the attendant costs, it was assumed that the primary abatement measures would be used to treat about 50 percent of the industrial, commercial, transportation, and institutional land areas, and about 10 percent of the residential land areas. The secondary abatement measures would be applied where needed to control critical nonpoint sources or to protect sensitive water resources.*

[b] *It was assumed that implementation of the Milwaukee River Priority Watersheds Program would result in the achievement of about 50 percent of the maximum achievable level of control.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

As already noted, the more recent studies of urban nonpoint source pollution abatement measures listed in Table 17 have indicated that those urban nonpoint source control measures classified as minimum measures in the areawide plan may be expected to result in only relatively minor reductions in pollutant loadings. The studies have indicated that to achieve the maximum level of pollution control practicable, substantial proportions of an urban area—ranging from about 10 percent of residential areas up to 50 percent of commercial and industrial areas—would have to be drained to wet detention basins or infiltration systems. These measures may be expected to result in the following reductions in pollutant loadings from urban nonpoint sources: lead, about 30 percent; suspended solids, about 25 percent; chemical oxygen demand, about 25 percent; phosphorus, about 20 percent; and fecal coliform organisms, about 5 percent. For the purpose of evaluating the abatement of nonpoint sources of pollution alternative, it was assumed that implementation of the priority watersheds program would achieve about 50 percent of the maximum level of control practicable. Thus, it was assumed that about 25 percent of the industrial, commercial, transportation, and institutional land areas, and about 5 percent of the residential land areas, would be drained to wet detention basins or infiltration systems. Such measures may be expected to result in a reduction of approximately 15 percent in loadings of suspended solids, lead, and chemical oxygen demand; 10 percent in loadings of phosphorus; and less than 5 percent in loadings of fecal coliform organisms.

The urban nonpoint source control measures expected to be implemented under the priority watersheds program would have an estimated capital cost of $170 million. The annual operation and maintenance cost of the urban nonpoint source controls expected to be implemented would be $3.0 million.

Table 20 sets forth the nonpoint source control measures for urban land under construction, the expected level of sediment loading reduction achieved, and the approximate cost of construction site erosion control. Construction site erosion control measures may be expected to reduce suspended solids loadings from such activity by 75 to 90 percent. Somewhat lower reductions may be expected for other pollutants. The recommended construction erosion control measures are expected to be fully implemented under the priority watersheds program.

The construction site erosion control measures would have an estimated capital cost of $10.3 million, and an average annual operation and maintenance cost of about $100,000.

The nonpoint source control measures expected to be implemented under the Milwaukee River Priority Watersheds Program would thus entail a total

Table 20

CONSTRUCTION SITE EROSION CONTROL MEASURES FOR THE MILWAUKEE HARBOR ESTUARY TRIBUTARY DRAINAGE AREA: 1986-2000[a]

Primary Erosion Control Measures	Secondary Erosion Control Measures	Expected Reduction in Sediment Loadings (percent)	Capital Cost (millions)	Average Annual Operation and Maintenance Cost
Stormwater Runoff Diversion and Control Mulching Modification of Construction Techniques and Timing	Sediment Basins Grade Stabilization Structures Revegetation of Disturbed Areas Filter Berms	75 - 90	$10.3	$100,000

[a]*It was assumed that construction site erosion control measures would be fully implemented under the Milwaukee River Priority Watersheds Program.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

capital cost of about $195.8 million, and an annual operation and maintenance cost of about $3,750,000. The measures expected to be implemented, which have a total annual cost about twice that estimated to be needed in the areawide plan, include the more costly measures which more recent studies have shown must be implemented if a significant reduction in nonpoint source pollutant loadings is to be achieved. It is hoped that in the conduct of the Milwaukee River Priority Watersheds Program, lower cost measures will also be found to be effective in reducing pollutant loadings from nonpoint sources. The abatement of nonpoint sources of pollution alternative does not include the above costs, which are expected to be expended under the priority watersheds program to improve water quality conditions upstream of the estuary. The cost of the alternative is limited to those expenditures required, beyond the anticipated expenditures under the priority watersheds program, to achieve the maximum level of nonpoint source control. Thus, the abatement of nonpoint sources of pollution alternative includes the implementation of additional urban and rural nonpoint source abatement measures that would entail a capital cost of about $185.5 million, and an annual operation and maintenance cost of about $3,650,000.

Reduction in Point Source Phosphorus Loadings Alternative

This alternative includes a level of phosphorus removal at sewage treatment plants beyond that presently achieved at such plants. As of 1986, there were 13 public sewage treatment plants discharging to the surface waters tributary to the Milwaukee River estuary and one treatment plant discharging to surface waters tributary to the Menomonee River estuary. The areawide water quality management plan recommended that two of these plants—the Thiensville treatment plant which discharges to Pigeon Creek, and the Germantown treatment plant which discharges to the Menomonee River—be abandoned.[7,8] The compre-

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[7]*SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, Volume Three, Recommended Plan, June 1979.*

[8]*As of December 1986, construction was underway for the connecting trunk sewer needed to provide for the abandonment of the Germantown sewage treatment plant, and facility planning had been completed for the trunk sewer needed for the connection of the Thiensville sewage treatment plant.*

hensive plan for the Milwaukee River watershed recommended that two additional plants be constructed—one at Forest Lake and one at Kettle Moraine Lake, both in Fond du Lac County. These plants would discharge to surface waters tributary to the Milwaukee River estuary.[9] Because of the small size of these plants, it was recommended in the regional water quality management plan that these two facilities consider alternatives providing for land application of plant effluent. If those options are implemented, no surface water discharge would be added to the Milwaukee River system. Additionally, even if these plants discharged to the surface water, the plant flows would be of such a size—less than 0.1 million gallon per day (mgd)—that there would be no significant impact on the estuary water quality. Selected characteristics of the existing sewage treatment plants—except those to be abandoned—are set forth in Table 21. The table shows that six of the sewage treatment plants provide conventional phosphorus removal, being designed to achieve an effluent concentration of about 1.0 mg/l of total phosphorus.

Regional Planning Commission studies undertaken as part of the areawide water quality management planning effort concluded that phosphorus concentrations in excess of 0.1 mg/l measured as total phosphorus in the streamwater may cause excessive aquatic plant growth and subsequent dissolved oxygen depletion. Excessive plant growth can occur in lakes and estuaries at phosphorus levels as low as 0.02 mg/l. Such plant growth may have an adverse effect on fish populations, either by impairing the aquatic environment or by causing dissolved oxygen problems as the plants die and decay and consume oxygen in the water. In addition, excessive aquatic plant growth impairs the aesthetic appeal and interferes with the recreational use of the water. Relatively luxuriant algal growths, which contribute to the observed dissolved oxygen problems, were measured in the Milwaukee River estuary. Much lower levels of algae were measured in the Menomonee and Kinnickinnic River estuaries, in part because of the faster flow velocities in these rivers.

[9] *SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed, Volume Two, Alternative Plans and Recommended Plan, October 1971.*

Section NR 102.04 of the Wisconsin Administrative Code requires that all sewage treatment plants that discharge to the Lake Michigan basin and serve a population exceeding 2,500 persons remove, on an annual basis, at least 85 percent of the phosphorus contributed to the plant. The Wisconsin Legislature in 1979 enacted a ban on the use of phosphorus-containing detergents. That ban expired in 1982 and was reinstated in 1984. With the ban, the concentration of phosphorus in the influent to sewage treatment plants averages 5 mg/l.[10] Thus, these treatment plants are required to consistently achieve, using conventional methods of phosphorus removal, an effluent concentration of 1.0 mg/l total phosphorus or less.

In order to prevent excessive aquatic plant growth in streams, the Commission's areawide water quality management plan recommended that a maximum total phosphorus concentration of 0.1 mg/l be achieved at least 90 percent of the time in those streams where full recreational use was desired. To meet that standard, the preliminary areawide water quality management plan, as taken to public hearing in April 1979, recommended that 11 sewage treatment plants in the area—the existing Adell, Campbellsport, Cascade, Fredonia, Grafton, Kewaskum, Newburg, Random Lake, and Saukville plants and the proposed Forest Lake and Kettle Moraine Lake plants—implement conventional phosphorus removal to achieve a phosphorus concentration of about 1.0 mg/l in the effluent. It was also recommended that three sewage treatment plants—West Bend, Jackson, and Cedarburg—implement a second level of phosphorus removal to achieve a phosphorus concentration of about 0.1 mg/l in the effluent.

This latter recommendation received a great deal of attention during the public review of the proposed preliminary plan. Opposition to the recommendation for a second level of phosphorus removal was lead by consulting engineers and centered on three concerns. First, concern was expressed about the added cost burden entailed in providing the additional phosphorus removal. Second, the technical feasibility of achieving an effluent discharge of 0.1

[10] *D. H. Schuettpelz, M. Roberts, and R. H. Martin, "Report on the Water Quality Related Effects of Restricting the Use of Phosphates in Laundry Detergents," Water Quality Evaluation Section, Wisconsin Department of Natural Resources, 1982.*

Table 21

SELECTED CHARACTERISTICS OF PUBLIC SEWAGE TREATMENT PLANTS IN THE MILWAUKEE RIVER WATERSHED: 1984[a]

Plant	Level of Treatment Provided	Type of Treatment	Disposal of Effluent	1984 Effluent Conditions: Flow (mgd) Annual Mean	Monthly Maximum	Monthly Minimum	Daily Maximum	Daily Minimum	Annual Mean Effluent Concentration: Suspended Solids (mg/l)	Total Phosphorus (mg/l)	Ammonia Nitrogen (mg/l)	BOD_5 (mg/l)
Kewaskum	Secondary Advanced Auxiliary	Activated Sludge Phosphorus Removal Disinfection	Milwaukee River	0.44	0.73	0.27	1.26	1.11	8.4	0.7	0.9	7.6
West Bend	Secondary Advanced Auxiliary	Activated Sludge Phosphorus Removal Disinfection	Milwaukee River	3.75	4.37	3.20	7.01	1.00	1.0	0.5	0.1	1.5
Jackson	Secondary Advanced Auxiliary Tertiary	Rotating Biological Contactors Phosphorus Removal Disinfection Sand Filters	Cedar Creek	0.35	0.44	0.22	1.06	0.17	3.6	0.6	0.7	4.3
Newburg	Secondary Auxiliary	Activated Sludge Disinfection	Milwaukee River	0.06	0.08	0.04	0.18	0.04	16.5	N/A	N/A	25.8
Fredonia	Secondary Auxiliary	Activated Biological Filtration Disinfection	Tributary of Milwaukee River	0.20	0.30	0.12	0.64	0.10	3.8	N/A	N/A	9.3
Grafton	Secondary Advanced Auxiliary	Activated Sludge Phosphorus Removal Disinfection	Milwaukee River	1.19	1.35	0.91	2.23	0.74	8.0	0.7	0.5	4.3
Cedarburg	Secondary Advanced Auxiliary	Trickling Filter Activated Sludge Phosphorus Removal Disinfection	Cedar Creek	2.02	2.90	1.20	6.90	1.20	20.4	0.7	0.3	7.3
Saukville	Secondary Advanced Auxiliary	Activated Sludge Phosphorus Removal Disinfection	Milwaukee River	0.52	0.91	0.00	1.01	0.28	8.9	0.6	N/A	10.7
Campbellsport	Secondary Auxiliary	Activated Sludge Disinfection	Milwaukee River and Soil Absorption	0.32	0.44	0.28	0.91	0.16	13.2	10.1	5.0	13.8
Random Lake	Secondary Auxiliary Tertiary	Rotating Biological Contactors Disinfection Sand Filter	Silver Creek	0.30	0.47	0.23	0.58	0.18	2.7	1.4	N/A	3.7
Cascade	Secondary Auxiliary	Aerated Lagoons Disinfection	Tributary of N. Branch Milwaukee River and Soil Absorption	0.05	0.06	0.05	0.07	0.04	19.3	N/A	N/A	18.7
Adell	Secondary Auxiliary	Activated Sludge Disinfection	Soil Absorption	0.08	0.08	0.04	0.09	0.02	18.0	N/A	N/A	24.1

NOTE: N/A indicates data not available.

[a] *Data not included for the Village of Germantown and the Village of Thiensville sewage treatment plants since both of those facilities are scheduled for abandonment early in the plan period.*

Source: SEWRPC.

mg/l total phosphorus on a continuous basis was questioned. Third, there were objections to the increased energy use that would be required in order to provide a high level of phosphorus removal. In response to these concerns and objections, the preliminary recommendations concerning phosphorus removal were revised. The final areawide water quality management plan adopted by the Regional Planning Commission on July 12, 1979, continued to recognize phosphorus as an important pollutant, and retained the recommended phosphorus standard of 0.1 mg/l to support full recreational use of streams. The plan recommended further study of the levels of phosphorus removal needed to support full recreational use on a reach-by-reach basis, and of the technology needed to consistently achieve high levels of phosphorus reduction in both large and small sewage treatment plants. Pending the results of these studies, the plan recommended that all sewage wastewater treatment plants continue to provide conventional phosphorus removal and discharge phosphorus at a level of 1.0 mg/l.

The effects of phosphorus on aquatic plant growth and instream dissolved oxygen levels were subsequently studied further by the Wisconsin Department of Natural Resources.[11] Nutrient levels in the water column and bottom sediments, and dissolved oxygen levels were measured and related to observed rooted aquatic plant and attached algae growth in southern Wisconsin streams in 1981 and 1982. The study developed an empirical relationship between aquatic plant biomass and phosphorus concentrations in the water column of small streams. The study also evaluated methods of documenting phosphorus impacts, and recommended various monitoring strategies. In larger rivers where algae, rather than macrophytes, predominate, mathematical models can be used to predict the changes in algal populations and related water quality conditions that will result from changes in phosphorus levels. To assess phosphorus impacts on lakes, the DNR developed a classification system for determining appropriate phosphorus management needs.[12] The Department has thus undertaken the research needed to develop techniques that may be used to quantify some of the effects of phosphorus on aquatic plants and associated dissolved oxygen levels.

The areawide water quality management plan incorporated certain assumptions concerning the performance of various types of sewage treatment processes and facilities. These performance standards were derived from technical data presented in SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume One, Point Sources, and related to pollutant concentrations in treatment plant effluent expressed in terms of monthly averages. In the technical report, it was concluded that with two-stage lime clarification and final effluent filtration, it would be possible to consistently achieve an effluent total phosphorus concentration of approximately 0.1 mg/l. Conventional primary and secondary sewage treatment processes remove up to 30 percent of the total influent phosphorus through biological assimilation and settling, resulting in effluent phosphorus concentrations of about 3.5 to 5.0 mg/l.[13] Conventional phosphorus removal with chemical treatment removes an additional 75 to 90 percent of the influent phosphorus, resulting in effluent phosphorus concentrations of about 1.0 mg/l.

This alternative reconsiders the areawide water quality management plan recommendations concerning a high level of phosphorus removal, and evaluates the impacts of higher levels of phosphorus removal on the Milwaukee Harbor estuary itself, rather than on the upstream reaches. Under state policy, appropriate phosphorus controls for the upstream reaches are to be determined on a reach-by-reach basis. For purposes of analyzing the maximum benefits that could be achieved by implementing a high level of phosphorus removal at sewage treatment plants, it was assumed under this alternative that phosphorus reductions would be achieved by implementing a high level of phosphorus removal—to achieve a phosphorus concentration of 0.1 mg/l in the effluent—at all public sewage treatment plants, including those plants located outside the Southeastern Wisconsin Region in Fond du Lac and Sheboygan Counties. Land application of sewage effluent is not considered feasible in most cases, particularly with the larger plant flows, and was not assumed in the cost estimates.

The incremental costs of achieving a high level of phosphorus removal are set forth in Table 22. Incremental capital costs are required for the chemical treatment equipment. Operation and maintenance costs are for chemical usage, additional sludge handling, increased energy use, and higher labor requirements. The total capital cost over the period 1986 through 2000 of reducing phosphorus loadings from all public sewage treat-

[11] *S. E. Mace, P. Sorge, and T. Lowry, Impacts of Phosphorus on Streams, Final Report of the Phosphorus and High-Flow Field Studies, Wisconsin Department of Natural Resources, 1984.*

[12] *C. S. Schrank, D. H. Schuettpelz, and B. O'Flanagan, Lake Management Strategy for Phosphorus Control, Wisconsin Department of Natural Resources, 1983.*

[13] *C. S. Schrank and D. H. Schuettpelz, Rationale Document for Phosphorus Removal Policy, Wisconsin Department of Natural Resources, 1986.*

Table 22

ESTIMATED INCREMENTAL COSTS OF REDUCING PHOSPHORUS LOADINGS FROM MUNICIPAL SEWAGE TREATMENT PLANTS IN THE MILWAUKEE RIVER WATERSHED: 1986-2000

Sewage Treatment Plant	Year 2000 Average Hydraulic Design Capacity	Capital Cost (millions)	Annual Operation and Maintenance Cost (thousands)
Kewaskum	0.93	$ 1.7	$ 100
West Bend	8.03	5.0	530
Jackson	1.24	1.9	130
Newburg	0.45	1.2	60
Fredonia	0.54	1.3	70
Grafton	2.56	2.6	230
Cedarburg	3.07	2.9	270
Saukville	1.17	1.9	130
Campbellsport	0.62	1.4	80
Random Lake	0.58	1.3	80
Cascade	0.36	1.0	60
Adell	0.06	0.3	30
Forest Lake (proposed)	0.08	0.3	30
Kettle Moraine Lake (proposed)	0.10	0.4	40
Total	--	$23.2	$1,840

NOTE: The costs shown are the estimated incremental costs for reducing the phosphorus concentration in the plant effluent from 1.0 mg/l to 0.1 mg/l.

Source: SEWRPC.

ment plants is about $23.2 million. The estimated average annual operation and maintenance cost is $1.8 million.

Modification and/or Relocation of the Wisconsin Electric Power Company Valley Power Plant Outfalls Alternative

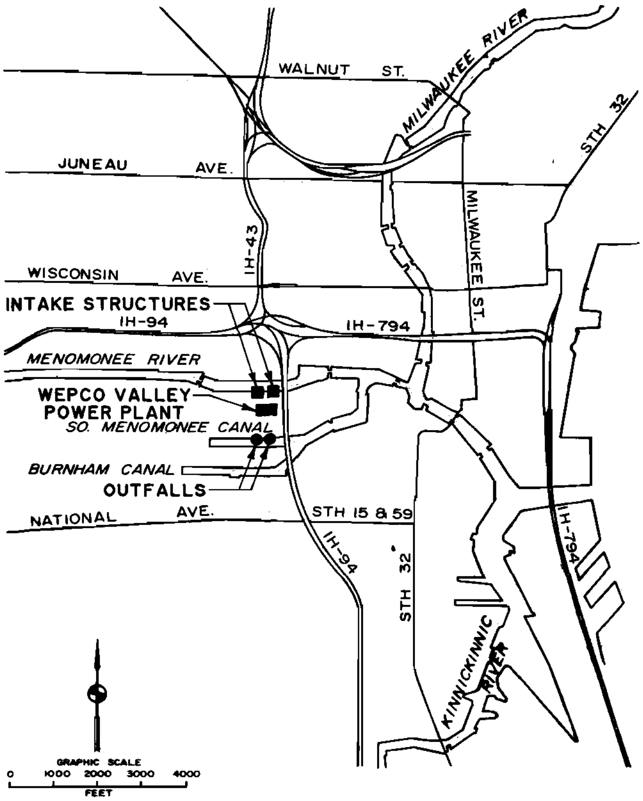
The valley power plant of the Wisconsin Electric Power Company is a coal-fired steam electric power generation facility located between the Menomonee River and the South Menomonee Canal, as shown on Map 8. The plant, constructed in 1968, consists of two units—each unit having two coal-fired boilers coupled to a single turbine. Water for condenser cooling is withdrawn from the Menomonee River through two intake structures located approximately 400 feet apart, and water is returned to the South Menomonee Canal from two outfalls, as shown on Map 8.

Each intake consists of a slot 2.25 feet high by 39.50 feet long located at a water depth of 21 feet, or two feet above the bottom of the river. Maximum velocities through the intake slots approximate 1.4 feet per second. Each outfall to the South Menomonee Canal consists of a 54-inch-diameter pipe which discharges vertically downward at a depth of 3.25 feet below the Lake Michigan low water datum—that is, 3.25 feet below elevation 578.10 feet National Geodetic Vertical Datum (NGVD).

The valley power plant normally operates continuously throughout the year. The maximum cooling water flow is 165 million gallons per day. In 1982, the average discharge from the plant was about 130 million gallons per day. During the summer, the average temperature of the spent cooling water was about 87.9°F, while the ambient temperature of

Map 8

WISCONSIN ELECTRIC POWER COMPANY VALLEY POWER PLANT CONDENSER COOLING WATER INTAKES AND OUTFALLS



The Wisconsin Electric Power Company valley power plant was constructed in 1968. Water for condenser cooling is withdrawn from the Menomonee River and the spent cooling water is returned to the South Menomonee Canal. The average discharge from the plant in 1982 was about 130 million gallons per day, equivalent to an average rate of 192 cubic feet per second. Under various alternatives considered, the discharge of heated water to the South Menomonee Canal from the plant would be reduced or eliminated.

Source: SEWRPC.

the river water was about 70.9°F. During the winter, the temperatures of the spent cooling water and the river water averaged about 67.9°F and 43.7°F, respectively. The average daily quantity of heat discharged from the plant in 1982 was about 10 billion British thermal units (BTU's).

A thermal dynamic modeling study conducted for the Wisconsin Electric Power Company when the plant was under construction in 1967 indicated that the large difference between the temperature of the spent cooling water and the temperature of the ambient river water would induce strong thermal stratification in the surrounding channel area.[14] The environmental effects of the valley power plant were evaluated in studies completed in 1976 after the plant had been in operation for about eight years.[15] The conclusions of the 1976 studies were:

1. Most desirable sport fish species avoided the plant intake because it is located near the bottom of the river beneath the photic zone.

2. Over 18,000 fish—mostly alewife and rough fish—were impinged on the intake screen over a one-year study period.

3. Phytoplankton (floating algae) were more numerous and less diverse downstream of the plant outfall than in the upstream Menomonee River.

4. The power plant discharge had no apparent effect on periphyton (attached algae) populations.

5. Zooplankton populations were significantly higher downstream of the plant outfall than upstream of the intakes.

6. The power plant discharge had no apparent effect on benthic communities.

Under this alternative, the existing flushing tunnels would continue to discharge to the Milwaukee and Kinnickinnic River estuaries. The continued operation of the existing flushing tunnels would entail a capital cost of about $300,000, and an average annual operation and maintenance cost of $70,000.

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[14] *D. R. F. Harleman and K. D. Stolzenbach, A Model Study of Thermal Stratification Produced by Condenser Water Discharge, Massachusetts Institute of Technology Hydrodynamics Laboratory Report No. 107, October 1967.*

[15] *Environmental Consultants of Milwaukee, Wisconsin, Aquatic Studies at Valley Commerce Street, and Wells Street Power Plants, prepared for the Wisconsin Electric Power Company, 1976; and Wisconsin Electric Power Company, Valley Power Plant Final Report, Wisconsin Pollutant Discharge Elimination System Intake Monitoring Studies, June 1976.*

The discharge of heated water to the South Menomonee Canal from the valley power plant would be reduced or eliminated under this alternative. One method—referred to as the cooling tower subalternative—would provide a cooling tower to reduce the temperature of the spent cooling water prior to discharge to the South Menomonee Canal. The cooling tower would be located on the power plant site.

For water quality analysis purposes, it was assumed that the cooling tower would reduce the temperature of the spent cooling water to about the average ambient river temperature. The provision of a cooling tower would involve a capital cost of about $2.9 million and an annual operation and maintenance cost of about $280,000. The implementation of this subalternative could result in traffic safety hazards in that the vapor resulting from the cooling process could interfere with the operation of the high level bridge carrying IH 94 over the Menomonee River Valley.

The capital and operation and maintenance cost estimates for the cooling tower were based upon generalized costs for cooling tower systems developed by the Regional Planning Commission. The Wisconsin Electric Power Company engineering staff does not have detailed cost estimates of a cooling tower available for this specific location. That staff, however, expressed concerns that the costs as presented may be too low. Upon review of the costs, it was concluded that the cost estimates set forth herein are suitable for use in systems level planning; it must be recognized, however, that the costs are based upon the following assumptions, which would have to be investigated further in more detailed feasibility studies: 1) that a cooling tower could be physically located within the available space at the site; 2) that the inlet water from the river would not require pretreatment for use in a cooling tower system; and 3) that the operation and maintenance costs would not include allowances for a power penalty which would be developed owing to the increased back pressure on the condenser system. Should this subalternative appear to be viable when compared to other alternatives, a more detailed analysis of the subalternative costs, including the cost of reducing the power output of the facility, would have to be investigated. The Wisconsin Electric Power Company engineering staff estimates this preliminary engineering work would entail 200 man-hours of effort.

A second method—referred to as the outfall diversion subalternative—would convey the spent cooling water directly to the outer harbor. A 7,000-foot-long, 84-inch-diameter concrete pipe would convey the cooling water to the outer harbor in the vicinity of the Henry W. Maier festival grounds, as shown on Map 9. Although there would be a large amount of dilution water available, the cooling water could increase the potential for un-ionized ammonia nitrogen toxicity in portions of the outer harbor. Removal of the outfalls from the South Menomonee Canal would also induce more inflow of cleaner Milwaukee River and Lake Michigan water into the Menomonee River. Diversion of the spent cooling water directly to the outer harbor would involve a capital cost of about $16 million and an annual operation and maintenance cost of about $10,000.

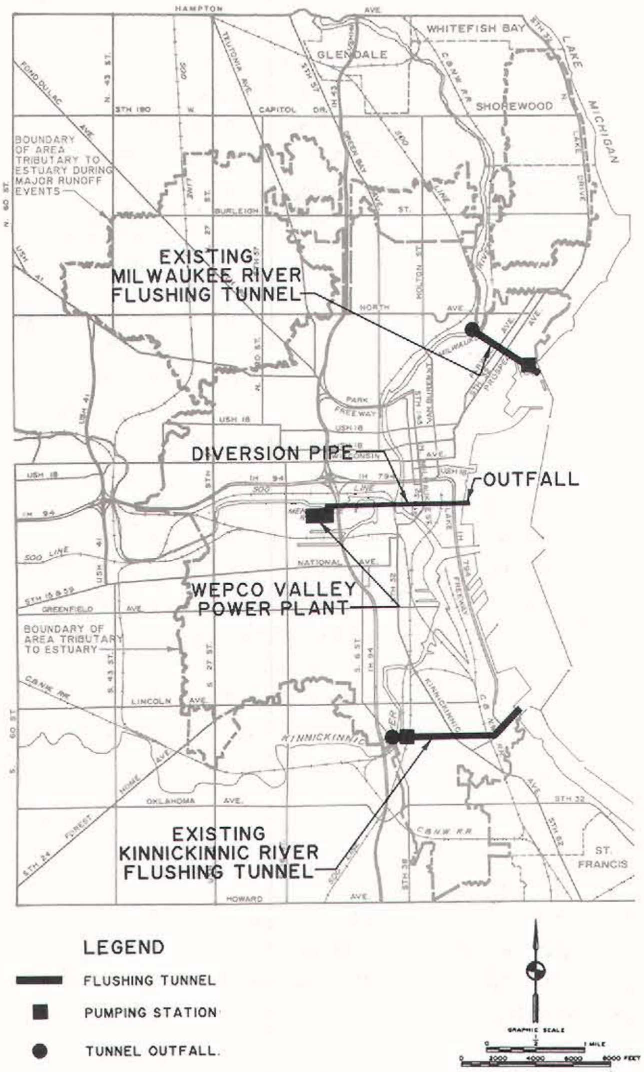
A third method—referred to as the deep tunnel discharge subalternative—would discharge the spent cooling water to the inline storage tunnel constructed directly below W. Canal Street along which the power plant is located. A buried conduit or tunnel would be constructed from the power plant to a proposed dropshaft located either 2,500 feet east of the power plant or 2,500 feet west of the power plant. The plant would discharge to the deep tunnel during periods of dry weather, or about 90 percent of the time, and the spent cooling water would be immediately pumped out and discharged directly to Lake Michigan near the Jones Island sewage treatment plant, as shown on Map 10. During wet-weather periods when stormwater enters the deep tunnel and is subsequently pumped to the Jones Island sewage treatment plant, the power plant would discharge to the South Menomonee Canal utilizing the existing outfalls. Diversion of the spent cooling water to the deep tunnel would involve a capital cost of about $6.1 million and an annual operation and maintenance cost of about $180,000.

COMPARATIVE EVALUATION OF WATER QUALITY MANAGEMENT ALTERNATIVES

The previous sections of this chapter described water quality management alternatives for the Milwaukee Harbor estuary. This section compares the major features of those alternatives, including the economics and the water quality benefits. The following evaluation and comparison serves as the basis for the development of a recommended water quality management plan for the Milwaukee Harbor estuary.

Map 9

RELOCATION OF THE WISCONSIN ELECTRIC POWER COMPANY VALLEY POWER PLANT CONDENSER COOLING WATER OUTFALLS UNDER THE OUTFALL DIVERSION SUBALTERNATIVE

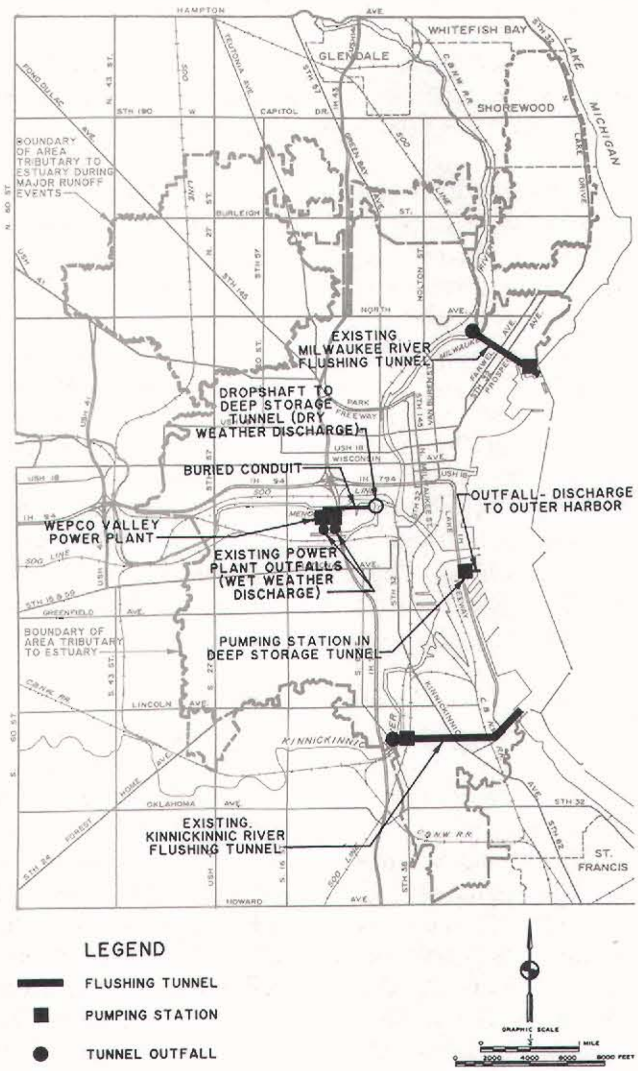


Under this subalternative, spent cooling water from the Wisconsin Electric Power Company valley power plant would be conveyed to the outer harbor, near the Henry W. Maier festival grounds, in an 84-inch-diameter concrete pipe. In addition, the existing Milwaukee and Kinnickinnic River flushing tunnels would continue to operate at a modified duration and frequency. Elimination of the power plant discharge would be expected to reduce the temperature of the Menomonee River during low-flow periods by 10 to 15 degrees Fahrenheit. The lower water temperatures would help increase the level of dissolved oxygen in the Menomonee River, since the solubility of oxygen increases as the temperature decreases. The recommended dissolved oxygen levels, although higher, would still violate some of the standards supporting warmwater fish and aquatic life. In addition, water quality in the South Menomonee Canal would be degraded owing to a reduction in the circulation of Lake Michigan water up the canal which would result from a three-layer flow pattern caused by thermal stratification.

Source: SEWRPC.

Map 10

RELOCATION OF THE WISCONSIN ELECTRIC POWER COMPANY VALLEY POWER PLANT CONDENSER COOLING WATER OUTFALLS UNDER THE DEEP TUNNEL DISCHARGE SUBALTERNATIVE



Under this subalternative, spent cooling water from the Wisconsin Electric Power Company valley power plant would be discharged to the inline storage tunnel constructed beneath W. Canal Street. During dry-weather periods, or about 90 percent of the time, the plant would discharge to the deep tunnel, and the cooling water would be pumped out and discharged directly to the outer harbor, near the Jones Island sewage treatment plant. During wet-weather periods, or about 10 percent of the time, the power plant would discharge to the South Menomonee Canal utilizing the existing outfalls. The existing Milwaukee and Kinnickinnic River flushing tunnels would continue to operate at a modified duration and frequency. The water quality benefits would be about the same as under the outfall diversion subalternative.

Source: SEWRPC.

Water Quality Effects

The water quality benefits of each of the plan alternatives can best be demonstrated in terms of the degree to which each alternative would achieve the water quality standards which support the water use objectives. In order to fully test the potential performance of each alternative, as well as to identify the "highest" water use objectives which could technically be achieved by different combinations of alternatives, two sets of water use objectives were used in the evaluation.

The first set of objectives used was those recommended in Chapter II. Based on the analysis of the inventory data collected, it was concluded that these objectives represent the desired water uses which could practicably be achieved. The water use objectives recommended for the Milwaukee River estuary were full recreational use and maintenance of a warmwater fishery. The use objectives recommended for the Menomonee River estuary—including the Burnham and South Menomonee Canals—and for the Kinnickinnic River estuary were limited recreational use and maintenance of a limited fishery. The use objectives recommended for the outer harbor were full recreational use and maintenance of a warmwater fishery.

The second set of water use objectives, evaluated at the insistence of the U. S. Environmental Protection Agency, were those that would provide fully "fishable-swimmable" water quality throughout the estuary—that is, the achievement of full recreational use and maintenance of a warmwater fishery. Both the initial set of recommended objectives and the fully "fishable-swimmable" objectives for the estuary are shown on Map 11. The initially recommended water quality standards supporting these objectives are set forth in Table 5 in Chapter II. The performance of the alternative water quality management plans with respect to the achievement of the standards supporting the maintenance of a warmwater fishery was evaluated.

An attempt was thus made to evaluate the performance of the alternative plans with respect to the achievement of the standards supporting full recreational use. However, based on the water quality and pollution source inventory study results, and a water quality standards review conducted by the Wisconsin Department of Natural Resources, it became apparent that the entire inner harbor should be classified for limited, or partial body contact, recreational use. The rationale for a partial body contact use classification is as follows:

1. It is not believed practical to reduce the existing fecal coliform levels in the tributary rivers entering the inner harbor to the levels of 200/400 most probable number per 100 milliliters (MPN/100 ml),[16,17] which would be required to support full body contact recreational uses. Bacterial levels upstream of the estuary would need to be reduced by 96 to 99 percent to meet the full recreational use standards. These high levels of reduction in fecal coliform concentrations cannot be achieved because many of the specific sources of bacteria cannot be readily identified, nor controlled by economically feasible measures.

2. The inner harbor is not likely to be used for full body contact recreational activities such as swimming, water skiing, sailboarding, or scuba diving. Partial body contact waters may be defined as those used for human recreation where immersion of the head is not frequent and contact is accidental or incidental and therefore less frequent. Examples are boating, canoeing, and fishing.[18] A partial body contact classification is thus appropriate for the types of uses that would likely occur within the inner harbor. A full body contact recreational use classification is appropriate for the outer harbor.

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[16] *To support full body contact recreational uses, Chapter II of this volume recommends that fecal coliform levels not exceed 200 MPN/100 ml as a geometric mean based on not fewer than five samples per month, nor exceed 400 MPN/100 ml in more than 10 percent of all samples during any month.*

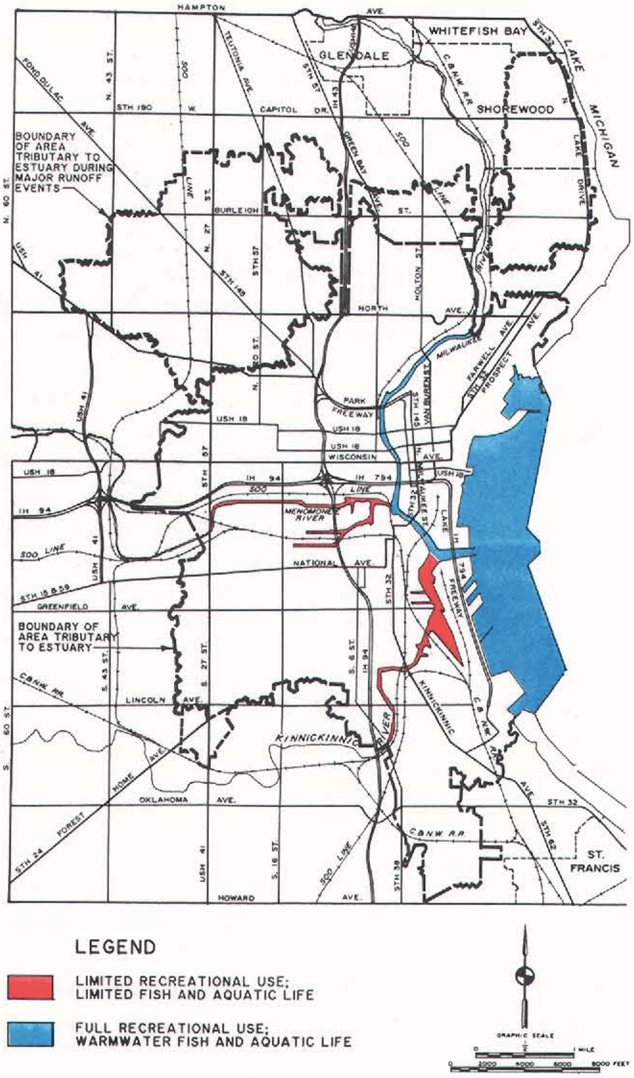
[17] *The standards set forth in this report have been referenced to values using the most probable number per 100 milliliters (MPN/100 ml) since the water quality samples taken under the study were analyzed for fecal coliform organisms using the most probable number technique. Since the membrane filter technique is also commonly used for analyzing samples for fecal coliform organisms, it should be noted that standards may be set based upon membrane filter fecal coliform counts per 100 milliliters (MFFCC/100 ml) also.*

[18] *W. J. Chantry, Analysis of the Recreational Water Quality Criterion, Wisconsin Department of Natural Resources, May 1985.*

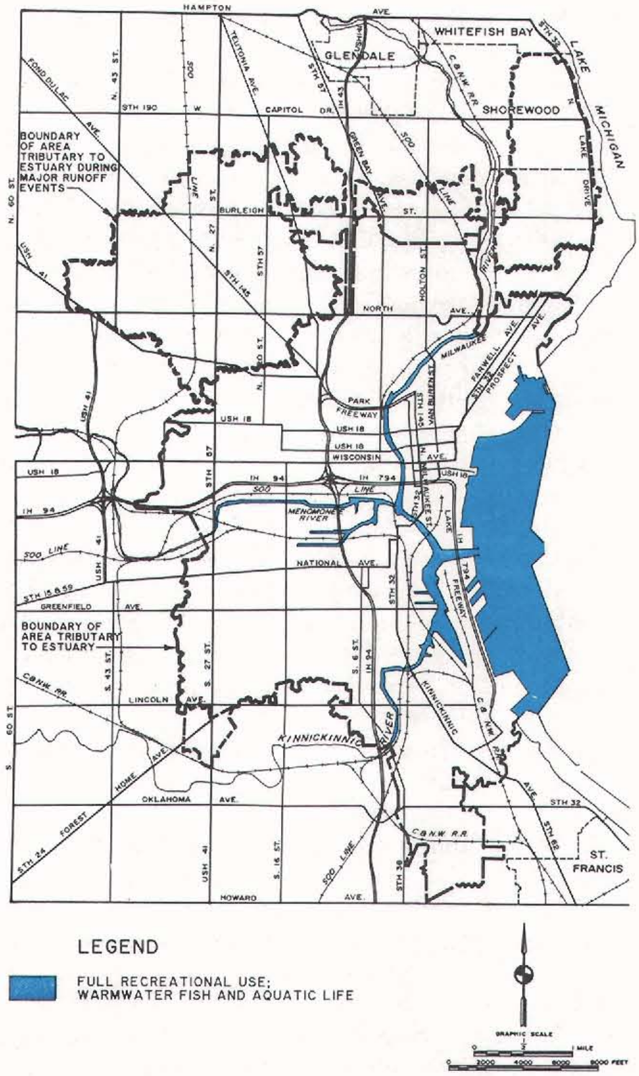
Map 11

INITIAL RECOMMENDED AND FULL "FISHABLE-SWIMMABLE" WATER USE OBJECTIVES FOR THE MILWAUKEE HARBOR ESTUARY

INITIAL RECOMMENDED



FULL "FISHABLE-SWIMMABLE"



Fully "fishable and swimmable" water use objectives—that is, full recreational use and the maintenance of a healthy warmwater fishery—were initially recommended for the outer harbor and for the Milwaukee River estuary. The maintenance of limited—fishing and boating—recreational use and the maintenance of a limited fishery were recommended for the Menomonee and Kinnickinnic River estuaries. This initial recommendation was based on the character of the Menomonee and Kinnickinnic Rivers with their dredged deepwater navigation channels and sheer dock walls, and on the character of the adjacent land uses. The achievement of both the initial recommended water use objectives and the fully "fishable and swimmable" water use objectives was evaluated for the Milwaukee Harbor estuary.

Source: SEWRPC.

Because the full recreational use fecal coliform standard apparently cannot be achieved, a series of fecal coliform standards supporting limited recreational use were developed. The following three fecal coliform standards were established to support a limited—or partial body contact—recreational use classification for the inner harbor:

1. A monthly geometric mean fecal coliform level of 1,000 MPN/100 ml shall not be exceeded more than 5 percent of the time, or about once every two years.
2. A fecal coliform level of 2,000 MPN/100 ml shall not be exceeded more than 10 percent of the time.
3. A fecal coliform level of 10,000 MPN/100 ml shall not be exceeded more than 2 percent of the time, or about one week per year.

The 1,000 and 2,000 MPN/100 ml standards ensure that fecal coliform levels will not increase over the levels currently allowed by the state variances. A report by the Wisconsin Department of Natural Resources indicated that outbreaks of waterborne disease have generally not occurred at fecal coliform levels of less than 2,000 MPN/100 ml.[19] The 10,000 MPN/100 ml standard is consistent with the DNR preliminary proposed fecal coliform standard to support partial body contact recreational uses.[20] Serious outbreaks of waterborne diseases have been associated with fecal coliform levels exceeding 10,000 MPN/100 ml. A 1976 outbreak of shigellosis that affected 45 persons who swam in the Mississippi River below Dubuque, Iowa, was associated with a fecal coliform level of about 17,500 MPN/100 ml.[21] Based on these findings, it was concluded that the fecal coliform standards supporting full recreational use could not practicably be achieved in the inner harbor under any alternative plan. The evaluation of alternative plans, therefore, considered the achievement of standards supporting limited—or partial body contact—recreational use within the inner harbor, and full body contact recreational use within the outer harbor. The evaluation also considered the achievement of standards supporting both a warmwater fishery and a limited fishery throughout the estuary.

The water quality analyses presented in this section focus on those water quality indicators of major importance which could be quantitatively evaluated—namely, dissolved oxygen, fecal coliform, lead, and ammonia nitrogen. To fully assess dissolved oxygen impacts, related indicators such as biochemical oxygen demand, nitrate nitrogen, phosphorus, and chlorophyll-a—as well as sediment fluxes of oxygen-demanding substances—were also considered. The evaluation of un-ionized ammonia nitrogen levels required projections of total ammonia, pH, and temperature levels. Two sets of dissolved oxygen standards were used in the analysis of alternative plans: those for the maintenance of a warmwater fishery, and those for the maintenance of a limited fishery. The un-ionized ammonia nitrogen and lead standards used in the analysis are the same for both a warmwater fishery and a limited fishery. The impacts of the alternative water quality management measures on these important water quality indicators were assessed using the mathematical simulation modeling techniques described in Chapter VII of Volume One of this report. The impacts of the alternative water quality management measures on toxic metals were analyzed by simulating the concentrations of lead—as a representative metal—in the water column, and by using the information presented in Chapter VI of Volume One of this report to estimate the effect of the alternatives on the concentrations of lead, cadmium, copper, and zinc in both the water column and the bottom sediments. While toxic organic substances are of great importance to the full achievement of water use objectives, it was not possible, within the scope of this study, to fully quantitatively demonstrate the impacts of the alternatives on these indicators.

Initial Model Verification

A series of simulation model analyses were conducted to evaluate the degree to which the dissolved oxygen standards were met under various flow and water temperature conditions. The steady-state model was run under nine categories of flow and water temperature conditions. The categories were defined by the flow and temperature conditions present in the Milwaukee River at the North Avenue dam, as set forth in Table 23. The baseline data collected in the Milwaukee River at the North Avenue dam from 1981 through 1983, as presented in Chapter IV of Volume One of this report, were used to classify each of the baseline sampling days into the appropriate category. The mean temperature and flow were then calculated for each tributary river within each category under a steady-state analysis; the results of these calculations are set forth in Table 24. To verify the accuracy of the steady-state model under these various conditions, the modeling results were compared to the baseline data for dissolved oxygen, biochemical oxygen demand, chlorides, conductivity, temperature, ammonia nitrogen, nitrate nitrogen, and chlorophyll-a. The baseline data were divided into the same nine categories based on the flow and temperature conditions existing in the Milwaukee River at the North Avenue dam at the time the measurements were taken. The comparison of the simulated water quality data to the

[19] *Ibid.*

[20] *C. S. Shrank, "Rationale for Water Quality Standards to Protect Health of Humans Recreating in Surface Waters," Wisconsin Department of Natural Resources, Draft, September 1986.*

[21] *V. J. Cabelli, Health Effects Criteria for Marine Recreational Waters, U. S. Environmental Protection Agency, EPA-600/180031, August 1983.*

baseline data is shown in Figure 48 for the low-flow, high-temperature category, these comparative data being representative of the comparative data for the other eight categories. Overall, the simulated water quality conditions were found to replicate well the mean conditions measured under the baseline sampling program, indicating that the steady-state model adequately represented water quality conditions under these various flow and temperature categories.

Table 23

FLOW AND WATER TEMPERATURE CONDITIONS IN THE MILWAUKEE RIVER AT NORTH AVENUE DAM USED TO CLASSIFY THE BASELINE DATA INTO APPROPRIATE FLOW AND TEMPERATURE CATEGORIES

Flow	Water Temperature		
	Low	Moderate	High
Low	<50°F <200 cfs	50 - 68°F <200 cfs	>68°F <200 cfs
Moderate	<50°F 200 - 400 cfs	50 - 68°F 200 - 400 cfs	>68°F 200 - 400 cfs
High	<50°F >400 cfs	50 - 68°F >400 cfs	>68°F >400 cfs

Source: HydroQual, Inc.

Committed Action Alternative

Under the committed action alternative, about 97 percent of the existing pollutant loadings from combined sewer overflows and virtually all pollutant loadings from other sanitary sewer flow relief devices would be eliminated. The effects of these reductions on water quality conditions within the Milwaukee Harbor estuary are presented below.

Dissolved Oxygen: The most severe dissolved oxygen problems are generally associated with low-flow and high-temperature periods. To evaluate the effect that the committed action alternative would have on these critical dissolved oxygen conditions, a low-flow steady-state simulation analysis was conducted. The steady-state analysis estimated dissolved oxygen levels under 7-day, 10-year recurrence interval low-flow conditions at the high temperature levels measured during Survey Period 1, July 25 to August 8, 1983. Spatial plots of low-flow, steady-state dissolved oxygen levels under the committed action alternative are shown in Figure 49. The figure compares the simulated dissolved oxygen levels to standards for a warmwater fishery and for a limited fishery.

Table 24

UPSTREAM RIVER FLOW AND TEMPERATURE CONDITIONS USED FOR THE STEADY-STATE MODELING ANALYSIS

River Station	Flow	Water Temperature		
		Low	Moderate	High
Milwaukee River at North Avenue Dam	Low Moderate High	N/A 291.0 cfs, 36.4°F 974.0 cfs, 40.3°F	151.8 cfs, 60.7°F 291.0 cfs, 61.8°F 974.0 cfs, 55.8°F	151.8 cfs, 75.8°F 291.0 cfs, 74.4°F 974.0 cfs, 71.8°F
Menomonee River at S. 37th Street	Low Moderate High	N/A 58.2 cfs, 36.8°F 175.2 cfs, 43.2°F	19.8 cfs, 60.2°F 58.2 cfs, 63.2°F 175.2 cfs, 55.4°F	19.8 cfs, 73.8°F 58.2 cfs, 71.8°F 175.2 cfs, 69.3°F
Kinnickinnic River at S. 9th Place	Low Moderate High	N/A 26.8 cfs, 41.7°F 28.6 cfs, 47.0°F	10.4 cfs, 64.7°F 26.8 cfs, 67.8°F 26.6 cfs, 61.3°F	10.4 cfs, 81.6°F 26.8 cfs, 76.6°F 28.6 cfs, 74.7°F

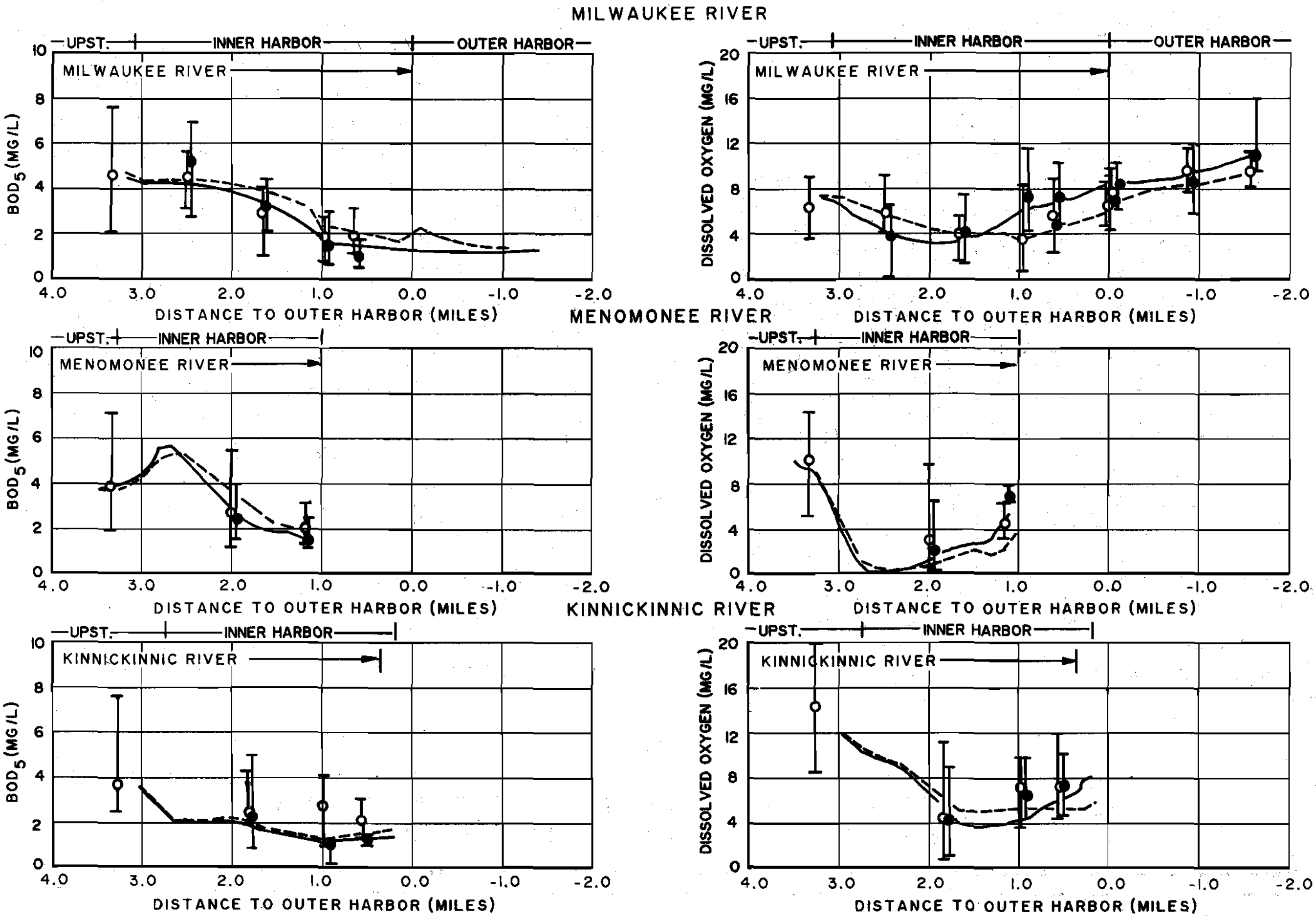
NOTES: N/A indicates data not available.

No baseline data were collected under low-flow, low-temperature conditions. Such conditions would be expected to rarely occur.

Source: HydroQual, Inc.

Figure 48

COMPARISON OF SIMULATED WATER QUALITY DATA TO MEASURED DATA UNDER LOW-FLOW AND HIGH WATER TEMPERATURE CONDITIONS



LEGEND

MEASURED WATER QUALITY DATA[b]

- I RANGE OF DATA
- o SURFACE LAYER MEAN
- ● BOTTOM LAYER MEAN

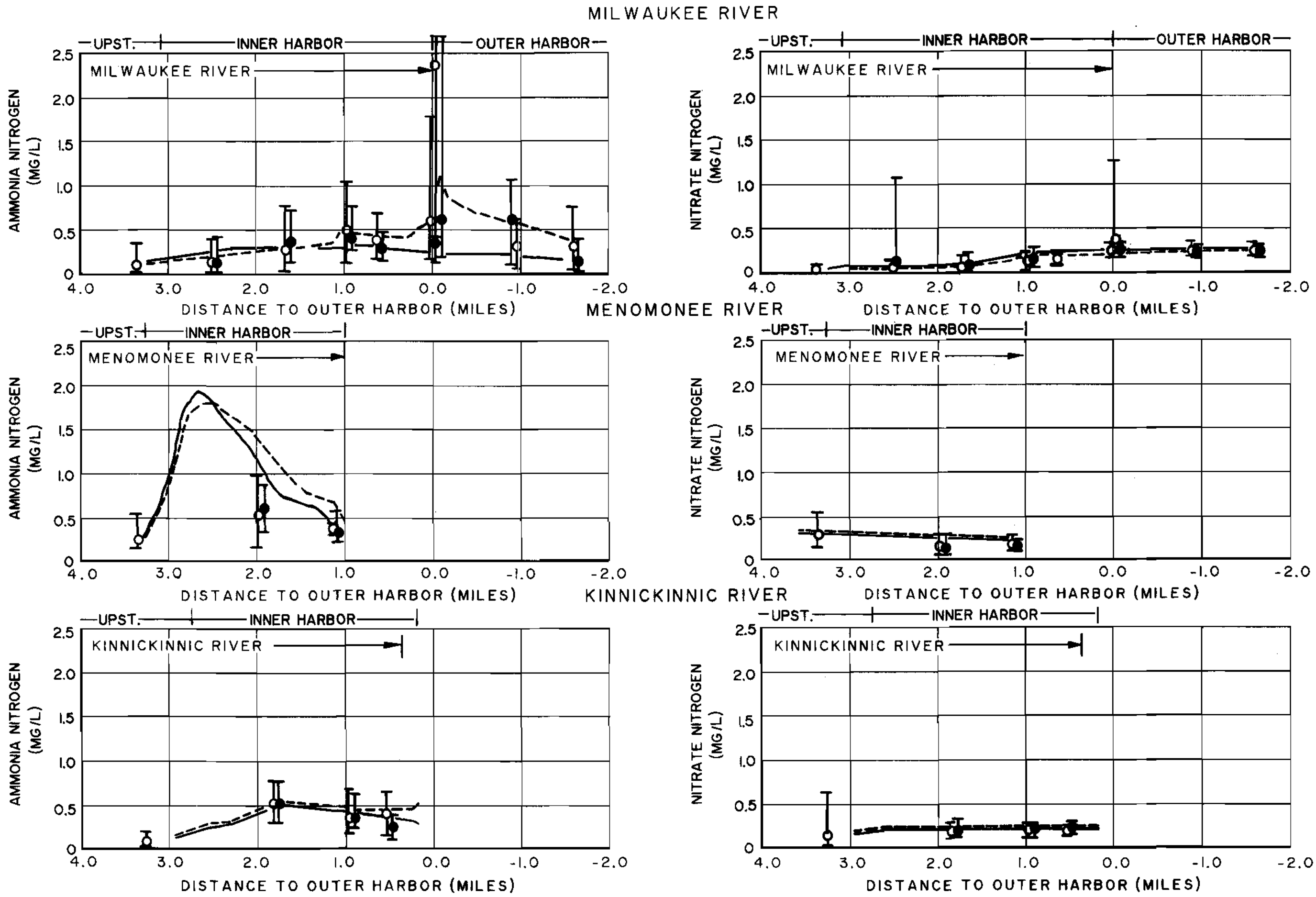
SIMULATED WATER QUALITY DATA[a]

- --- SURFACE LAYER
- —— BOTTOM LAYER

[a] THE SIMULATED DATA WERE CALCULATED WITH THE STEADY STATE MODEL UNDER LOW-FLOW AND HIGH TEMPERATURE CONDITIONS. AVERAGE FLUSHING TUNNEL DISCHARGE CONDITIONS WERE ASSUMED.

[b] THE MEASURED DATA PRESENTED IN THIS FIGURE ARE THOSE COLLECTED UNDER THE BASELINE SAMPLING PROGRAM FROM 1981 THROUGH 1983 WHEN THE FLOWS IN THE MILWAUKEE RIVER AT THE NORTH AVENUE DAM WERE LESS THAN 200 CFS, AND THE WATER TEMPERATURE EXCEEDED 68°F.

Figure 48 (continued)



LEGEND

MEASURED WATER QUALITY DATA[b]

- I RANGE OF DATA
- o SURFACE LAYER MEAN
- ● BOTTOM LAYER MEAN

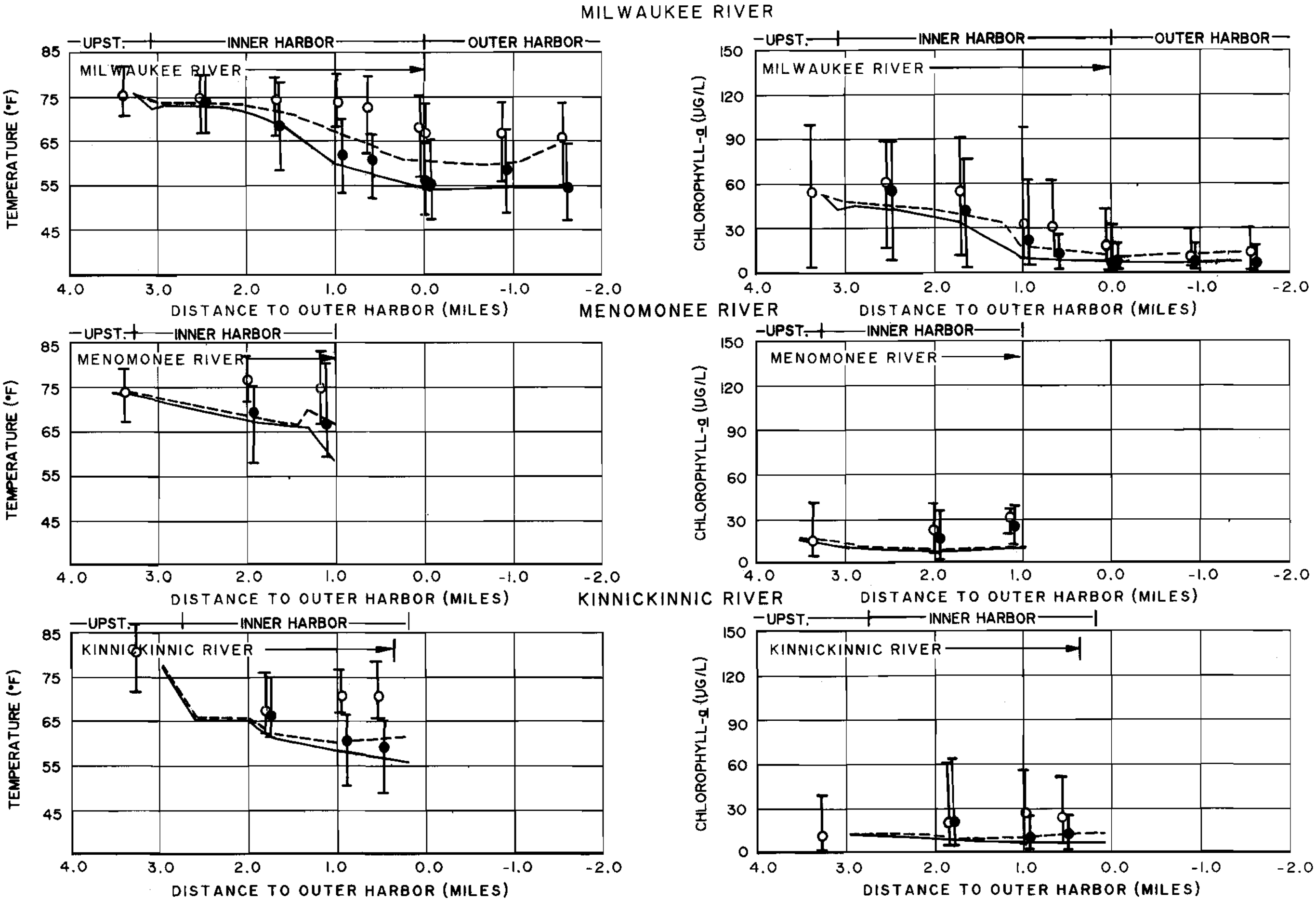
SIMULATED WATER QUALITY DATA[a]

- --- SURFACE LAYER
- —— BOTTOM LAYER

[a] THE SIMULATED DATA WERE CALCULATED WITH THE STEADY STATE MODEL UNDER LOW-FLOW AND HIGH TEMPERATURE CONDITIONS. AVERAGE FLUSHING TUNNEL DISCHARGE CONDITIONS WERE ASSUMED.

[b] THE MEASURED DATA PRESENTED IN THIS FIGURE ARE THOSE COLLECTED UNDER THE BASELINE SAMPLING PROGRAM FROM 1981 THROUGH 1983 WHEN THE FLOWS IN THE MILWAUKEE RIVER AT THE NORTH AVENUE DAM WERE LESS THAN 200 CFS, AND THE WATER TEMPERATURE EXCEEDED 68°F.

Figure 48 (continued)



LEGEND

MEASURED WATER QUALITY DATA[b]

- I RANGE OF DATA
- o SURFACE LAYER MEAN
- ● BOTTOM LAYER MEAN

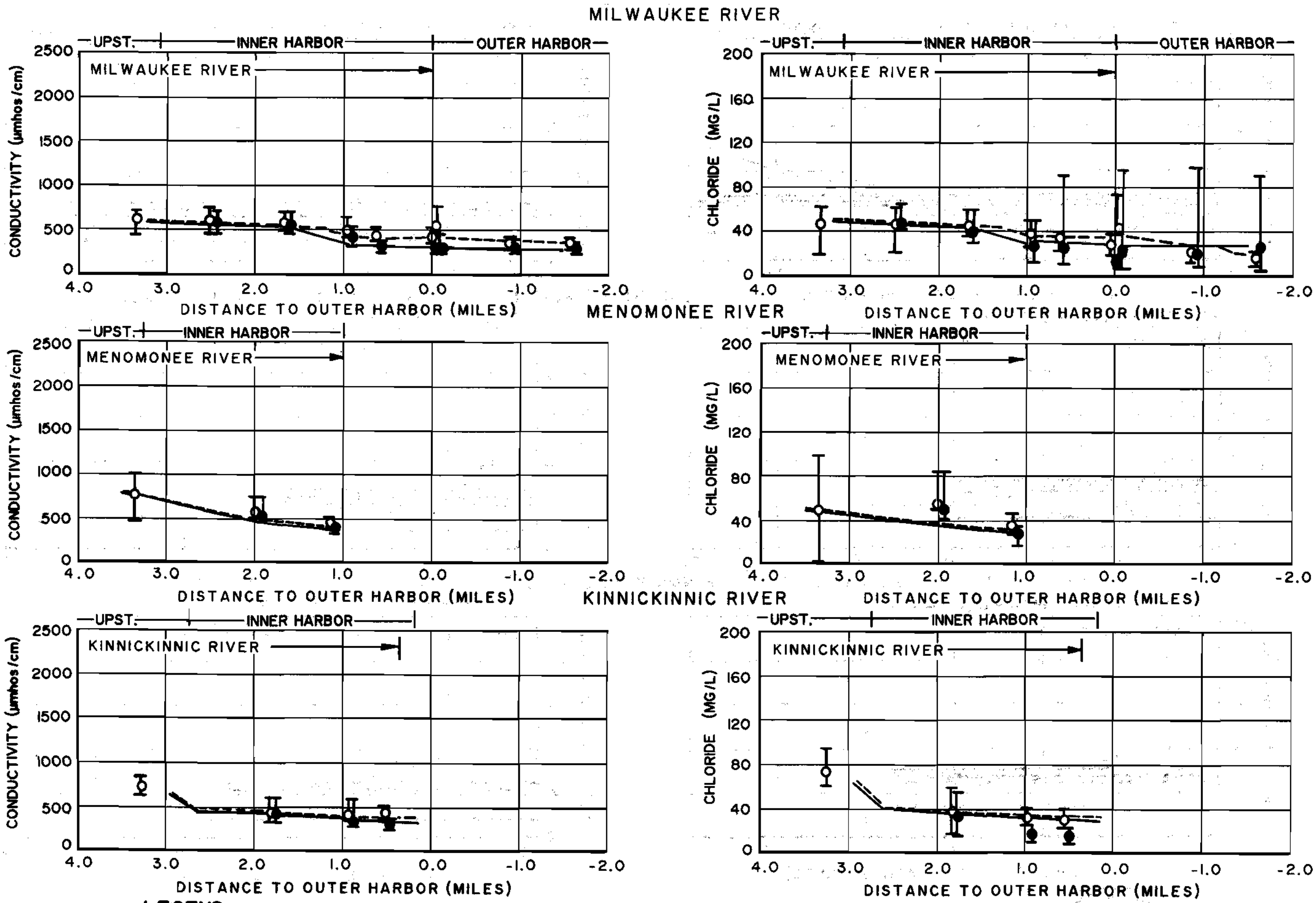
SIMULATED WATER QUALITY DATA[a]

- --- SURFACE LAYER
- —— BOTTOM LAYER

[a] THE SIMULATED DATA WERE CALCULATED WITH THE STEADY STATE MODEL UNDER LOW-FLOW AND HIGH TEMPERATURE CONDITIONS.AVERAGE FLUSHING TUNNEL DISCHARGE CONDITIONS WERE ASSUMED.

[b] THE MEASURED DATA PRESENTED IN THIS FIGURE ARE THOSE COLLECTED UNDER THE BASELINE SAMPLING PROGRAM FROM 1981 THROUGH 1983 WHEN THE FLOWS IN THE MILWAUKEE RIVER AT THE NORTH AVENUE DAM WERE LESS THAN 200 CFS,AND THE WATER TEMPERATURE EXCEEDED 68°F.

Figure 48 (continued)



LEGEND

MEASURED WATER QUALITY DATA[b]

- I RANGE OF DATA
- ○ SURFACE LAYER MEAN
- ● BOTTOM LAYER MEAN

SIMULATED WATER QUALITY DATA[a]

- - - - SURFACE LAYER
- —— BOTTOM LAYER

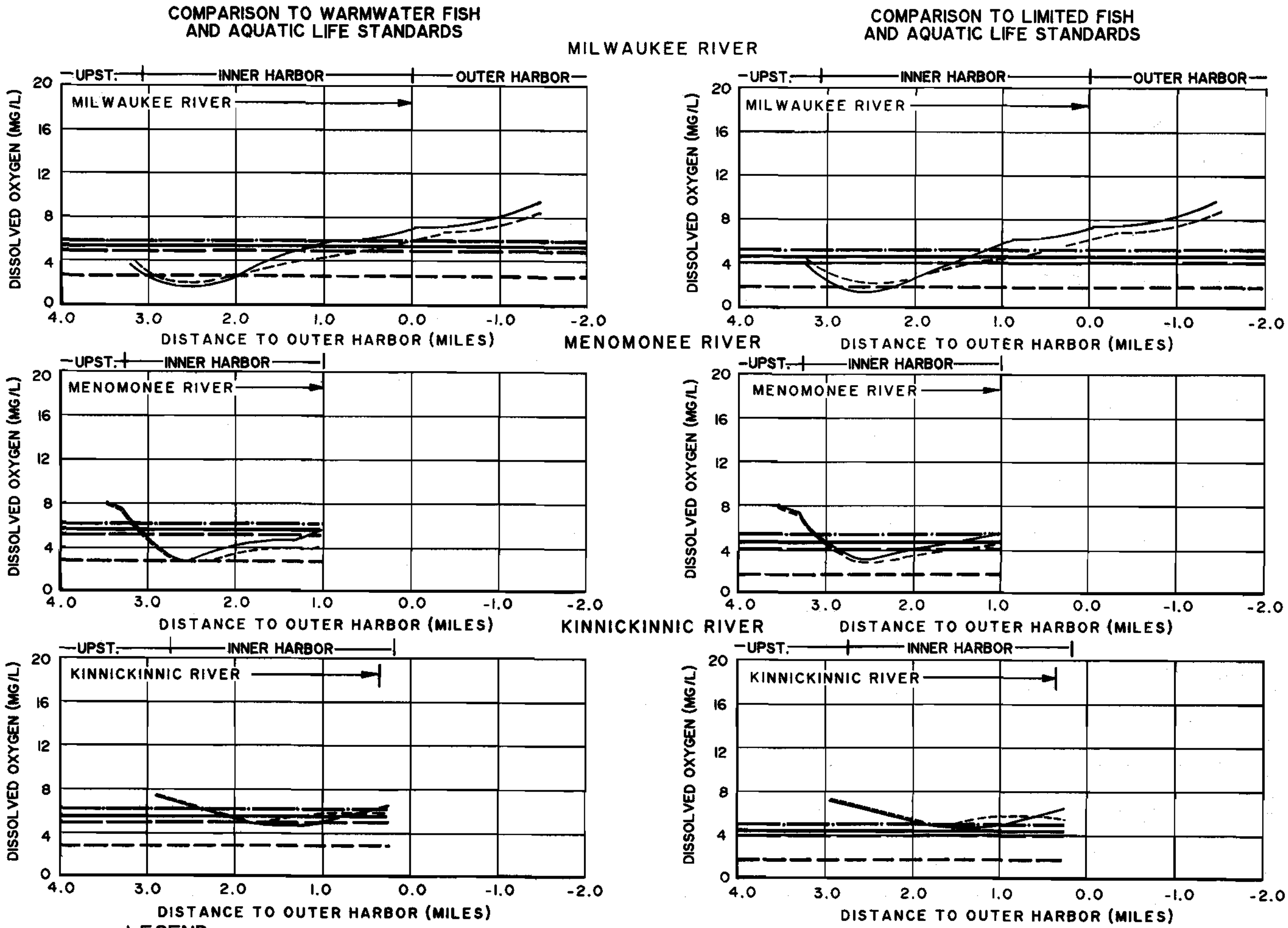
Source: HydroQual, Inc.

[a] THE SIMULATED DATA WERE CALCULATED WITH THE STEADY STATE MODEL UNDER LOW-FLOW AND HIGH TEMPERATURE CONDITIONS.AVERAGE FLUSHING TUNNEL DISCHARGE CONDITIONS WERE ASSUMED.

[b] THE MEASURED DATA PRESENTED IN THIS FIGURE ARE THOSE COLLECTED UNDER THE BASELINE SAMPLING PROGRAM FROM 1981 THROUGH 1983 WHEN THE FLOWS IN THE MILWAUKEE RIVER AT THE NORTH AVENUE DAM WERE LESS THAN 200 CFS,AND THE WATER TEMPERATURE EXCEEDED 68°F.

Figure 49

LOW-FLOW, STEADY-STATE ANALYSIS OF DISSOLVED OXYGEN UNDER THE COMMITTED ACTION ALTERNATIVE



LEGEND

MODEL SIMULATED DATA

- - - SURFACE LAYER

—— BOTTOM LAYER

STANDARDS (MG/L)

		WARMWATER	LIMITED
——	30 DAY MEAN MINIMUM STANDARD	5.5	4.5
—·—	7 DAY MEAN MINIMUM STANDARD (3/15-7/31)	6.0	5.0
— —	1 DAY MEAN MINIMUM STANDARD (3/15-7/31)	5.0	4.0
- - -	ABSOLUTE MINIMUM STANDARD	2.5	1.5

NOTE: THE EXISTING WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS SPECIFY MINIMUM DISSOLVED OXYGEN LEVELS OF 5.0 MG/L AND 3.0 MG/L FOR THE FULL WARMWATER FISH AND AQUATIC LIFE AND THE LIMITED FISH AND AQUATIC LIFE WATER USE OBJECTIVES,RESPECTIVELY. THESE STANDARDS ARE APPLIED BY THE DEPARTMENT AS A MINIMUM NOT TO BE VIOLATED AT ANY FLOW EQUAL TO OR GREATER THAN THE 7-DAY,10-YEAR MINIMUM FLOW.

Source: HydroQual, Inc.

The 7-day mean, 1-day mean, and absolute minimum standards can be directly compared to the simulated dissolved oxygen data. The 7-day mean and 1-day mean standards, which apply from March 15 through July 31, were used for analysis purposes because critical dissolved oxygen levels are most likely to occur during the summer, and because aquatic organisms are most likely to be harmed by low dissolved oxygen levels during the reproduction period of late spring to mid-summer. Although the 30-day mean standards are also considered, the simulated data do not necessarily indicate a violation of those standards because the low-flow period would have a duration of less than 30 days.

The comparison to the standards indicates that at least some of the dissolved oxygen standards for a warmwater fishery, and for a limited fishery, would be violated in both the surface and bottom water layers within the inner harbor. Simulated dissolved oxygen levels in all three river estuaries would violate the 7-day mean standards for both warmwater and limited fisheries. The 30-day mean and 1-day mean standards for a warmwater fishery would be violated in all river estuaries, and the 30-day mean and 1-day mean standards for a limited fishery would be violated in the Milwaukee and Menomonee River estuaries. The absolute minimum standards for both warmwater and limited fish and aquatic life would be violated in the Milwaukee River estuary, but achieved in the Menomonee and Kinnickinnic River estuaries. Portions of the Milwaukee and Menomonee Rivers located just upstream of the estuary would also be expected to violate the 30-day mean, 7-day mean, and 1-day mean standards supporting warmwater and limited fisheries. All dissolved oxygen standards would be expected to be met within the outer harbor under low-flow, steady-state conditions.

Analysis of the components of the dissolved oxygen deficit can help assess the significance of the individual sinks of oxygen under the committed action alternative. The components of the deficit that were studied in the steady-state analysis include the sediment flux of methane and ammonia, sediment oxygen demand, carbonaceous biochemical oxygen demand from upstream sources, carbonaceous biochemical oxygen demand from the Jones Island sewage treatment plant, and net photosynthesis/respiration. The computed components of the dissolved oxygen deficit under low-flow, steady-state conditions in the surface and bottom water layers are shown in Figure 50.

The dissolved oxygen deficit associated with sediment processes—sediment oxygen demand and the sediment flux of methane and ammonia—would be more significant in the Menomonee and Kinnickinnic River estuaries than in the Milwaukee River estuary. The effect of net photosynthesis/respiration would be considerable only in the Milwaukee River estuary because of the high algal levels. The figure also shows that algae are sometimes a net source of oxygen in the surface layers of the Kinnickinnic River estuary and in the outer harbor, as shown by the crossover of lines delineating the deficit due to upstream carbonaceous biochemical oxygen demand and net photosynthesis/respiration. The carbonaceous biochemical oxygen demand deficit from upstream sources would be significant in all three river estuaries. The deficit due to carbonaceous biochemical oxygen demand discharged from the Jones Island sewage treatment plant would be an important component of the deficit only in the surface layer of the outer harbor.

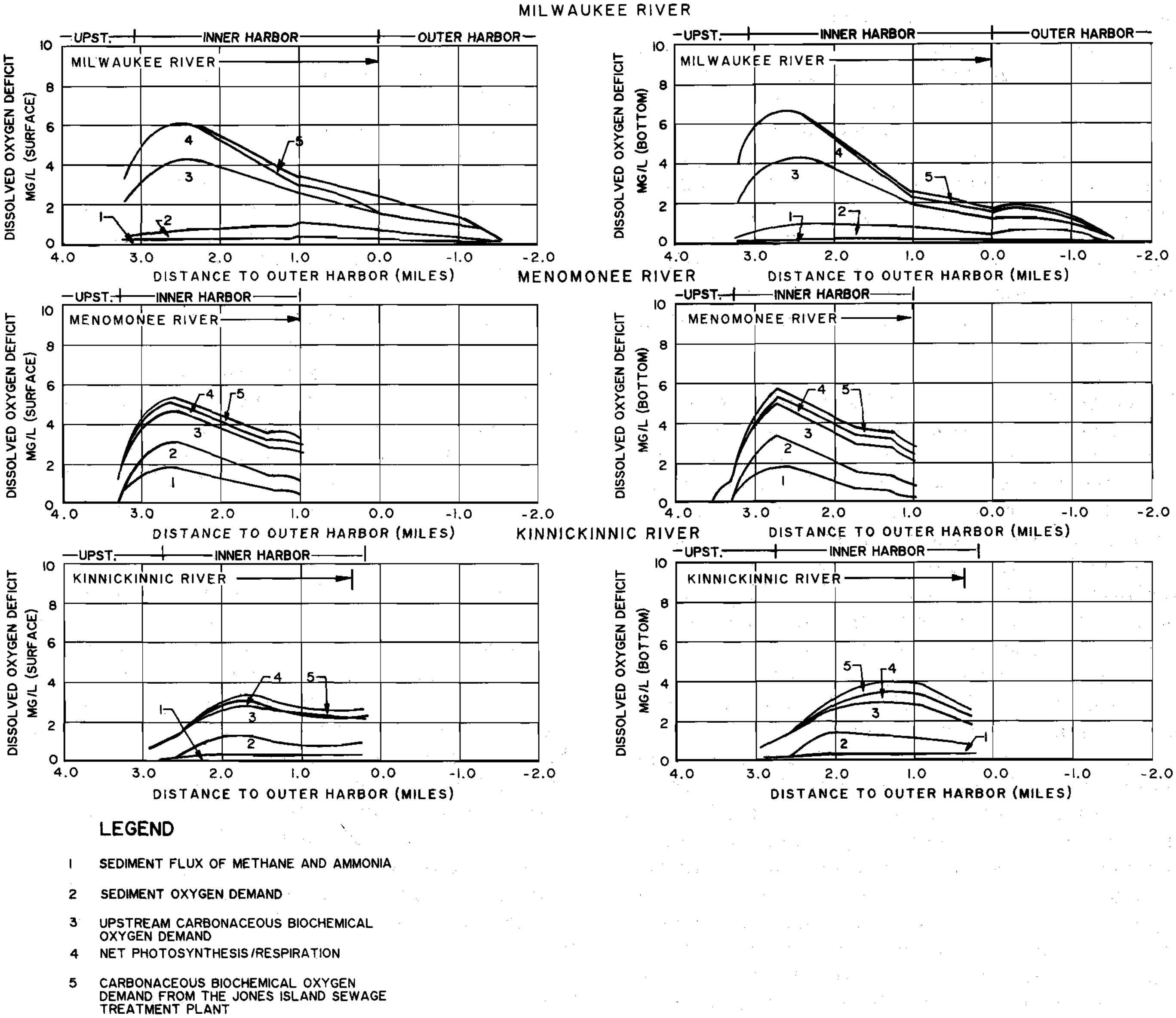
As previously noted, a series of simulation model analyses were conducted to determine the violation of the dissolved oxygen standards that could be expected under various flow and temperature conditions. The steady-state model was run under a series of flow and temperature conditions to assess the improvement in dissolved oxygen levels under the committed action alternative relative to existing conditions. The modeling results were then used to modify the measured baseline data collected from 1981 through 1983, as presented in Chapter VI of Volume One of this report. The modified baseline data were then compared to the dissolved oxygen standards for a warmwater fishery and for a limited fishery.

The expected violation of the dissolved oxygen standards over a three-year period is set forth in Table 25. For the surface and bottom water layers of several upstream, inner harbor, and outer harbor sampling stations, the anticipated violation of the dissolved oxygen standards is classified as slight—occurring up to 5 percent of the time; moderate—occurring from 6 to 10 percent of the time; or severe—occurring more than 10 percent of the time.

Under the committed action alternative, the upstream Milwaukee and Menomonee Rivers would exhibit moderate violations of the 7-day mean dissolved oxygen standard for a warmwater fishery. All other standards for both warmwater and limited fisheries would be met by the upstream Milwaukee and Menomonee Rivers. The upstream

Figure 50

COMPONENTS OF THE DISSOLVED OXYGEN DEFICIT UNDER LOW-FLOW, STEADY-STATE CONDITIONS: COMMITTED ACTION ALTERNATIVE



Source: HydroQual, Inc.

Kinnickinnic River would meet both 30-day mean standards and the absolute minimum standard for a limited fishery. All other standards for both warmwater and limited fisheries would be slightly violated in the upstream Kinnickinnic River.

Within the inner harbor, none of the sampling stations would achieve all of the dissolved oxygen standards for warmwater or limited fisheries. The absolute minimum standards would be met the most often, with all violations being slight. Violations of the 30-day mean, 7-day mean, and 1-day mean standards for both warmwater and limited fisheries would occur in all three river estuaries. In general, the violations of the dissolved oxygen standards would be more severe in the upstream portions of the inner harbor than in the downstream portions, particularly in the Menomonee and Kinnickinnic River estuaries. The inflow of lake water into the lower reaches would help improve dissolved oxygen conditions in those reaches.

Within the outer harbor, slight violations of some of the dissolved oxygen standards would be expected at some stations under the committed action alternative. These violations would generally occur near the Jones Island sewage treatment plant outfall, in the adjacent southern portion of the outer harbor, and near the Hoan Bridge.

Table 25

VIOLATION OF DISSOLVED OXYGEN STANDARDS UNDER THE COMMITTED ACTION ALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Warmwater Fish and Aquatic Life: 30-Day Mean All Year 5.5 mg/l	7-Day Mean 3/15-7/31 6.0 mg/l	1-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 8/1-3/14 4.0 mg/l	Absolute Minimum All Year 2.5 mg/l	Limited Fish and Aquatic Life: 30-Day Mean All Year 4.5 mg/l	7-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 3/15-7/31 4.0 mg/l	1-Day Mean 8/1-3/14 3.0 mg/l	Absolute Minimum All Year 1.5 mg/l
Upstream												
Milwaukee River	North Avenue Dam (RIV-5)	DI	None	Moderate	None	None	None	None	None	None	None	None
Menomonee River	S. 37th Street (RIV-10)	DI	None	Moderate	None	None	None	None	None	None	None	None
Kinnickinnic River	S. 9th Place (RIV-13)	DI	None	Slight	Slight	Slight	Slight	None	Slight	Slight	Slight	None
Inner Harbor												
Milwaukee River	Walnut Street (RIV-6)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	Severe	Moderate	None	None	None	Moderate	Slight	None	None
	Wells Street (RIV-7)	S	Moderate	Severe	Moderate	Slight	Slight	Slight	Moderate	None	Slight	None
		B	Slight	Severe	Severe	None	None	None	Severe	Moderate	None	None
	Water Street (RIV-8)	S	Severe	Severe	Severe	Moderate	Slight	Moderate	Severe	Slight	Slight	None
		B	Slight	Moderate	Slight	Slight	None	Slight	Slight	Slight	Slight	None
	C&NW Railway (RIV-15)	S	Moderate	Severe	None	None	None	None	None	None	None	None
		B	Slight	Severe	None	Slight	None	Slight	None	None	None	None
Menomonee River	Muskego Avenue (RIV-11)	S	Severe	Severe	Severe	Moderate	Slight	Moderate	Severe	Severe	Slight	None
		B	Severe	Severe	Severe	Slight	None	Moderate	Severe	Severe	None	None
	S. 2nd Street (RIV-17)	S	Severe	Severe	Severe	Moderate	None	Moderate	Severe	Moderate	None	None
		B	Moderate	Moderate	None	Moderate	None	Slight	None	None	None	None
Kinnickinnic River	S. 1st Street (RIV-14)	S	Severe	Severe	Severe	Severe	Slight	Moderate	Severe	Severe	Moderate	Slight
		B	Severe	Severe	Severe	Severe	Slight	Moderate	Severe	Severe	Severe	Slight
	Greenfield Avenue Extended (RIV-18)	S	None	Severe	Moderate	None	None	None	Moderate	None	None	None
		B	Slight	Severe	Moderate	Slight	None	Slight	Moderate	Moderate	None	None
	Jones Island (RIV-19)	S	None	Moderate	Moderate	None	None	None	Moderate	None	None	None
		B	Slight	Moderate	None	None	None	Slight	None	None	None	None
Outer Harbor	Hoan Bridge (OH-1)	S	Slight	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	None	None	Slight	None	None	None	None
	Central OH (OH-3)	S	Slight	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	None	None	Slight	None	None	None	None
	South OH (OH-11)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	Slight	None	Slight	Slight	Slight	None	None	None	None
	JI STP Plume (OH-2)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	Slight	None	Slight	None	None	Slight	None

NOTE: Standard violations that occur up to 5 percent of the time are classified as slight; violations that occur 6 to 10 percent of the time are classified as moderate; and violations that occur more than 10 percent of the time are classified as severe. The existing Wisconsin Department of Natural Resources standards specify minimum dissolved oxygen levels of 5.0 mg/l and 3.0 mg/l for the full warmwater fish and aquatic life and the limited fishery and aquatic life water use objectives, respectively. These standards are applied by the Department as a minimum not to be violated at any flow equal to or greater than the 7-day, 10-year minimum flow.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

Source: HydroQual, Inc., and SEWRPC.

Concentrations of dissolved oxygen fluctuate diurnally, largely because of the effects of photosynthesis and respiration by algae and rooted aquatic plants. Oxygen levels generally increase during the day owing to net photosynthesis, and decrease during the night owing to net respiration. Analyses of these diurnal fluctuations in the upstream and inner harbor stations indicated that, generally, the baseline data were representative of mean daily dissolved oxygen levels. Thus, the modified baseline data are appropriate for determining the achievement of the 30-day mean, 7-day mean, and 1-day mean standards. However, the absolute minimum standard should not be violated at any time. A diurnal analysis was therefore conducted to determine if the violation of the absolute minimum standards would be more severe than indicated above because of these diurnal fluctuations.

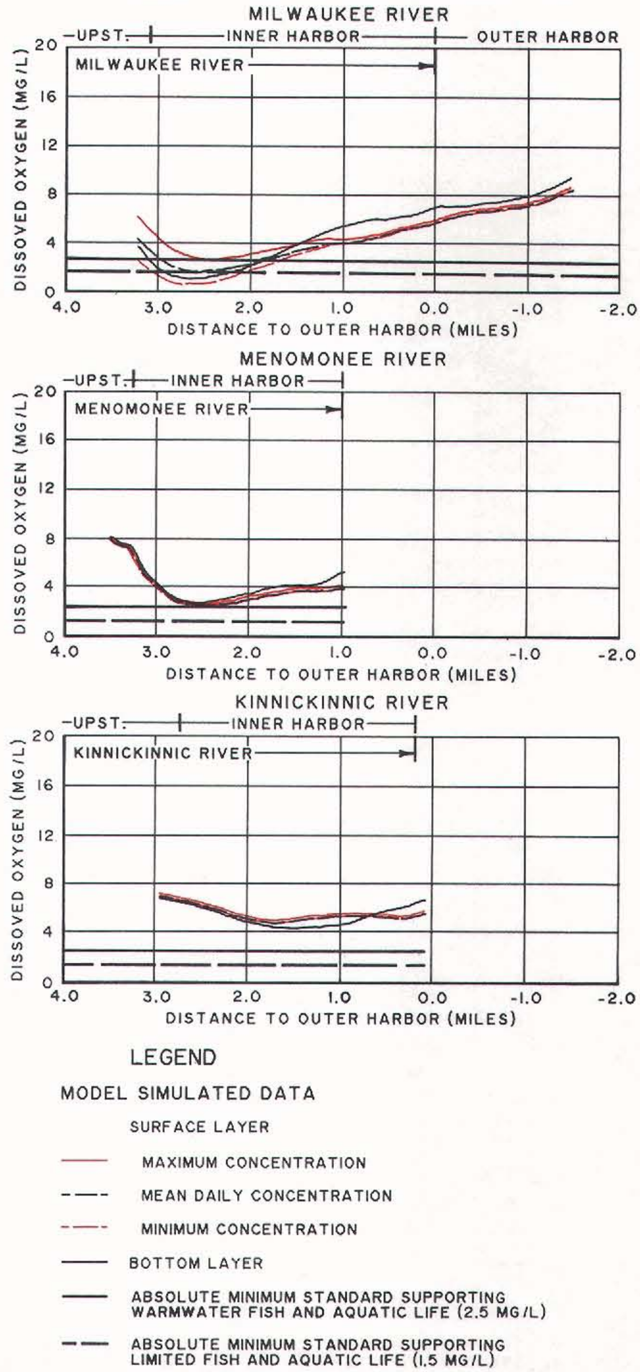
Diurnal fluctuations in dissolved oxygen levels were incorporated into the low-flow, steady-state simulation analysis. Spatial plots showing the maximum, mean, and minimum dissolved oxygen levels are shown in Figure 51. Within the upper portions of the Milwaukee River estuary, the figure shows that photosynthesis and respiration would result in a total fluctuation in dissolved oxygen levels of up to 4.0 mg/l. The minimum concentration would be up to 2.0 mg/l below the mean daily concentration, and the maximum level would be up to 2.0 mg/l above the mean. Within the Milwaukee River estuary, violations of the absolute minimum standards would become more severe at night, when minimum levels would likely occur. The figure also shows that diurnal fluctuations in dissolved oxygen concentrations would be very minor in the Menomonee and Kinnickinnic River estuaries, and in the outer harbor. The bottom water layers in all water bodies would not exhibit diurnal fluctuations.

The violations of the absolute minimum standards expected under various flow and temperature conditions, as summarized in Table 25, were reviewed to determine the extent to which diurnal fluctuations in dissolved oxygen concentrations would likely increase those violations in the Milwaukee River. It was concluded that slight violations of the absolute minimum standard for a warmwater fishery could indeed occur in the upstream reaches of the Milwaukee River. Violations of the absolute minimum standards would marginally increase within the Milwaukee River estuary—particularly at the Wells Street station (RIV-7).

<u>Fecal Coliform</u>: A substantial reduction in upstream fecal coliform levels may be expected to result from the abatement of combined sewer overflows that discharge upstream of the estuary, as well as from the virtual elimination of discharges from separate sanitary sewer flow relief devices. Based on a review of wet-weather and dry-weather fecal coliform concentrations and loadings, and of the relative contributions of coliform organisms from the various sources, abatement of the combined sewer overflows and of the separate sanitary sewer flow relief devices may be expected to result in reductions of approximately 50 percent in fecal coliform levels in the tributary rivers where the organisms enter the harbor estuary. In order to

Figure 51

DIURNAL LOW-FLOW, STEADY-STATE ANALYSIS OF DISSOLVED OXYGEN UNDER THE COMMITTED ACTION ALTERNATIVE



NOTE: THE EXISTING WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS SPECIFY MINIMUM DISSOLVED OXYGEN LEVELS OF 5.0 MG/L AND 3.0 MG/L FOR THE FULL WARMWATER FISH AQUATIC LIFE AND THE LIMITED FISH AQUATIC LIFE WATER USE OBJECTIVES, RESPECTIVELY. THESE STANDARDS ARE APPLIED BY THE DEPARTMENT AS A MINIMUM NOT TO BE VIOLATED AT ANY FLOW EQUAL TO OR GREATER THAN THE 7-DAY, 10-YEAR LOW FLOW.

Source: HydroQual, Inc., and SEWRPC.

evaluate future fecal coliform levels under the committed action alternative, the standards supporting limited recreational use were compared to the estimated fecal coliform levels in the inner harbor. The standards supporting full recreational use were compared to the estimated fecal coliform levels in the outer harbor.

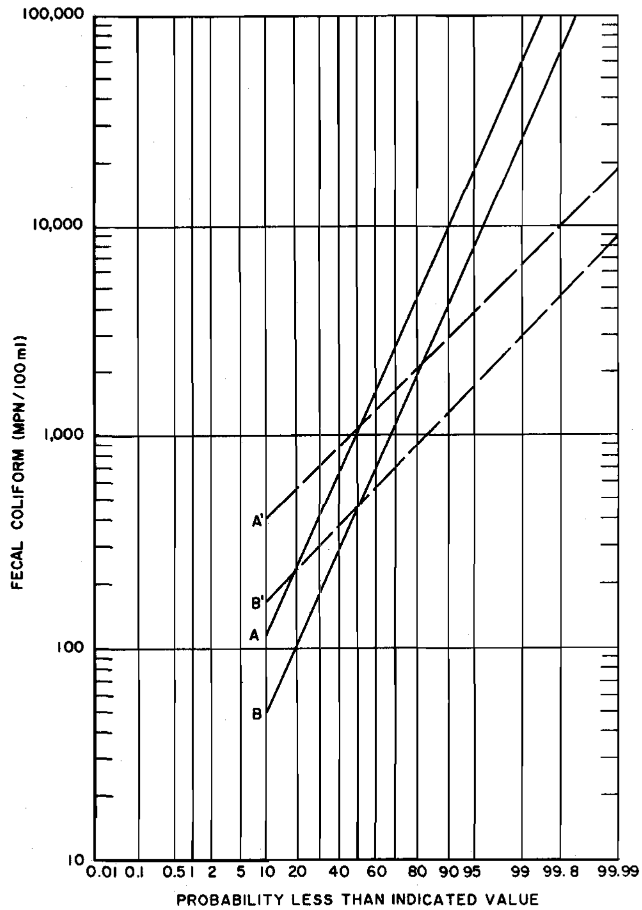
For the tributary rivers upstream of the inner harbor, the frequency distribution plots shown in Figures 52, 53, and 54 compare the existing fecal coliform levels to the levels that may be expected to occur under the committed action alternative. The solid line plots—A and B—show the distribution of all data, and can be compared to the 2,000 and 10,000 MPN/100 ml standards. The dashed line plots—A^1 and B^1—show the distribution of the geometric means of groups of five consecutive samples, and can be compared to the geometric mean standard of 1,000 MPN/100 ml.

The existing fecal coliform data—shown as plots A and A^1—were collected on a weekly basis from 1981 through 1983 by the Milwaukee Metropolitan Sewerage District. Data are given for the Milwaukee River at the North Avenue dam, the Menomonee River at S. 37th Street, and the Kinnickinnic River at S. 11th Street. These sampling stations are the first stations located upstream of the estuary.

Fecal coliform levels which may be expected upstream of the inner harbor under the committed action alternative are shown as plots B and B^1. It was assumed under this alternative that the fecal coliform levels would be similar to the existing fecal coliform levels during dry-weather periods, since the combined sewer overflows and other flow relief devices contribute bacteria only during wet-weather periods. Plots B and B^1, therefore, show the distribution of fecal coliform data during dry-weather periods from 1981 through 1983. The infrequent occurrence of overflows following abatement at a 0.7-year level of protection would not significantly affect the total distribution of fecal coliform levels on an annual basis. It is recognized that during wet-weather periods, fecal coliform levels are also affected by nonpoint sources of pollution. Thus, the assumed elimination of the wet-weather contributions—to represent the committed action alternative—also represents the assumed abatement of some nonpoint sources of fecal coliform organisms under implementation of the Milwaukee River Priority Watersheds Program. Many of the most severe nonpoint sources of fecal coliform organisms, such as livestock operations and malfunctioning septic tank systems, may contribute bacteria to surface waters during both wet- and dry-weather periods. An assumption was therefore made that the effect of nonpoint sources on fecal coliform levels is about the same during wet- and dry-weather periods.

Figure 52

FREQUENCY-DISTRIBUTION OF FECAL COLIFORM LEVELS IN THE MILWAUKEE RIVER AT THE NORTH AVENUE DAM UNDER EXISTING CONDITIONS AND THE COMMITTED ACTION ALTERNATIVE



LEGEND

DISTRIBUTION OF ALL DATA

A EXISTING CONDITIONS

B FUTURE CONDITIONS UNDER THE COMMITTED ACTION ALTERNATIVE

DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF 5 SAMPLES

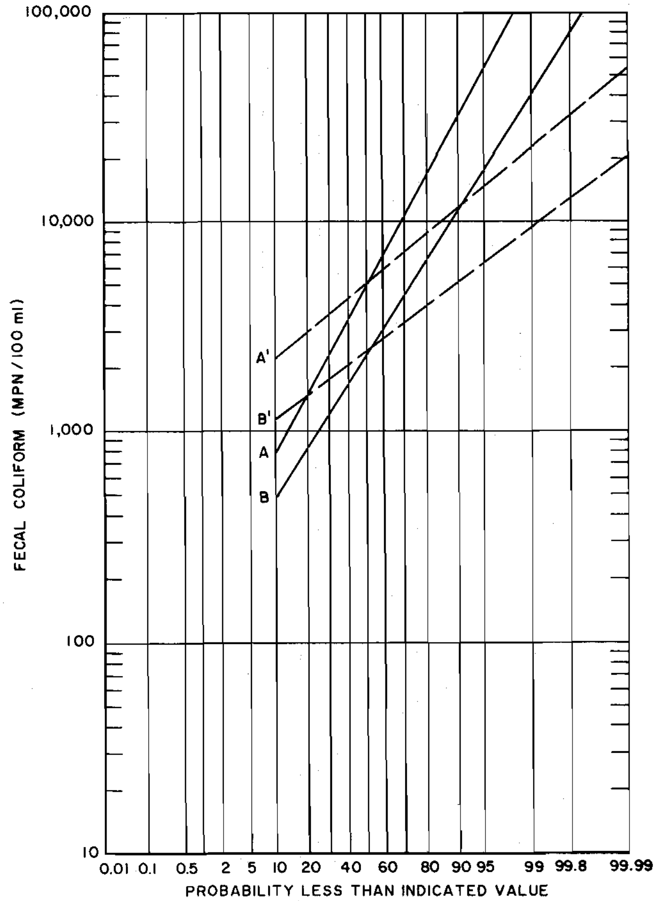
A' EXISTING CONDITIONS

B' FUTURE CONDITIONS UNDER THE COMMITTED ACTION ALTERNATIVE

Source: SEWRPC.

Figure 53

FREQUENCY-DISTRIBUTION OF FECAL COLIFORM LEVELS IN THE MENOMONEE RIVER AT S. 37TH STREET UNDER EXISTING CONDITIONS AND THE COMMITTED ACTION ALTERNATIVE



LEGEND

DISTRIBUTION OF ALL DATA

- A EXISTING CONDITIONS
- B FUTURE CONDITIONS UNDER THE COMMITTED ACTION ALTERNATIVE

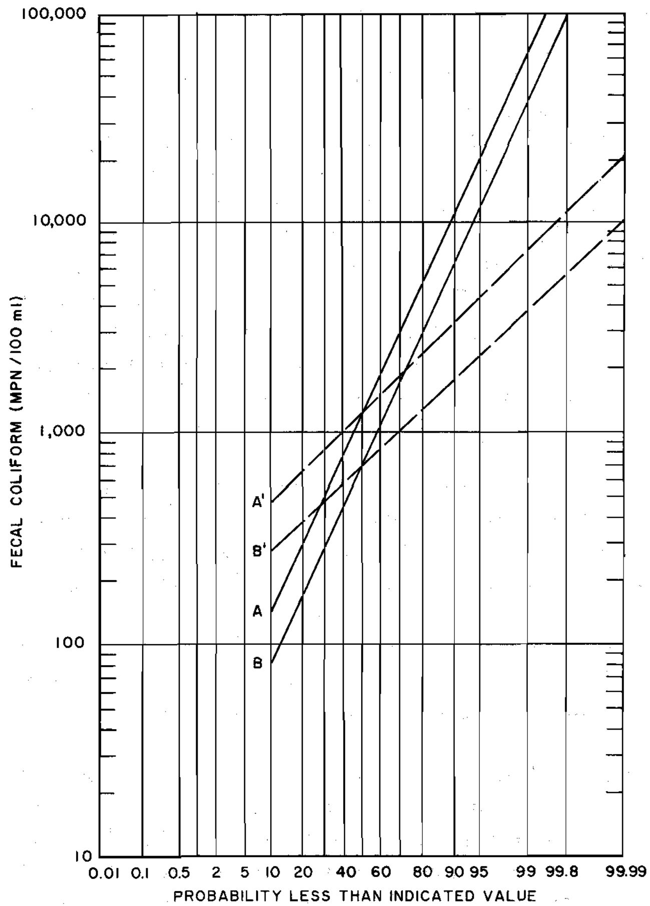
DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF 5 SAMPLES

- A' EXISTING CONDITIONS
- B' FUTURE CONDITIONS UNDER THE COMMITTED ACTION ALTERNATIVE

Source: SEWRPC.

Figure 54

FREQUENCY-DISTRIBUTION OF FECAL COLIFORM LEVELS IN THE KINNICKINNIC RIVER AT S. 11TH STREET UNDER EXISTING CONDITIONS AND THE COMMITTED ACTION ALTERNATIVE



LEGEND

DISTRIBUTION OF ALL DATA

- A EXISTING CONDITIONS
- B FUTURE CONDITIONS UNDER THE COMMITTED ACTION ALTERNATIVE

DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF 5 SAMPLES

- A' EXISTING CONDITIONS
- B' FUTURE CONDITIONS UNDER THE COMMITTED ACTION ALTERNATIVE

Source: SEWRPC.

The percent reductions in fecal coliform levels expected to be achieved under the committed action alternative are set forth in Table 26. The table indicates that a 44 to 57 percent reduction in the geometric mean level, and a 43 to 64 percent reduction in the 90 percentile level, may be expected to be achieved in the tributary rivers just upstream of the estuary. Under the committed action alternative, the fecal coliform standards supporting limited recreational use would be violated upstream of the estuary. The monthly geometric mean fecal coliform standard of 1,000 MPN/100 ml would be violated severely in the Menomonee River, but less so in the Milwaukee and Kinnickinnic Rivers. All three tributary rivers would exceed a level of 2,000 MPN/100 ml more than 10 percent of the time, and a level of 10,000 MPN/100 ml more than 2 percent of the time. Thus, the

Table 26

REDUCTIONS IN FECAL COLIFORM LEVELS EXPECTED IN THE TRIBUTARY RIVERS JUST UPSTREAM OF THE MILWAUKEE HARBOR ESTUARY UNDER THE COMMITTED ACTION ALTERNATIVE

Upstream River Station	Existing Fecal Coliform Level[a]	Committed Action Alternative: Level of Fecal Coliform[b]	Committed Action Alternative: Percent Reduction in Existing Levels
Milwaukee River at North Avenue Dam			
Geometric Mean[c]	1,070	460	57
Level Exceeded 10 Percent of Time[d]	10,160	4,300	58
Menomonee River at S. 37th Street			
Geometric Mean[c]	5,020	2,350	53
Level Exceeded 10 Percent of Time[d]	32,110	11,500	64
Kinnickinnic River at S. 11th Street			
Geometric Mean[c]	1,240	700	44
Level Exceeded 10 Percent of Time[d]	10,860	6,200	43

NOTE: All fecal coliform levels are in MPN/100 ml.

[a]*Shown as plot A in Figures 52, 53, and 54.*

[b]*Shown as plot B in Figures 52, 53, and 54.*

[c]*The geometric mean is the 50 percentile level shown on the frequency distribution plots in Figures 52, 53, and 54.*

[d]*The fecal coliform level exceeded 10 percent of the time is the 90 percentile level shown on the frequency distribution plots in Figures 52, 53, and 54.*

Source: SEWRPC.

upstream rivers would not be suitable for limited recreational uses under the committed action alternative.

The committed action alternative plots shown in Figures 52, 53, and 54 were used to generate fecal coliform loadings to the inner harbor from upstream sources. The statistical water quality model described in Chapter VII of Volume One of this report was then used to evaluate the fecal coliform levels which could be anticipated under the committed action alternative within the estuary.

The estimated distribution of fecal coliform levels under the committed action alternative is presented in Figure 55. The inner harbor would not be expected to fully achieve the fecal coliform standards supporting limited recreational use. The upstream portions of the inner harbor would exceed a level of 10,000 MPN/100 ml more than 2 percent of the time, and a level of 2,000 MPN/100 ml more than 10 percent of the time. The downstream portions of the inner harbor would, however, achieve these standards. The outer harbor would generally be able to achieve the full recreational use fecal coliform standard of 400 MPN/100 ml at least 90 percent of the time. Fecal coliform problems could exist, however, in the outer harbor near the entrance channel.

Figure 56 shows the distribution of the geometric means of groups of five fecal coliform samples for this alternative, and for the elimination of combined sewer overflows alternative discussed in the next section. This figure illustrates the achievement of the geometric mean standards. Within the inner harbor, it appears that only portions of the Kinnickinnic River estuary would be able to achieve the monthly geometric mean standard supporting limited recreational use of 1,000 MPN/100 ml at least 95 percent of the time. The Milwaukee River estuary would violate the standard about 10 percent of the time and the Menomonee River estuary, about 10 to more than 50 percent of the time. The figure indicates that the outer harbor would likely achieve the monthly geometric mean standard of 200 MPN/100 ml supporting full recreational use.

It can be noted from the previous data that the fecal coliform levels in the Menomonee River substantially exceed the levels in the Milwaukee and Kinnickinnic Rivers both under existing conditions and under the committed action alternative. Under the committed action alternative, the geometric mean value at the upper end of the Menomonee River estuary is estimated to be 2,350, compared to 460 and 700 at the upper end of the Milwaukee River and Kinnickinnic River estuaries, respectively, as shown in Table 26. These relatively high coliform levels, which are present during both dry and wet weather, are contributed by urban and rural land runoff, livestock operations, and septic systems, in addition to being caused by direct contamination from birds and animals and direct or indirect connections from leaking sanitary sewerage systems. The fecal coliform data collected on the Milwaukee River indicate that the coliform levels substantially increase as the river passes through the urban areas, indicating a higher contribution from the urban areas than from the rural areas. The Menomonee River watershed is largely urbanized and has a tributary urban area of about 71 square miles, or about 0.8 square mile per cfs of mean daily flow. The Kinnickinnic and Milwaukee Rivers have tributary urban areas of 18 square miles and 110 square miles, respectively, or about 0.8 square mile per cfs and 0.3 square mile per cfs of mean annual flow, respectively. Thus, it may be postulated that the impact of the urban areas contributes to the higher levels in the Kinnickinnic and Menomonee Rivers when compared to the Milwaukee River. However, it does not account for the difference in levels found in the Menomonee and Kinnickinnic Rivers. While the values for the Menomonee River are substantially higher than those for the Kinnickinnic River, they are, nevertheless, of the same order of magnitude. Because the fecal coliform levels can vary substantially, with only limited differences in sources, the values for the three rivers do not appear to be unreasonable. Review of the findings of the alternative plan evaluations presented later in this chapter indicate that the alternative plan recommendations would not be different if the Menomonee River coliform levels were similar to the levels in the Kinnickinnic River.

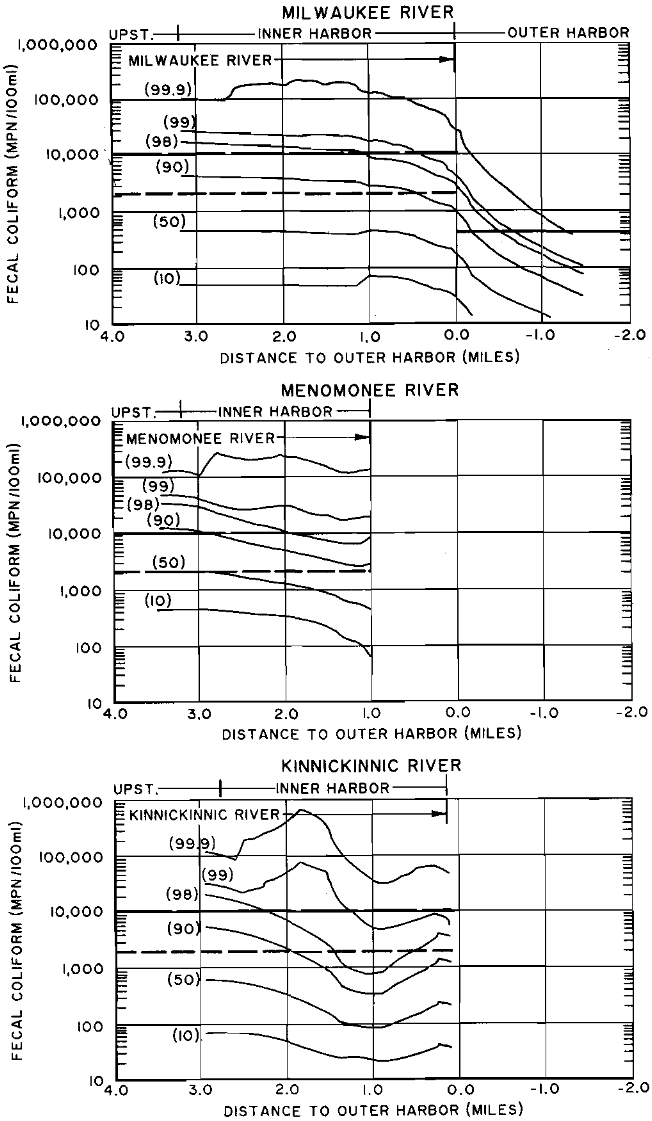
Thus, under the committed action alternative, the inner harbor would not be able to fully achieve the fecal coliform standards supporting limited recreational use. The lower reaches of the inner harbor would, however, have lower levels of fecal coliform than the upper reaches, and the lower portions of the Kinnickinnic River estuary in particular could achieve the limited recreational use standards. The outer harbor would be expected to achieve the fecal coliform standards supporting full recreational use.

Ammonia Nitrogen: As reported in Chapter VI of Volume One of this report, combined sewer overflows contribute about 117,000 pounds of ammonia nitrogen to the inner harbor annually. This accounts for about 31 percent of the total annual ammonia nitrogen load of about 376,000 pounds to the inner harbor from external sources. In addition, ammonia nitrogen fluxes from the bottom sediments contribute to the ammonia nitrogen concentration in the water column. Under the committed action alternative, the existing loading of ammonia nitrogen from combined sewer overflows would be reduced by about 97 percent, and the flux of nitrogen from the bottom sediments to the inner harbor water column would be reduced by 80 to 90 percent.

Simulated ammonia nitrogen concentrations under low-flow, steady-state conditions are presented in Figure 57. The figure indicates that ammonia nitrogen concentrations under the committed action alternative would be similar in the surface and bottom water layers within the upstream reaches and inner harbor. Within the outer harbor, however, the surface concentrations would be up to

Figure 55

ESTIMATED FECAL COLIFORM LEVELS UNDER THE COMMITTED ACTION ALTERNATIVE: DISTRIBUTION OF ALL DATA



LEGEND

(99.9) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE: OUTER HARBOR

—— LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 10 PERCENT OF THE TIME (400 MPN/100 ml)

LIMITED RECREATIONAL USE: INNER HARBOR

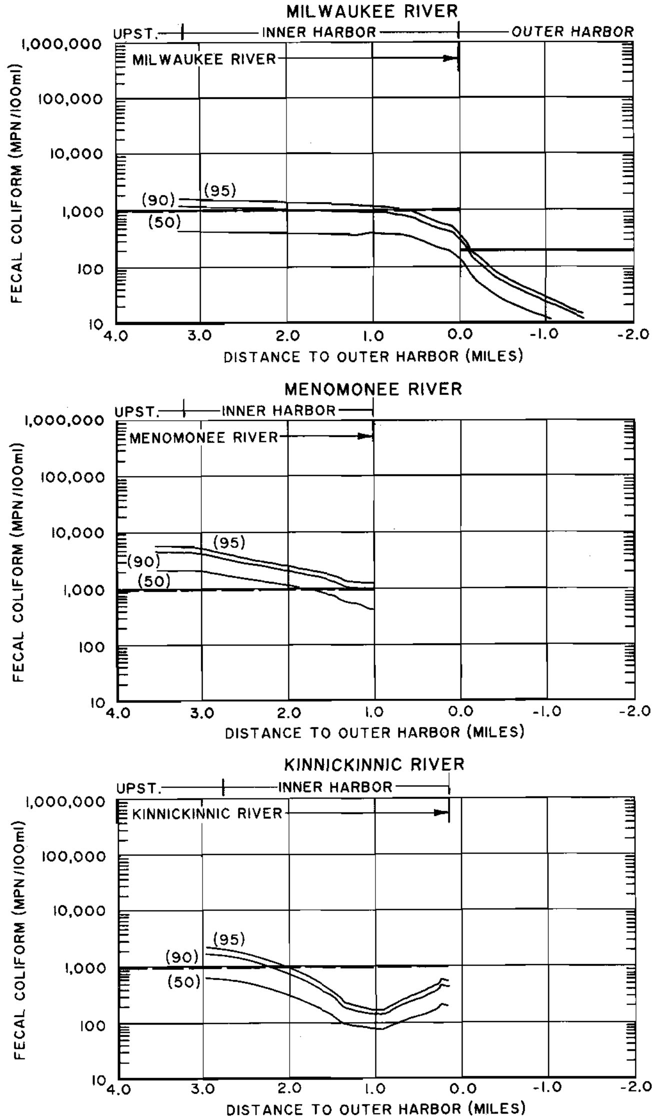
---- LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 10 PERCENT OF THE TIME (2,000 MPN/100ml)

— — LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 2 PERCENT OF THE TIME (10,000 MPN/100 ml)

Source: HydroQual, Inc.

Figure 56

ESTIMATED FECAL COLIFORM LEVELS UNDER THE COMMITTED ACTION ALTERNATIVE AND THE ELIMINATION OF COMBINED SEWER OVERFLOWS ALTERNATIVE: DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF FIVE SAMPLES



LEGEND

(90) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE: OUTER HARBOR

—— LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH (200 MPN/100 ml)

LIMITED RECREATIONAL USE: INNER HARBOR

— — LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH MORE THAN 5 PERCENT OF THE TIME (1,000 MPN/100 ml)

Source: HydroQual, Inc.

four times higher than the bottom concentrations because of the discharge of ammonia nitrogen to the outer harbor from the Jones Island sewage treatment plant. The Jones Island plant discharges over 2.5 million pounds of ammonia nitrogen to the outer harbor annually.

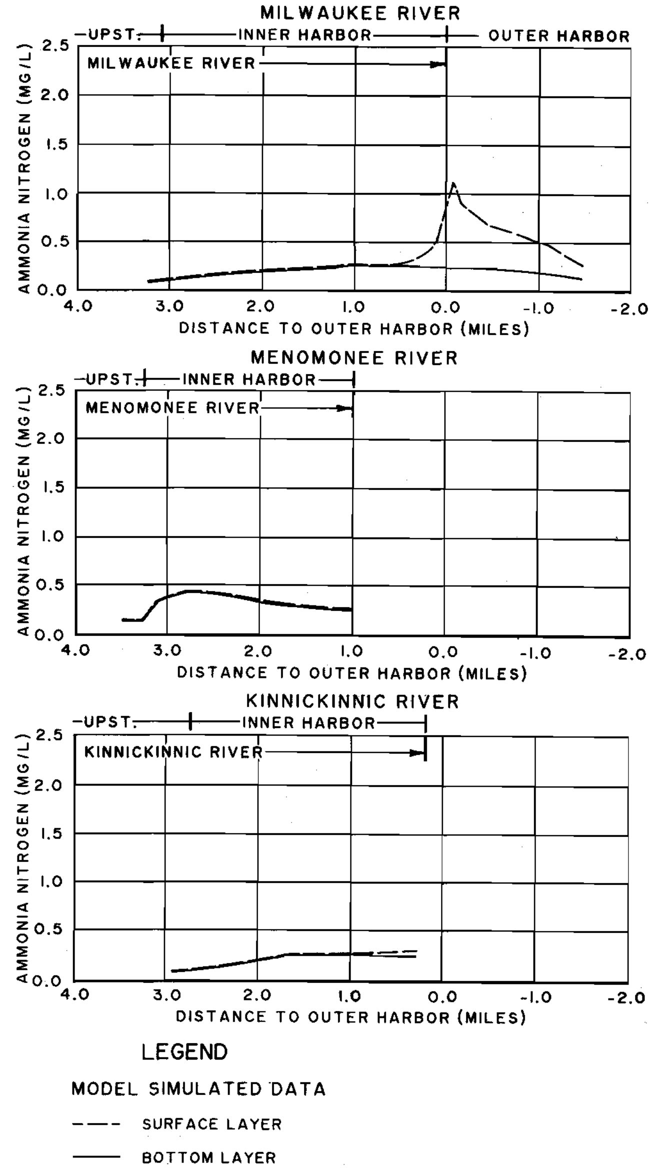
The un-ionized ammonia nitrogen concentrations expected under the committed action alternative, along with the comparison to acute and chronic toxicity standards, are set forth in Table 27. As discussed in Chapter II, the toxicity of un-ionized ammonia nitrogen varies substantially with temperature and pH. Thus, the acute and chronic toxicity standards were calculated using the pH and temperature levels measured under the baseline sampling program during the low-flow, high-temperature Survey Period 1, July 25 through August 8, 1983. These pH and temperature levels were also used to calculate the un-ionized ammonia nitrogen concentration at each sampling station.

Under low-flow, steady-state conditions, the un-ionized ammonia nitrogen concentration would range from 0.009 to 0.022 mg/l at the upstream river stations, from 0.004 to 0.025 mg/l at the inner harbor stations, and from 0.002 to 0.013 mg/l at the outer harbor stations. The chronic and acute toxicity standards would not be violated at any station under the committed action alternative. Although a relatively high total ammonia nitrogen concentration—1.1 mg/l—was estimated for the outer harbor near the Jones Island sewage treatment plant discharge, the calculated un-ionized ammonia nitrogen concentration was relatively low—0.013 mg/l—because the pH in the outer harbor was also low—7.4 standard units. It is probable that under the committed action alternative, occasional violations of the chronic toxicity standards would occur within portions of the outer harbor during periods of higher pH.

A review of the data utilized indicated that the pH of 7.4 standard units had been used because that was the measured value at the station near the Jones Island outfall during the low-flow, high-temperature period of Survey Period 1 that was considered to represent low-flow conditions. It is recognized that higher pH levels are common in other portions of the estuary. A review of the pH data from 1981 through 1983 provided the following values:

Figure 57

SIMULATED AMMONIA NITROGEN CONCENTRATIONS UNDER LOW-FLOW, STEADY-STATE CONDITIONS



Source: HydroQual, Inc.

Station	Year	pH Levels (standard units) Minimum	Maximum	Mean
OH-2	1981	7.3	8.1	7.6
(Jones Island	1982	6.8	8.0	7.4
Plume)	1983	6.2	8.3	7.6
OH-3	1981	7.5	8.1	7.8
(Central	1982	7.1	8.1	7.5
Outer Harbor)	1983	7.3	8.4	7.8

Table 27

COMPARISON OF ESTIMATED UN-IONIZED AMMONIA NITROGEN CONCENTRATIONS TO THE RECOMMENDED ACUTE AND CHRONIC TOXICITY STANDARDS UNDER THE COMMITTED ACTION ALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Total Ammonia Nitrogen[b] (mg/l)	pH[c] (standard units)	Temperature (°F)	Un-ionized Ammonia Nitrogen[d] (mg/l)	Un-ionized Ammonia Nitrogen Toxicity Standards		Violation of Un-ionized Ammonia Nitrogen Toxicity Standards	
							Acute[e]	Chronic[e]	Acute	Chronic
Upstream										
Milwaukee River	North Avenue Dam (RIV-5)	DI	0.1	8.5	81	0.017	0.117	0.025	--	--
Menomonee River	S. 37th Street (RIV-10)	DI	0.4	8.5	75	0.063	0.116	0.025	--	X
Kinnickinnic River	S. 9th Place (RIV-13)	DI	0.1	8.9	84	0.038	0.121	0.025	--	X
Inner Harbor										
Milwaukee River	Walnut Street	S	0.2	8.5	81	0.028	0.116	0.025	--	X
	(RIV-6)	B	0.2	8.4	81	0.024	0.115	0.025	--	--
	Wells Street	S	0.3	8.0	79	0.017	0.102	0.025	--	--
	(RIV-7)	B	0.3	8.1	75	0.021	0.108	0.025	--	--
	Water Street	S	0.3	7.9	79	0.013	0.098	0.025	--	--
	(RIV-8)	B	0.3	7.9	66	0.008	0.099	0.025	--	--
	C&NW Railway	S	0.3	7.5	77	0.004	0.073	0.025	--	--
	(RIV-15)	B	0.3	8.1	64	0.012	0.105	0.025	--	--
Menomonee River	Muskego Avenue	S	0.3	7.7	81	0.009	0.088	0.025	--	--
	(RIV-11)	B	0.3	7.5	72	0.004	0.077	0.025	--	--
	S. 2nd Street	S	0.6	7.7	79	0.021	0.088	0.025	--	--
	(RIV-17)	B	0.2	7.7	72	0.006	0.090	0.025	--	--
Kinnickinnic River	S. 1st Street	S	0.2	7.6	72	0.005	0.081	0.025	--	--
	(RIV-14)	B	0.2	7.6	72	0.005	0.081	0.025	--	--
	Greenfield Avenue	S	0.3	7.6	73	0.006	0.081	0.025	--	--
	Extended (RIV-18)	B	0.2	7.6	64	0.003	0.081	0.025	--	--
	Jones Island	S	0.5	7.6	73	0.010	0.083	0.025	--	--
	(RIV-19)	B	0.2	7.9	63	0.005	0.097	0.025	--	--
Outer Harbor	South OH (OH-11)	S	0.6	7.6	72	0.013	0.079	0.025	--	--
		B	0.2	7.6	57	0.002	0.083	0.025	--	--
	JI STP Plume	S	1.2	7.4	70	0.013	0.065	0.025	--	--
	(OH-2)	B	0.3	7.9	61	0.006	0.097	0.025	--	--

NOTE: The existing Wisconsin Department of Natural Resources standard for un-ionized ammonia nitrogen specifies a maximum level of 0.04 mg/l for the full warmwater fishery and aquatic life water use objective. The Department has issued no standard for the limited fishery and aquatic life objective. The standard for the warmwater fishery and aquatic life objective is applied by the Department as a maximum not to be exceeded at any flow equal to or greater than the 7-day, 10-year minimum flow.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

[b] *As estimated in Figure 57.*

[c] *Arithmetic mean pH and temperature levels measured during Survey Period 1, July 25 through August 8, 1983, under the baseline sampling program.*

[d] *The un-ionized ammonia nitrogen concentrations were calculated using the estimated total ammonia nitrogen, pH, and temperature levels.*

[e] *The acute and chronic toxicity standards, which vary in response to the pH and temperature of the water, were calculated in accordance with the procedures set forth in Chapter II of this volume.*

Source: SEWRPC.

It should be noted that the calculated un-ionized ammonia concentration was 0.013 using the pH of 7.4 standard units. As noted above, the mean pH value for 1981 and 1983 was 7.6 units, as opposed to 7.4 units in 1982. Using this pH, the calculated un-ionized ammonia concentration would be 0.021 mg/l, still below the chronic and acute standards levels. However, since the un-ionized ammonia concentration is very sensitive to pH calculations and because pH levels as high as 8.3 were observed at this station, it is likely that occasional violations of the chronic toxicity standards would occur within portions of the outer harbor nearest the mixing zone of the Jones Island outfall. However, potential violations would occur only in the vicinity of the Jones Island outfall, and would be reduced as dispersion of the plant effluent is increased.

Lead: It was estimated in Chapter VI of Volume One of this report that 85,000 pounds of lead are discharged annually to the inner harbor from the tributary rivers, of which about 25,500 pounds, or 30 percent, are from combined sewer overflows which discharge upstream of the estuary. An additional 47,000 pounds of lead are discharged directly to the inner harbor via combined sewer overflows. Combined sewer overflows account for about 55 percent of the total of nearly 132,000 pounds of lead contributed annually to the inner harbor. The committed action alternative would reduce loadings of lead from combined sewer overflows by about 97 percent. Thus, under the committed action alternative, total lead loadings to the inner harbor would be reduced by about 53 percent. The statistical water quality model described in Chapter VII of Volume One of this report was used to evaluate the lead levels which could be anticipated under the committed action alternative within the estuary.

The estimated distribution of lead concentrations in the surface and bottom water layers under the committed action alternative is presented in Figure 58. The median lead levels, plus and minus one standard deviation of the logs of the data, are shown in the figure. The data plots show total lead concentrations. Chronic and acute toxicity standards for lead are also shown in the figure. The same standards support both warmwater and limited fish and aquatic life. However, these standards apply to acid-soluble, not total, lead concentrations. Thus, exceedance of the acid-soluble lead standards by total lead concentrations would not necessarily indicate that toxic conditions would exist. Where total lead concentrations are below the standards, it can be assumed that toxic conditions would not exist.

Figure 58 indicates that lead levels in both the inner harbor and outer harbor would meet the acute and chronic toxicity standards for acid-soluble lead under the committed action alternative. There would be no significant difference between the lead concentrations in the bottom water layer and the concentrations in the surface water layer. The concentrations in the lower reaches of the inner harbor would be similar to the concentrations in the upper reaches of the harbor and in the upstream rivers. The median lead concentrations in the outer harbor would generally be less than one-half of the concentrations in the inner harbor.

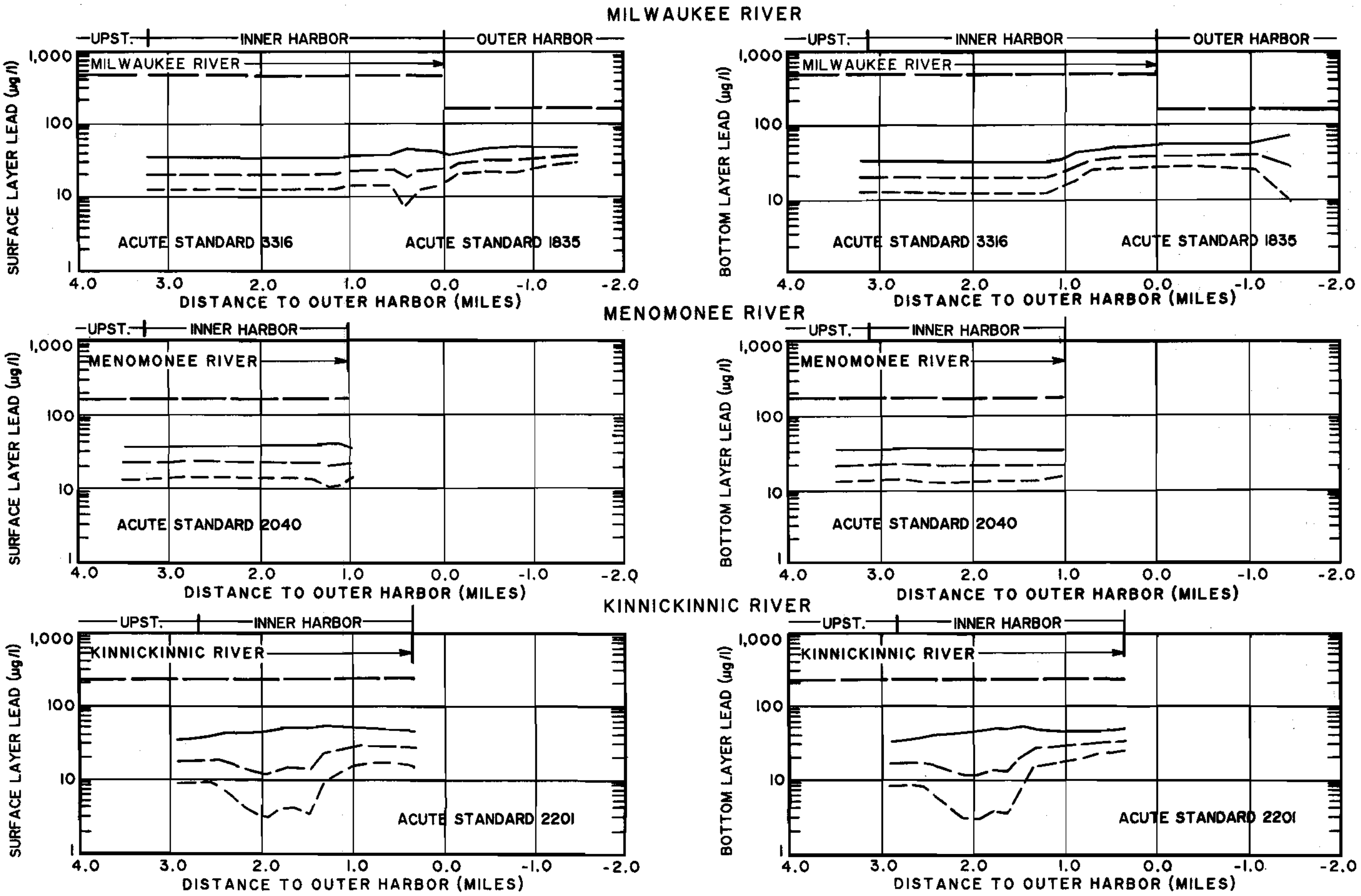
Based on a comparison to U. S. Environmental Protection Agency (EPA) sediment quality guidelines, the bottom sediments of the inner harbor are classified as heavily polluted with lead concentrations. To assess the long-term impacts of the committed action alternative on lead concentrations in the inner harbor sediments, it was assumed that the concentrations would be reduced proportionately to the reduction in total lead loadings. A 97 percent reduction in lead loadings from combined sewer overflows would thus result in a reduction of approximately 53 percent in lead levels in the bottom sediments of the inner harbor. Estimated concentrations of lead in the bottom sediments under the committed action alternative are set forth in Table 28. The estimated lead concentrations would result in the bottom sediments in all six inner harbor stations being rated as heavily polluted.

Other Toxic Metals: Analysis of the estimated pollutant loadings presented in Chapter VI of Volume One provides a general indication of the effect of the committed action alternative on the levels of cadmium, copper, and zinc in the inner harbor. Combined sewer overflows were estimated to account for 30 percent of the cadmium, 8 percent of the copper, and 88 percent of the zinc contributed to the inner harbor.

A portion of the metal loading is deposited in the bottom sediments, and the rest remains in solution or suspension. Based on EPA sediment quality guidelines, the inner harbor bottom sediments are heavily polluted with cadmium, copper, and zinc. The inner harbor baseline data collected from 1981 through 1983 indicated that total cadmium

Figure 58

ESTIMATED LEAD CONCENTRATIONS UNDER THE COMMITTED ACTION ALTERNATIVE



LEGEND

STANDARDS

—— ACUTE MAXIMUM STANDARD

— — CHRONIC 30 DAY MEAN MAXIMUM STANDARD

LEAD PLOTS

—— MEDIAN PLUS ONE STANDARD DEVIATION OF THE LOGS (84TH PERCENTILE)

— — MEDIAN (50TH PERCENTILE)

– – – MEDIAN MINUS ONE STANDARD DEVIATION OF THE LOGS (16TH PERCENTILE)

NOTE: THE ACUTE AND CHRONIC STANDARDS APPLY TO ACID-SOLUBLE LEAD CONCENTRATIONS, WHEREAS THE PLOTS REPRESENT TOTAL LEAD CONCENTRATIONS.THUS, VIOLATION OF THE STANDARD DOES NOT NECESSARILY INDICATE THAT TOXIC CONDITIONS WOULD EXIST.THE ACUTE AND CHRONIC STANDARDS, WHICH ARE A FUNCTION OF THE HARDNESS OF THE WATER, WERE CALCULATED USING THE BASELINE HARDNESS LEVELS MEASURED FROM 1981 THROUGH 1983 AT THE REPRESENTATIVE SAMPLING STATIONS PRESENTED IN CHAPTER VI OF VOLUME ONE OF THIS REPORT.

Source: HydroQual, Inc., and SEWRPC.

levels in the water column often exceeded the chronic toxicity standard for acid-soluble cadmium, but that the acute toxicity standard was not exceeded. A few total copper measurements collected over the three-year sampling program—during dry-weather periods—exceeded both the acute and chronic toxicity standards for acid-soluble copper. The measured total zinc levels did not exceed the acute or chronic toxicity standards for acid-soluble zinc. The baseline metals data

Table 28

ESTIMATED METAL CONCENTRATIONS IN THE BOTTOM SEDIMENTS OF THE INNER HARBOR UNDER THE COMMITTED ACTION ALTERNATIVE

Metal	U. S. Environmental Protection Agency Sediment Quality Classification			Milwaukee River				Menomonee River				Kinnickinnic River			
				Broadway Street		C&NW Railway		Muskego Avenue		Burnham Canal		S. 1st Street		Greenfield Avenue Extended	
	Nonpolluted	Moderately Polluted	Heavily Polluted	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating
Cadmium	--[a]	--[a]	> 6	2.6	--[a]	5.8	--[a]	8.4	H	4.8	--[a]	4.7	--[a]	7.1	H
Copper	< 25	25-50	>50	67	H	97	H	129	H	92	H	110	H	110	H
Lead	< 40	40-60	>60	338	H	183	H	240	H	129	H	272	H	179	H
Zinc	< 90	90-200	>200	33	N	64	N	68	N	46	N	96	M	79	N

NOTES: All units are in milligrams per kilogram on a dry-weight basis. The metal concentrations measured in the sediment core samples presented in Chapter VI of Volume One were reduced in proportion to the reduction in total metal loadings expected under the committed action alternative.

Pollution Ratings: N-Nonpolluted; M-Moderately Polluted; H-Heavily Polluted

[a] *Cadmium ranges for a nonpolluted or moderately polluted classification have not been established by the U. S. Environmental Protection Agency.*

Source: SEWRPC.

thus demonstrated potential chronic toxicity for cadmium, and a very slight potential for both acute and chronic toxicity for copper.

To provide a general assessment of the long-term impacts of the committed action alternative, it was assumed that the metal concentrations in both the bottom sediments and water column would be reduced proportionately to the reduction in total pollutant loadings. Thus, a reduction of approximately 97 percent in metal loadings from combined sewer overflows would result in reductions of approximately 29 percent in cadmium, 8 percent in copper, and 85 percent in zinc levels in the inner harbor bottom sediments and water column.

Estimated concentrations of cadmium, copper, and zinc in the bottom sediments of the inner harbor under the committed action alternative are set forth in Table 28. The anticipated reductions would significantly affect the pollution ratings for cadmium and zinc in the bottom sediments. Two of the six inner harbor stations would continue to be classified as heavily polluted based on the cadmium concentrations. The remaining four stations would not be rated as heavily polluted, but cadmium guidelines have not been established to distinguish between a nonpolluted and moderately polluted rating. The estimated zinc concentrations would result in a nonpolluted rating at five of the six stations, and a moderately polluted rating at the remaining station. The estimated copper concentrations would continue to result in heavily polluted ratings at all of the inner harbor stations.

The probability plots of the 1981 through 1983 baseline data for cadmium and copper in the water column set forth in Chapter VI of Volume One, along with the reductions in concentrations expected under the committed action alternative, were reviewed to compare violations of the standards for these metals under existing conditions with violations under the alternative. The violation of the chronic toxicity standards for acid-soluble cadmium and copper would be less severe under the committed action alternative, but the frequency of violations would not be significantly reduced. When violated under existing conditions, the standards tended to be exceeded by a relatively large margin. The chronic and acute toxicity standards for acid-soluble zinc were not violated under existing conditions, and the achievement of those standards would continue under the committed action alternative.

Elimination of Combined Sewer Overflows Alternative

Virtually all pollutant loadings discharged from combined sewer overflows upstream of the estuary and directly to the estuary itself would be eliminated under this alternative. Thus, the remaining 3 percent of the pollutant loadings discharged from combined sewer overflows under the committed action alternative would be eliminated. The estuary would not experience the severe water quality impacts expected during an occasional overflow event. Presented below are the water quality conditions expected within the Milwaukee Harbor estuary if combined sewer overflows are virtually eliminated.

Dissolved Oxygen: A low-flow, steady-state simulation analysis was conducted to determine the effect that virtual elimination of combined sewer overflows would have on the critical dissolved oxygen conditions expected during low-flow and high-temperature periods. The steady-state analysis estimated dissolved oxygen levels under 7-day, 10-year recurrence interval low-flow conditions at the high temperature levels measured during Survey Period 1, July 25 to August 8, 1983. Spatial plots of low-flow, steady-state dissolved oxygen levels under the elimination of combined sewer overflows alternative are shown in Figure 59. The figure compares the simulated dissolved oxygen levels to standards established for a warmwater fishery and for a limited fishery.

The comparison to the standards indicates a slight improvement in the dissolved oxygen levels in all three river estuaries over the levels that would be achieved under the committed action alternative. At least some of the dissolved oxygen standards for a warmwater fishery and a limited fishery would be violated in both the surface and bottom water layers within the inner harbor. Simulated dissolved oxygen levels in all three river estuaries were less than the 7-day mean standards for both warmwater and limited fisheries. The 30-day mean and one-day mean standards for both warmwater and limited fisheries would be violated in the Milwaukee and Menomonee River estuaries. The absolute minimum standard for a warmwater fishery would be violated in the Milwaukee River estuary. Dissolved oxygen levels in the upstream rivers and in the outer harbor would be about the same as under the committed action alternative.

The significance of the individual sinks of oxygen under the elimination of combined sewer overflows alternative can be determined by analyzing the components of the dissolved oxygen deficit. The components of the deficit that were studied in the steady-state analysis included the sediment flux of methane and ammonia, sediment oxygen demand, carbonaceous biochemical oxygen demand from upstream sources and from the Jones Island sewage treatment plant, and net photosynthesis/respiration. The computed components of the dissolved oxygen deficit under low-flow, steady-state conditions in the surface and bottom water layers are shown in Figure 60.

The total dissolved oxygen deficit is lower under the elimination of combined sewer overflows alternative than under the committed action alternative. This results from the lower dissolved oxygen deficit associated with sediment processes—sediment oxygen demand and the sediment flux of methane and ammonia. The effects of net photosynthesis/respiration in the Milwaukee River estuary, and of carbonaceous biochemical oxygen demand from upstream sources and from the Jones Island sewage treatment plant, would be about the same as under the committed action alternative.

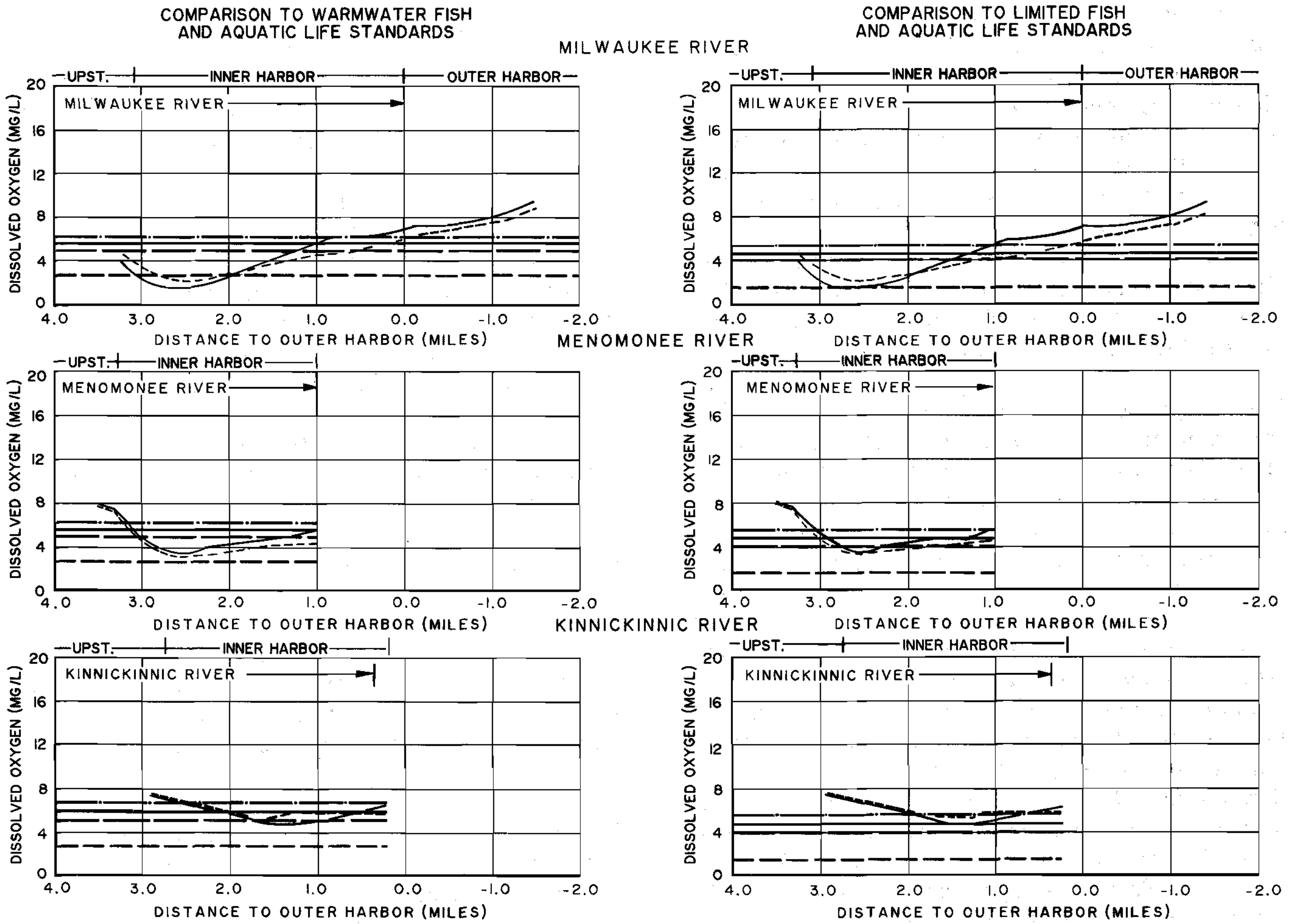
Dissolved oxygen conditions under a series of flow and temperature conditions were evaluated to assess the improvement in dissolved oxygen levels under the elimination of combined sewer overflows alternative. Estimated dissolved oxygen levels were then compared to the standards for a warmwater fishery and for a limited fishery. The expected violations of the dissolved oxygen standards are set forth in Table 29. For the surface and bottom water layers of several upstream, inner harbor, and outer harbor sampling stations, the anticipated violation of the dissolved oxygen standards is classified as slight, moderate, or severe.

The violations of the dissolved oxygen standards expected under the elimination of combined sewer overflows alternative would be very similar to those expected under the committed action alternative, as shown in Table 29. Within the tributary rivers upstream of the estuary, the improvement in dissolved oxygen levels would be insignificant, with all of the violation ratings being the same as under the committed action alternative. Within the inner harbor, about 10 percent of the violation ratings would indicate a significant improvement in dissolved oxygen levels, with the remaining 90 percent of the ratings remaining the same as under the committed action alternative. Dissolved oxygen levels in the outer harbor would be the same as under the committed action alternative, with only one station near the Hoan Bridge indicating an improvement.

Diurnal fluctuations in dissolved oxygen levels would be similar to those expected under the committed action alternative. Within the Milwaukee River estuary, violations of the absolute minimum standards would become more severe during the night, when minimum dissolved oxygen levels would likely occur. Diurnal fluctuations in dissolved oxygen concentrations would be very minor in the Menomonee and Kinnickinnic River estuaries, and in the outer harbor. The bottom water layers would not exhibit diurnal fluctuations in any of the water bodies.

Figure 59

LOW-FLOW, STEADY-STATE ANALYSIS OF DISSOLVED OXYGEN UNDER THE ELIMINATION OF COMBINED SEWER OVERFLOWS ALTERNATIVE



LEGEND

MODEL SIMULATED DATA

- - - SURFACE LAYER

—— BOTTOM LAYER

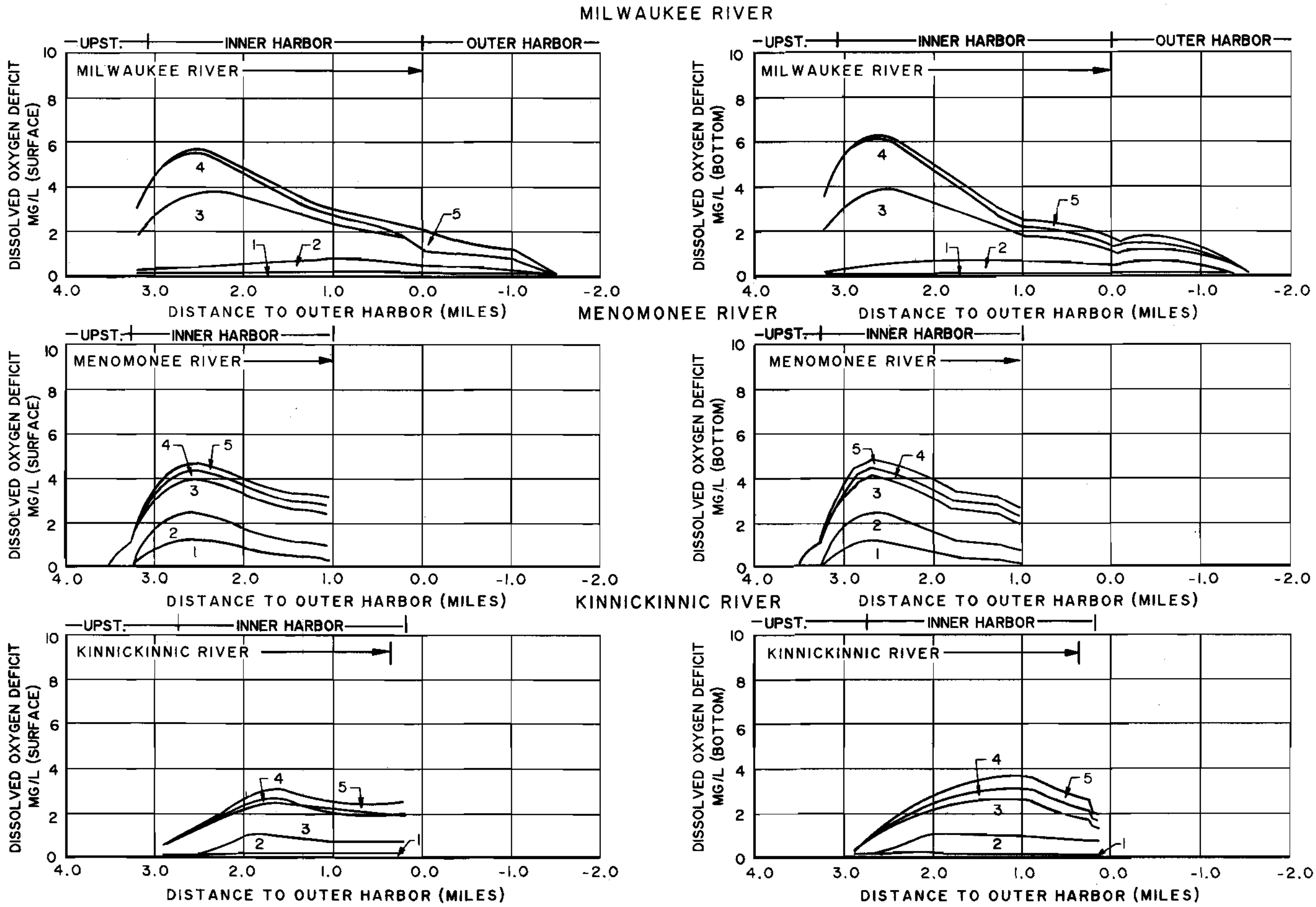
STANDARDS (MG/L)	WARMWATER	LIMITED
—— 30 DAY MEAN MINIMUM STANDARD	5.5	4.5
—·— 7 DAY MEAN MINIMUM STANDARD (3/15-7/31)	6.0	5.0
— — 1 DAY MEAN MINIMUM STANDARD (3/15-7/31)	5.0	4.0
- - - ABSOLUTE MINIMUM STANDARD	2.5	1.5

NOTE: THE EXISTING WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS SPECIFY MINIMUM DISSOLVED OXYGEN LEVELS OF 5.0 MG/L AND 3.0 MG/L FOR THE FULL WARMWATER FISH AND AQUATIC LIFE AND THE LIMITED FISH AND AQUATIC LIFE WATER USE OBJECTIVES,RESPECTIVELY. THESE STANDARDS ARE APPLIED BY THE DEPARTMENT AS A MINIMUM NOT TO BE VIOLATED AT ANY FLOW EQUAL TO OR GREATER THAN THE 7-DAY,10-YEAR MINIMUM FLOW.

Source: HydroQual, Inc.

Figure 60

COMPONENTS OF THE DISSOLVED OXYGEN DEFICIT UNDER LOW-FLOW, STEADY-STATE CONDITIONS: ELIMINATION OF COMBINED SEWER OVERFLOWS ALTERNATIVE



LEGEND

1 SEDIMENT FLUX OF METHANE AND AMMONIA

2 SEDIMENT OXYGEN DEMAND

3 UPSTREAM CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND

4 NET PHOTOSYNTHESIS/RESPIRATION

5 CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND FROM THE JONES ISLAND SEWAGE TREATMENT PLANT

Source: HydroQual, Inc.

Table 29

VIOLATION OF DISSOLVED OXYGEN STANDARDS UNDER THE ELIMINATION OF COMBINED SEWER OVERFLOWS ALTERNATIVE

			Warmwater Fish and Aquatic Life					Limited Fish and Aquatic Life				
Water Body	Baseline Sampling Station	Water Layer[a]	30-Day Mean All Year 5.5 mg/l	7-Day Mean 3/15-7/31 6.0 mg/l	1-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 8/1-3/14 4.0 mg/l	Absolute Minimum All Year 2.5 mg/l	30-Day Mean All Year 4.5 mg/l	7-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 3/15-7/31 4.0 mg/l	1-Day Mean 8/1-3/14 3.0 mg/l	Absolute Minimum All Year 1.5 mg/l
Upstream												
Milwaukee River	North Avenue Dam (RIV-5)	DI	None	Moderate	None	None	None	None	None	None	None	None
Menomonee River	S. 37th Street (RIV-10)	DI	None	Moderate	None	None	None	None	None	None	None	None
Kinnickinnic River	S. 9th Place (RIV-13)	DI	None	Slight	Slight	Slight	Slight	None	Slight	Slight	Slight	None
Inner Harbor												
Milwaukee River	Walnut Street (RIV-6)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	Moderate	Moderate	None	None	None	Moderate	Slight	None	None
	Wells Street (RIV-7)	S	Slight	Severe	Moderate	Slight	None	Slight	Moderate	None	Slight	None
		B	None	Severe	Severe	None	None	None	Severe	Slight	None	None
	Water Street (RIV-8)	S	Moderate	Severe	Severe	Moderate	Slight	Moderate	Severe	Slight	Slight	None
		B	Slight	Moderate	Slight	Slight	None	Slight	Slight	Slight	None	None
	C&NW Railway (RIV-15)	S	Moderate	Severe	None	None	None	None	None	None	None	None
		B	Slight	Severe	None	Slight	None	Slight	None	None	None	None
Menomonee River	Muskego Avenue (RIV-11)	S	Severe	Severe	Severe	Moderate	Slight	Slight	Severe	Moderate	Slight	None
		B	Severe	Severe	Severe	Slight	None	Slight	Severe	Severe	None	None
	S. 2nd Street (RIV-17)	S	Severe	Severe	Severe	Moderate	None	Moderate	Severe	Moderate	None	None
		B	Moderate	Moderate	None	Moderate	None	Slight	None	None	None	None
Kinnickinnic River	S. 1st Street (RIV-14)	S	Severe	Severe	Severe	Severe	Slight	Moderate	Severe	Severe	Moderate	None
		B	Severe	Severe	Severe	Severe	Slight	Moderate	Severe	Moderate	Moderate	None
	Greenfield Avenue Extended (RIV-18)	S	None	Severe	Moderate	None	None	None	Moderate	None	None	None
		B	Slight	Moderate	Moderate	Slight	None	Slight	Moderate	Moderate	None	None
	Jones Island (RIV-19)	S	None	Moderate	Moderate	None	None	None	Moderate	None	None	None
		B	Slight	Slight	None	None	None	Slight	None	None	None	None
Outer Harbor	Hoan Bridge (OH-1)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	None	None	Slight	None	None	None	None
	Central OH (OH-3)	S	Slight	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	None	None	Slight	None	None	None	None
	South OH (OH-11)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	Slight	None	Slight	None	Slight	None	None	None	None
	JI STP Plume (OH-2)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	Slight	None	Slight	None	None	Slight	None

NOTE: Standard violations that occur up to 5 percent of the time are classified as slight; violations that occur 6 to 10 percent of the time are classified as moderate; and violations that occur more than 10 percent of the time are classified as severe. Underlined ratings indicate a significant improvement in dissolved oxygen levels over the levels expected under the committed action alternative.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

Source: HydroQual, Inc., and SEWRPC.

Fecal Coliform: A substantial reduction in fecal coliform levels may be expected to result from the virtual elimination of combined sewer overflows and separate sanitary sewer flow relief devices. The statistical water quality model described in Chapter VII of Volume One of this report was used to determine the fecal coliform levels that could be anticipated within the estuary under the elimination of combined sewer overflows alternative.

The estimated distribution of fecal coliform levels is presented in Figure 61. The 10, 50, 90, and 98 percentile plots are the same as those presented in Figure 55 for the committed action alternative. However a substantial reduction is shown for the 99 and 99.9 percentile plots. The elimination of the occasional overflows would not affect the percent of time that the 10,000 MPN/100 ml and 2,000 MPN/100 ml fecal coliform standards supporting limited recreational use would be violated.

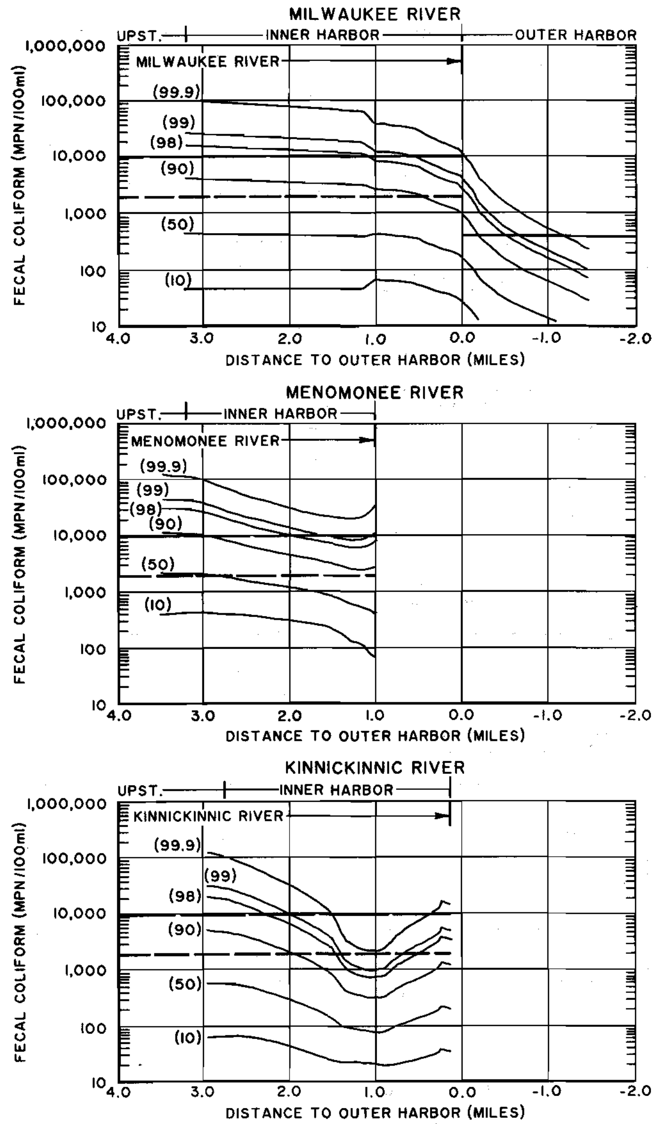
Figure 56 shows the distribution of the geometric means of groups of five fecal coliform samples under this alternative, as well as under the committed action alternative. Elimination of the occasional overflows would not significantly affect the distribution of the geometric means of groups of five samples, nor the achievement of the geometric mean fecal coliform standards.

Thus, under the elimination of combined sewer overflows alternative, the fecal coliform levels in the estuary would be slightly lower than under the committed action alternative. Overall, within the inner harbor, the fecal coliform standards supporting limited recreational use would not be achieved. The lower reaches of the inner harbor would have lower levels of fecal coliform than would the upper reaches, and the lower portions of the Kinnickinnic River estuary in particular could achieve the limited recreational use standards. The outer harbor would be expected to achieve the fecal coliform standards supporting full recreational use.

Ammonia Nitrogen: Under the elimination of combined sewer overflows alternative, the existing loading of ammonia nitrogen from combined sewer overflows would be virtually eliminated, and the flux of nitrogen from the bottom sediments to the inner harbor water column would be reduced by 85 to 95 percent. Simulated ammonia nitrogen concentrations under low-flow, steady-state conditions are presented in Figure 62. The ammonia nitrogen levels are very similar to those anticipated

Figure 61

ESTIMATED FECAL COLIFORM LEVELS UNDER THE ELIMINATION OF COMBINED SEWER OVERFLOWS ALTERNATIVE: DISTRIBUTION OF ALL DATA



LEGEND

(99.9) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE: OUTER HARBOR

——— LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 10 PERCENT OF THE TIME (400 MPN/100 ml)

LIMITED RECREATIONAL USE: INNER HARBOR

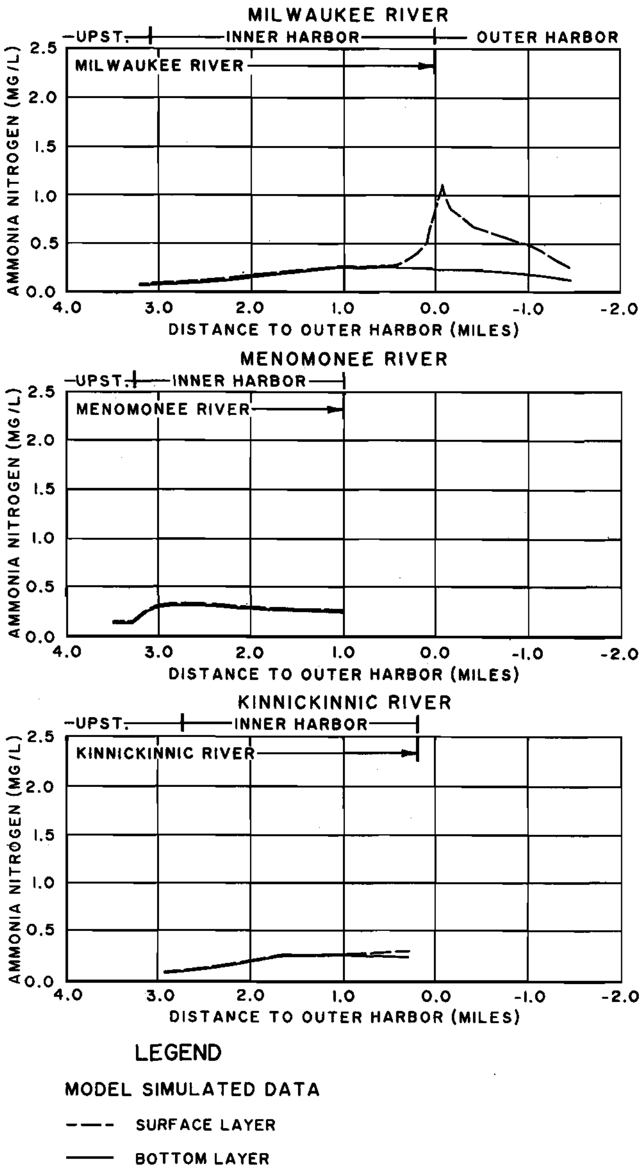
- - - LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THEN 10 PERCENT OF THE TIME (2,000 MPN/100ml)

——— LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 2 PERCENT OF THE TIME (10,000 MPN/100 ml)

Source: HydroQual, Inc.

Figure 62

ESTIMATED AMMONIA NITROGEN LEVELS UNDER THE ELIMINATION OF COMBINED SEWER OVERFLOWS ALTERNATIVE



Source: HydroQual, Inc.

under the committed action alternative, the estimated levels being slightly lower only in the upper portions of the Milwaukee River and Menomonee River estuaries.

Table 30 sets forth the un-ionized ammonia nitrogen concentrations expected under the elimination of combined sewer overflows alternative, and compares these concentrations to acute and chronic toxicity standards. The un-ionized ammonia nitrogen concentrations and acute and chronic toxicity standards were calculated in accordance with the procedures described for the committed action alternative.

Under low-flow, steady-state conditions, the un-ionized ammonia nitrogen concentration would range from 0.009 to 0.022 mg/l at the upstream river stations, from 0.004 to 0.017 mg/l at the inner harbor stations, and from 0.002 to 0.013 mg/l at the outer harbor stations. No stations would violate the chronic or acute toxicity standards. Although Table 30 indicates that standard violations would probably not occur within the outer harbor, occasional violations of the chronic toxicity standards could occur within portions of the outer harbor during periods of higher pH because of the high ammonia nitrogen concentrations.

Lead: The elimination of combined sewer overflows alternative would remove the combined sewer annual discharges of about 25,500 pounds of lead to the tributary rivers upstream of the estuary, 47,000 pounds of lead directly to the inner harbor, and 4,600 pounds of lead directly to the outer harbor. This alternative would reduce the total loadings of lead to the inner harbor by about 55 percent. The statistical water quality model described in Chapter VII of Volume One of this report was used to evaluate the lead levels that could be achieved within the estuary under the elimination of combined sewer overflows alternative.

The estimated distribution of lead concentrations in the surface and bottom water layers is presented in Figure 63. The median lead levels, plus and minus one standard deviation of the logs of the data, are shown in the figure. The data plots show total lead concentrations. Chronic and acute toxicity standards for acid-soluble lead are also shown in the figure.

Figure 63 indicates that lead levels in both the inner harbor and the outer harbor may be expected to meet the acute and chronic toxicity standards for acid-soluble lead under the elimination of combined sewer overflows alternative. The estimated lead levels would be the same as those predicted under the committed action alternative, except in the Kinnickinnic River estuary, where the variability of the lead concentrations would be less under this alternative. Median lead levels in the Kinnickinnic River estuary would, however, remain the same as estimated under the committed action alternative.

Table 30

COMPARISON OF ESTIMATED UN-IONIZED AMMONIA NITROGEN CONCENTRATIONS TO THE RECOMMENDED ACUTE AND CHRONIC TOXICITY STANDARDS UNDER THE ELIMINATION OF COMBINED SEWER OVERFLOWS ALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Total Ammonia Nitrogen[b] (mg/l)	pH[c] (standard units)	Temperature (°F)	Un-ionized Ammonia Nitrogen[d] (mg/l)	Un-ionized Ammonia Nitrogen Toxicity Standards		Violation of Un-ionized Ammonia Nitrogen Toxicity Standards	
							Acute[e]	Chronic[e]	Acute	Chronic
Upstream										
Milwaukee River	North Avenue Dam (RIV-5)	DI	0.1	8.5	81	0.017	0.117	0.025	--	--
Menomonee River	S. 37th Street (RIV-10)	DI	0.3	8.5	75	0.043	0.116	0.025	--	X
Kinnickinnic River	S. 9th Place (RIV-13)	DI	0.1	8.9	84	0.038	0.121	0.025	--	X
Inner Harbor										
Milwaukee River	Walnut Street (RIV-6)	S	0.1	8.5	81	0.017	0.116	0.025	--	--
		B	0.1	8.4	81	0.015	0.115	0.025	--	--
	Wells Street (RIV-7)	S	0.2	8.0	79	0.013	0.102	0.025	--	--
		B	0.2	8.1	75	0.018	0.108	0.025	--	--
	Water Street (RIV-8)	S	0.3	7.9	79	0.013	0.098	0.025	--	--
		B	0.3	7.9	66	0.008	0.099	0.025	--	--
	C&NW Railway (RIV-15)	S	0.2	7.5	77	0.004	0.073	0.025	--	--
		B	0.2	8.1	64	0.009	0.105	0.025	--	--
Menomonee River	Muskego Avenue (RIV-11)	S	0.3	7.7	81	0.009	0.088	0.025	--	--
		B	0.3	7.5	72	0.004	0.077	0.025	--	--
	S. 2nd Street (RIV-17)	S	0.6	7.7	79	0.021	0.088	0.025	--	--
		B	0.2	7.7	72	0.006	0.090	0.025	--	--
Kinnickinnic River	S. 1st Street (RIV-14)	S	0.2	7.6	72	0.005	0.081	0.025	--	--
		B	0.2	7.6	72	0.005	0.081	0.025	--	--
	Greenfield Avenue Extended (RIV-18)	S	0.3	7.6	73	0.006	0.081	0.025	--	--
		B	0.2	7.6	64	0.003	0.081	0.025	--	--
	Jones Island F (RIV-19)	S	0.5	7.6	73	0.010	0.083	0.025	--	--
		B	0.2	7.9	63	0.005	0.097	0.025	--	--
Outer Harbor	South OH (OH-11)	S	0.6	7.6	72	0.013	0.079	0.025	--	--
		B	0.2	7.6	57	0.002	0.083	0.025	--	--
	JI STP Plume (OH-2)	S	1.2	7.4	70	0.013	0.065	0.025	--	--
		B	0.3	7.9	61	0.006	0.097	0.025	--	--

NOTE: The existing Wisconsin Department of Natural Resources standard for un-ionized ammonia nitrogen specifies a maximum level of 0.04 mg/l for the full warmwater fishery and aquatic life water use objective. The Department has issued no standard for the limited fishery and aquatic life objective. The standard for the warmwater fishery and aquatic life objective is applied by the Department as a maximum not to be exceeded at any flow equal to or greater than the 7-day, 10-year minimum flow.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

[b] *As estimated in Figure 62.*

[c] *Arithmetic mean pH and temperature levels measured during Survey Period 1, July 25 through August 8, 1983, under the baseline sampling program.*

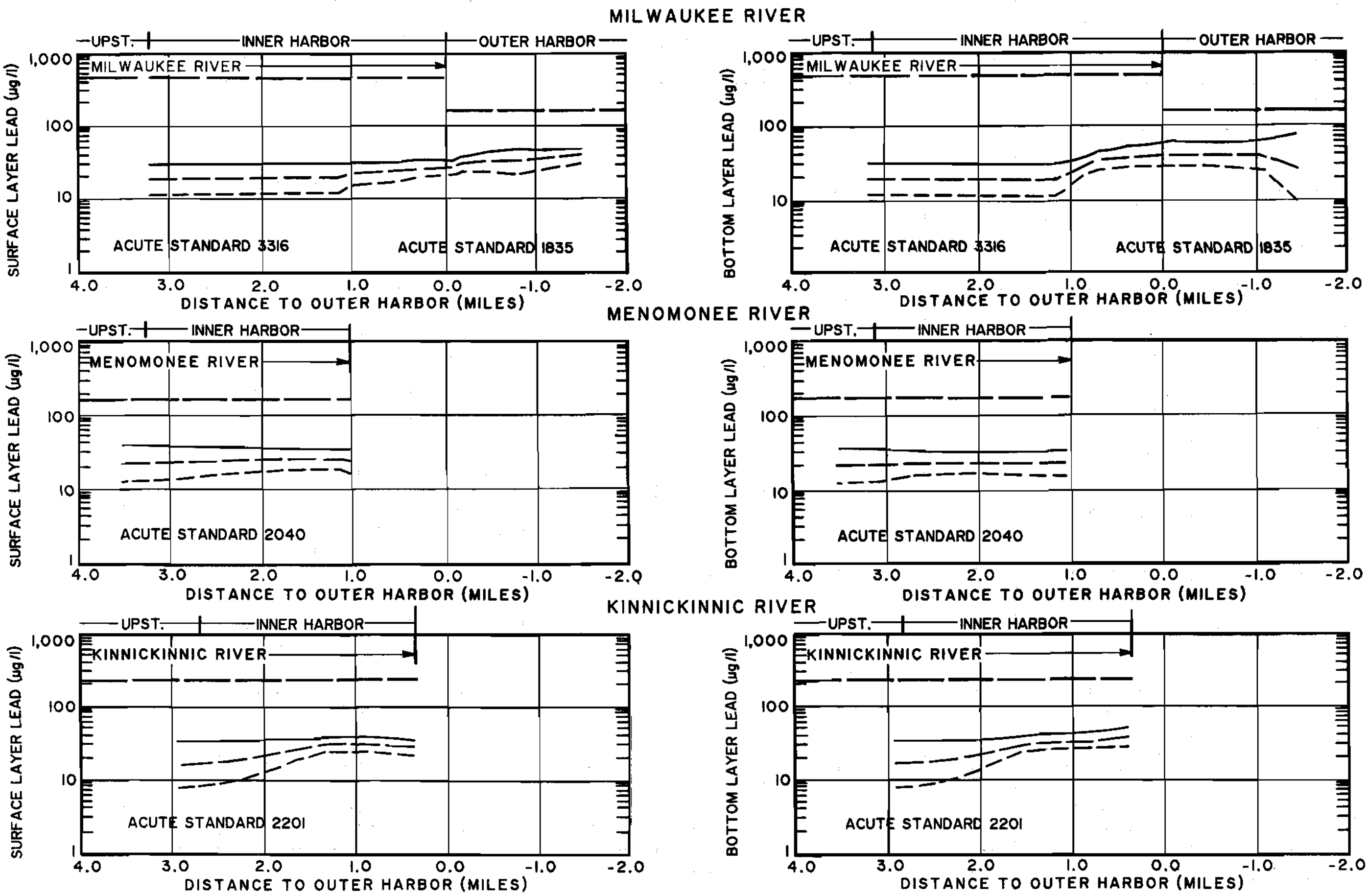
[d] *The un-ionized ammonia nitrogen concentrations were calculated using the estimated total ammonia nitrogen, pH, and temperature levels.*

[e] *The acute and chronic toxicity standards, which vary in response to the pH and temperature of the water, were calculated in accordance with the procedures set forth in Chapter II of this volume.*

Source: SEWRPC.

Figure 63

ESTIMATED LEAD CONCENTRATIONS UNDER THE ELIMINATION OF COMBINED SEWER OVERFLOWS ALTERNATIVE



LEGEND

STANDARDS

——— ACUTE MAXIMUM STANDARD

— — CHRONIC 30 DAY MEAN MAXIMUM STANDARD

LEAD PLOTS

——— MEDIAN PLUS ONE STANDARD DEVIATION OF THE LOGS (84TH PERCENTILE)

— — MEDIAN (50TH PERCENTILE)

– – – MEDIAN MINUS ONE STANDARD DEVIATION OF THE LOGS (16TH PERCENTILE)

NOTE: THE ACUTE AND CHRONIC STANDARDS APPLY TO ACID-SOLUBLE LEAD CONCENTRATIONS, WHEREAS THE PLOTS REPRESENT TOTAL LEAD CONCENTRATIONS.THUS, VIOLATION OF THE STANDARD DOES NOT NECESSARILY INDICATE THAT TOXIC CONDITIONS WOULD EXIST.THE ACUTE AND CHRONIC STANDARDS, WHICH ARE A FUNCTION OF THE HARDNESS OF THE WATER, WERE CALCULATED USING THE BASELINE HARDNESS LEVELS MEASURED FROM 1981 THROUGH 1983 AT THE REPRESENTATIVE SAMPLING STATIONS PRESENTED IN CHAPTER VI OF VOLUME ONE OF THIS REPORT.

Source: HydroQual, Inc., and SEWRPC.

Table 31

ESTIMATED METAL CONCENTRATIONS IN THE BOTTOM SEDIMENTS OF THE INNER HARBOR UNDER THE ELIMINATION OF COMBINED SEWER OVERFLOWS ALTERNATIVE

Metal	U. S. Environmental Protection Agency Sediment Quality Classification			Milwaukee River				Menomonee River				Kinnickinnic River			
				Broadway Street		C&NW Railway		Muskego Avenue		Burnham Canal		S. 1st Street		Greenfield Avenue Extended	
	Nonpolluted	Moderately Polluted	Heavily Polluted	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating
Cadmium	- -[a]	- -[a]	> 6	2.6	- -[a]	5.7	- -[a]	8.3	H	4.7	- -[a]	4.6	- -[a]	7.0	H
Copper	< 25	25-50	>50	67	H	97	H	129	H	92	H	110	H	110	H
Lead	<40	40-60	>60	324	H	175	H	230	H	124	H	261	H	171	H
Zinc	< 90	90-200	>200	26	N	52	N	54	N	37	N	77	N	63	N

NOTES: All units are in milligrams per kilogram on a dry-weight basis. The metal concentrations measured in the sediment core samples presented in Chapter VI of Volume One were reduced in proportion to the reduction in total metal loadings expected under the committed action alternative.

Pollution Ratings: N-Nonpolluted; M-Moderately Polluted; H-Heavily Polluted

[a] *Cadmium ranges for a nonpolluted or moderately polluted classification have not been established by the U. S. Environmental Protection Agency.*

Source: SEWRPC.

To assess the long-term impacts of the elimination of combined sewer overflows alternative on lead concentrations in the inner harbor sediments, it was assumed that the concentrations would be reduced proportionately to the reduction in total lead loadings. Virtual elimination of lead loadings from combined sewer overflows would thus result in a reduction of approximately 55 percent in lead levels in the bottom sediments of the inner harbor. Estimated concentrations of lead in the bottom sediments are set forth in Table 31. The estimated lead concentrations would result in the bottom sediments in all six inner harbor stations being rated as heavily polluted.

Other Toxic Metals: In order to determine the long-term impacts of the elimination of combined sewer overflows alternative, it was assumed that the metal concentrations in both the bottom sediments and the water column would be reduced proportionately to the reduction in total pollutant loadings. Based on pollutant loading estimates set forth in Chapter VI of Volume One, elimination of metal loadings from combined sewer overflows would result in a reduction of approximately 30 percent in cadmium, 8 percent in copper, and 88 percent in zinc levels in the inner harbor bottom sediments and the water column.

Estimated concentrations of cadmium, copper, and zinc in the bottom sediments of the inner harbor under the elimination of combined sewer overflows alternative are set forth in Table 31. The metal concentrations in the bottom sediments would be slightly lower than those under the committed action alternative. The anticipated reductions would significantly affect the existing pollution ratings for cadmium and zinc in the bottom sediments. Two of the six inner harbor stations would continue to be classified as heavily polluted based on the cadmium concentrations. The estimated zinc concentrations would result in a nonpolluted rating at all six inner harbor stations.

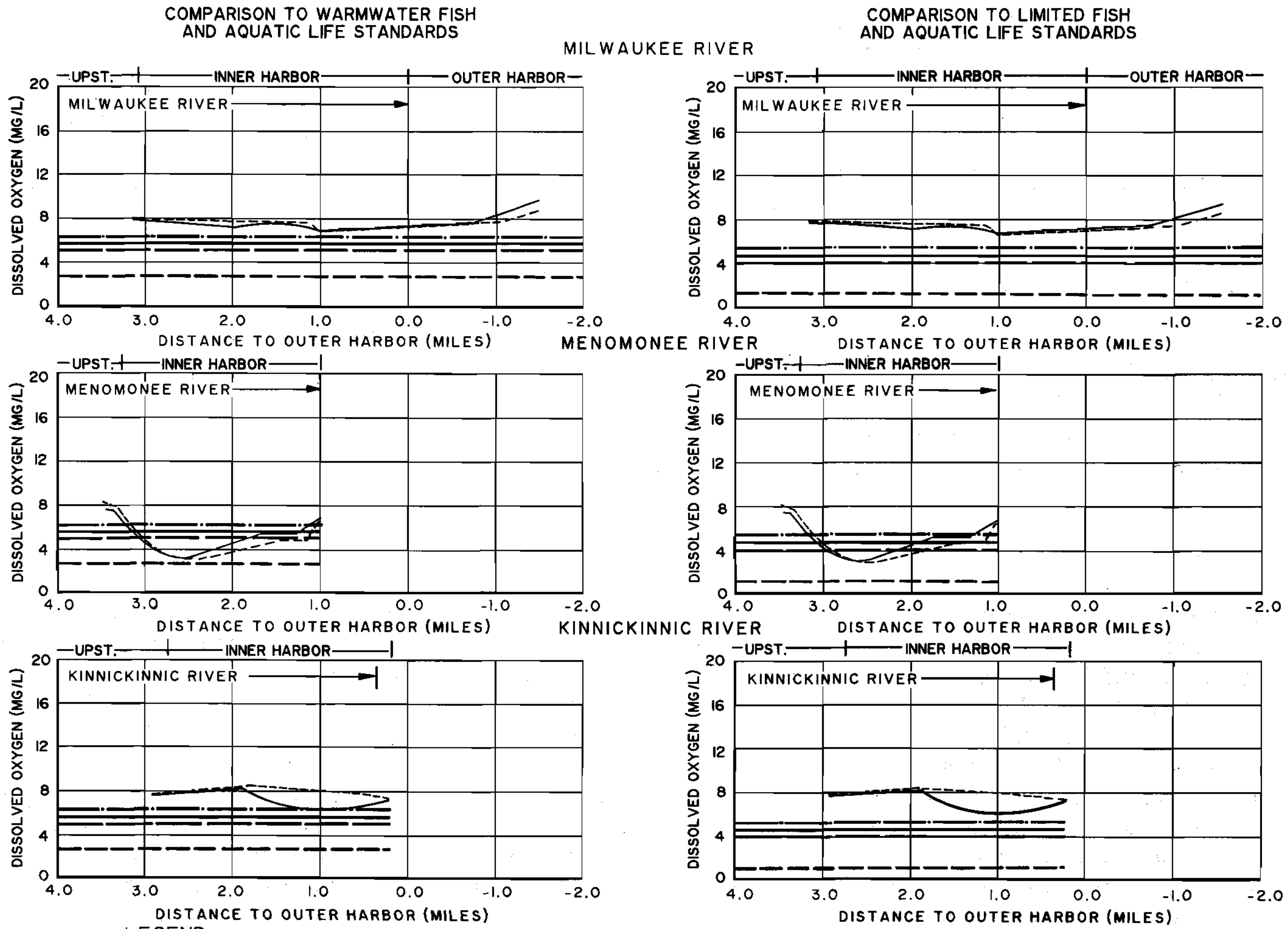
Within the water column of the Milwaukee Harbor estuary, total metal concentrations would exceed the chronic toxicity standards for acid-soluble cadmium and copper. These apparent standard violations would be less severe than under the committed action alternative, although the frequency of violations would not be significantly reduced. The chronic and acute toxicity standards for acid-soluble zinc would continue to be achieved under this alternative.

Low Flow Augmentation: Existing Flushing Tunnels Subalternative

This subalternative calls for continued operation of the existing flushing tunnels that discharge to the Milwaukee River and the Kinnickinnic River during periods of critically low dissolved oxygen levels. The water quality conditions expected within the Milwaukee Harbor estuary with the continued operation of the existing flushing tunnels are presented below.

Figure 64

LOW-FLOW, STEADY-STATE ANALYSIS OF DISSOLVED OXYGEN UNDER THE LOW-FLOW AUGMENTATION: EXISTING FLUSHING TUNNELS SUBALTERNATIVE



LEGEND

MODEL SIMULATED DATA

- - - SURFACE LAYER

—— BOTTOM LAYER

STANDARDS (MG/L)

		WARMWATER	LIMITED
——	30 DAY MEAN MINIMUM STANDARD	5.5	4.5
—·—	7 DAY MEAN MINIMUM STANDARD (3/15-7/31)	6.0	5.0
——	1 DAY MEAN MINIMUM STANDARD (3/15-7/31)	5.0	4.0
- - -	ABSOLUTE MINIMUM STANDARD	2.5	1.5

NOTE: THE EXISTING WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS SPECIFY MINIMUM DISSOLVED OXYGEN LEVELS OF 5.0 MG/L AND 3.0 MG/L FOR THE FULL WARMWATER FISH AND AQUATIC LIFE AND THE LIMITED FISH AND AQUATIC LIFE WATER USE OBJECTIVES,RESPECTIVELY. THESE STANDARDS ARE APPLIED BY THE DEPARTMENT AS A MINIMUM NOT TO BE VIOLATED AT ANY FLOW EQUAL TO OR GREATER THAN THE 7-DAY,10-YEAR MINIMUM FLOW.

Source: HydroQual, Inc.

Dissolved Oxygen: A low-flow, steady-state simulation analysis was conducted to determine the effect that the operation of the existing flushing tunnels would have on the critical dissolved oxygen conditions expected during low-flow and high-temperature periods. The steady-state analysis estimated dissolved oxygen levels under 7-day, 10-year recurrence interval low-flow conditions at the high temperature levels measured during Survey Period 1, July 25 to August 8, 1983. Spatial plots of low-flow, steady-state dissolved oxygen levels under the existing flushing tunnels subalternative are shown in Figure 64. The figure compares the simulated dissolved oxygen levels to standards established for a warmwater fishery and for a limited fishery.

The comparison to the standards indicates that all standards for a warmwater fishery and for a limited fishery would be met within the Milwaukee and Kinnickinnic River estuaries. Within the Menomonee River estuary, the dissolved oxygen levels would be up to 0.8 mg/l higher than those expected under the committed action alternative. The 30-day mean, 7-day mean, and 1-day mean standards supporting both warmwater and limited fisheries would continue to be violated in the Menomonee River estuary, particularly in the upper portion.

The absolute minimum dissolved oxygen standards would not be violated within the inner harbor. The dissolved oxygen levels in the outer harbor would be about the same as those estimated under the committed action alternative, and all standards would be met.

The significance of the individual sinks of oxygen under the existing flushing tunnels subalternative can be determined by analyzing the components of the dissolved oxygen deficit. The components of the deficit that were studied in the steady-state analysis included the sediment flux of methane and ammonia, sediment oxygen demand, carbonaceous biochemical oxygen demand from upstream sources and from the Jones Island sewage treatment plant, and net photosynthesis/respiration. The computed components of the dissolved oxygen deficit under low-flow, steady-state conditions in the surface and bottom water layers are shown in Figure 65.

The total dissolved oxygen deficit would be low—less than 2.0 mg/l—in the surface water layer of the Milwaukee and Kinnickinnic River estuaries, and slightly higher—up to about 3.0 mg/l—in the bottom water layers. Near the upper ends of these estuaries, where the tunnels discharge, the deficits would be negligible, but would then increase in the downstream direction. Within these estuaries, the largest component of the deficit in both the surface and bottom water layers would be carbonaceous biochemical oxygen demand from upstream sources. The dissolved oxygen deficit in the Menomonee River estuary would be about the same as under the committed action alternative, while the deficit in the outer harbor would be slightly lower under this alternative.

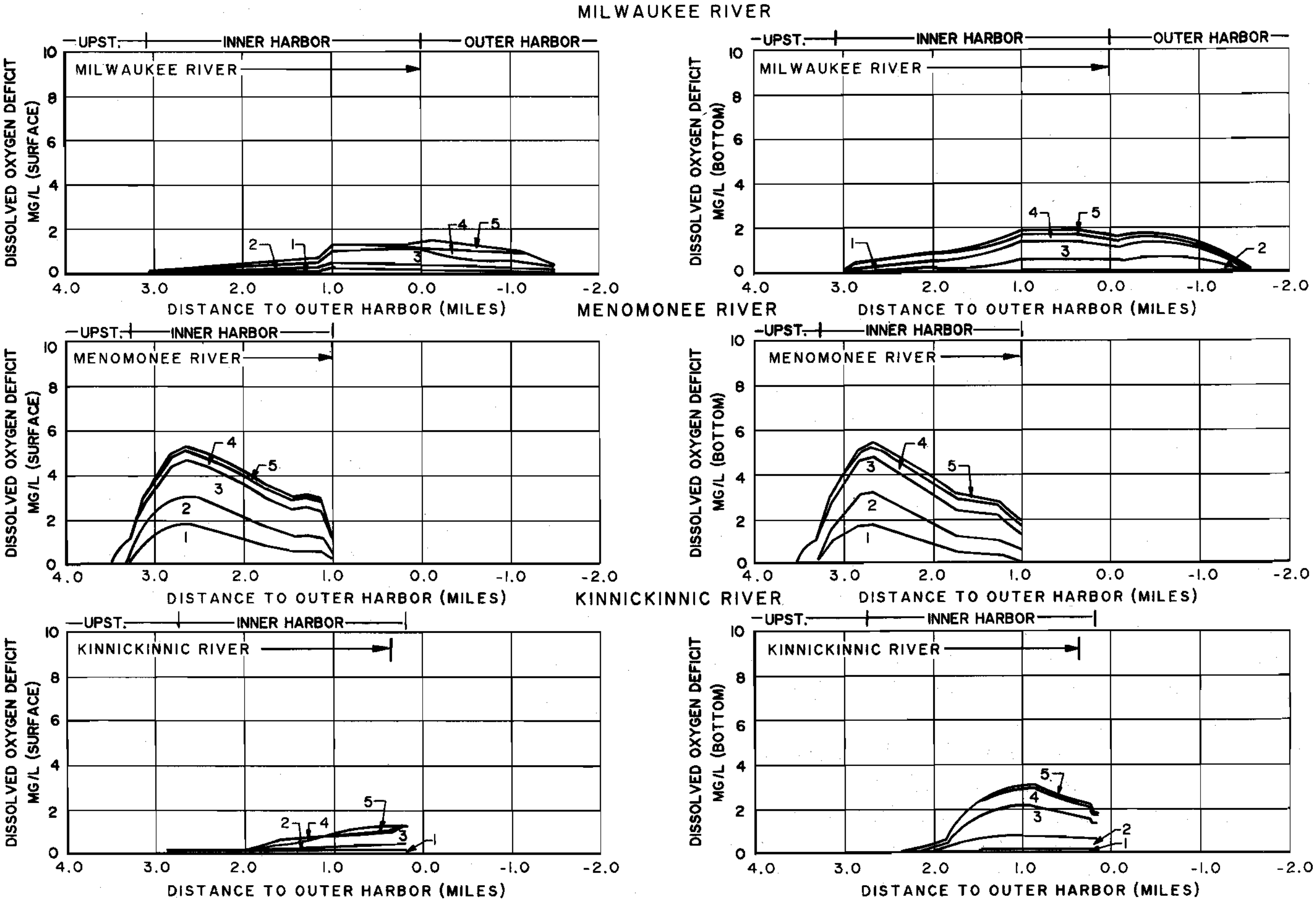
Dissolved oxygen conditions under a series of flow and temperature conditions were evaluated to assess the improvement in dissolved oxygen levels under the existing flushing tunnels subalternative. Estimated dissolved oxygen levels were then compared to the standards for a warmwater fishery and for a limited fishery. The expected violations of the dissolved oxygen standards are set forth in Table 32. For the surface and bottom water layers of several upstream, inner harbor, and outer harbor sampling stations, the anticipated violation of the dissolved oxygen standards is classified as slight, moderate, or severe.

In the tributary rivers upstream of the estuary, the violations of the dissolved oxygen standards would be the same as those expected under the committed action alternative. Within the Milwaukee River estuary, all of the dissolved oxygen standards for both warmwater and limited fisheries would be expected to be met. Within the Kinnickinnic River estuary, all of the dissolved oxygen standards would be met except near Greenfield Avenue extended, where slight violations of the 7-day and 1-day mean standards for a warmwater fishery and of the 7-day standard for a limited fishery could occur in the bottom water layer. The steady-state analysis shown in Figure 64 indicates that the dissolved oxygen levels in the bottom water layer of the Kinnickinnic River estuary may be up to 2 mg/l lower than in the surface water layer. Dissolved oxygen levels in the Menomonee River estuary would be slightly improved over the levels expected under the committed action alternative. Generally, moderate to severe violations of the standards for a warmwater fishery, and slight to moderate violations of the standards for a limited fishery, would continue within the Menomonee River estuary. The dissolved oxygen levels in the outer harbor would remain about the same as under the committed action alternative, with a minor improvement being noted at the Hoan Bridge and near the Jones Island sewage treatment plant outfall, which is located near the mouth of the inner harbor.

Diurnal fluctuations in dissolved oxygen levels within the Milwaukee River estuary would be less than under the committed action alternative. Chlorophyll-a levels at the upstream end of the Milwaukee Harbor estuary would be reduced by more than 50 percent. Diurnal fluctuations in dissolved oxygen concentrations would continue to be very minor in the Menomonee and Kinnickinnic River estuaries, and in the outer harbor. The bottom water layers would not exhibit diurnal fluctuations in any of the water bodies.

Figure 65

COMPONENTS OF THE DISSOLVED OXYGEN DEFICIT UNDER LOW-FLOW, STEADY-STATE CONDITIONS: EXISTING FLUSHING TUNNELS SUBALTERNATIVE



LEGEND

1 SEDIMENT FLUX OF METHANE AND AMMONIA

2 SEDIMENT OXYGEN DEMAND

3 UPSTREAM CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND

4 NET PHOTOSYNTHESIS/RESPIRATION

5 CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND FROM THE JONES ISLAND SEWAGE TREATMENT PLANT

Source: HydroQual, Inc.

Fecal Coliform: The existing flushing tunnels would substantially reduce the fecal coliform levels in the Milwaukee and Kinnickinnic River estuaries. The statistical water quality model described in Chapter VII of Volume One of this report was used to determine the fecal coliform levels that could be anticipated within the estuary under the existing flushing tunnels subalternative. To determine the maximum benefit that could be achieved using the existing flushing tunnels, it was assumed for the statistical analysis that the tunnels would operate continuously.

The estimated distribution of fecal coliform levels is presented in Figure 66. In the upstream Milwaukee and Menomonee Rivers and in the Menomonee River estuary, the 10,000 MPN/100 ml standard supporting limited recreational use would be violated more than the allowed maximum of 2 percent of the time, and the 2,000 MPN/100 ml standard would be violated more than the allowed maximum of 10 percent of the time. The 400 MPN/100 ml standard supporting full recreational use would be violated less than the maximum of 10 percent of the time in most of the outer harbor.

Table 32

VIOLATION OF DISSOLVED OXYGEN STANDARDS UNDER THE EXISTING FLUSHING TUNNELS SUBALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Warmwater Fish and Aquatic Life					Limited Fish and Aquatic Life				
			30-Day Mean All Year 5.5 mg/l	7-Day Mean 3/15-7/31 6.0 mg/l	1-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 8/1-3/14 4.0 mg/l	Absolute Minimum All Year 2.5 mg/l	30-Day Mean All Year 4.5 mg/l	7-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 3/15-7/31 4.0 mg/l	1-Day Mean 8/1-3/14 3.0 mg/l	Absolute Minimum All Year 1.5 mg/l
Upstream												
Milwaukee River	North Avenue Dam (RIV-5)	DI	None	Moderate	None	None	None	None	None	None	None	None
Menomonee River	S. 37th Street (RIV-10)	DI	None	Moderate	None	None	None	None	None	None	None	None
Kinnickinnic River	S. 9th Place (RIV-13)	DI	None	Slight	Slight	Slight	Slight	None	Slight	Slight	Slight	None
Inner Harbor												
Milwaukee River	Walnut Street (RIV-6)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Wells Street (RIV-7)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Water Street (RIV-8)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	C&NW Railway (RIV-15)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
Menomonee River	Muskego Avenue (RIV-11)	S	Severe	Severe	Severe	Moderate	Slight	Slight	Moderate	Severe	Slight	None
		B	Severe	Severe	Severe	Slight	None	Moderate	Severe	Moderate	None	None
	S. 2nd Street (RIV-17)	S	Severe	Severe	Moderate	Slight	None	Moderate	Moderate	Slight	None	None
		B	Severe	Moderate	None	Moderate	None	Moderate	None	None	None	None
Kinnickinnic River	S. 1st Street (RIV-14)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Greenfield Avenue Extended (RIV-18)	S	None	None	None	None	None	None	None	None	None	None
		B	None	Slight	Slight	None	None	None	Slight	None	None	None
	Jones Island (RIV-19)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
Outer Harbor	Hoan Bridge (OH-1)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Central OH (OH-3)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	South OH (OH-11)	S	None	None	None	None	None	None	None	None	None	None
		B	None	Slight	None	Slight	None	None	None	None	None	None
	JI STP Plume (OH-2)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	Slight	None	None	None	None	Slight	None

NOTE: Standard violations that occur up to 5 percent of the time are classified as slight; violations that occur 6 to 10 percent of the time are classified as moderate; and violations that occur more than 10 percent of the time are classified as severe. Underlined ratings indicate a significant improvement in dissolved oxygen levels over the levels expected under the committed action alternative.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

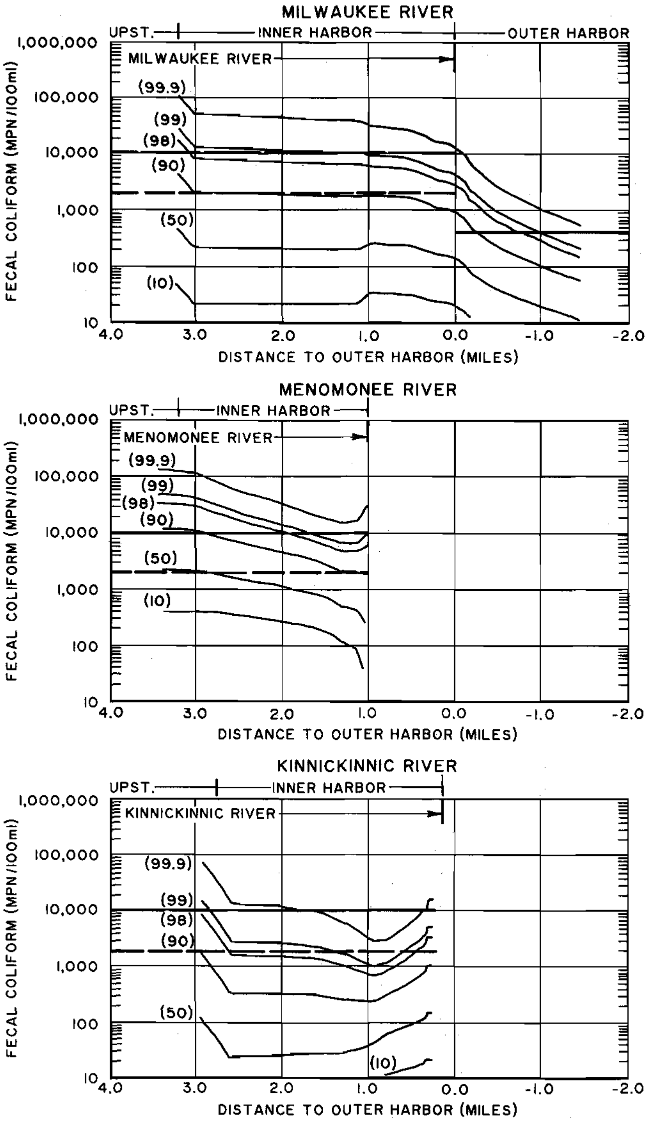
Source: HydroQual, Inc., and SEWRPC.

The standard for the outer harbor would be violated more than 10 percent of the time only near the mouth of the inner harbor.

Figure 67 shows the distribution of the geometric means of groups of five fecal coliform samples. This figure illustrates the achievement of the geometric mean standards. The geometric mean standard of 1,000 MPN/100 ml supporting limited recreational use would be violated more than the allowed maximum of 5 percent of the time in the upstream Milwaukee and Menomonee Rivers and in the Menomonee River estuary. The geometric mean standard of 200 MPN/100 ml supporting full recreational use would be met within the outer harbor.

Figure 66

ESTIMATED FECAL COLIFORM LEVELS UNDER THE EXISTING FLUSHING TUNNELS SUBALTERNATIVE: DISTRIBUTION OF ALL DATA



LEGEND

(99.9) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE: OUTER HARBOR

—— LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 10 PERCENT OF THE TIME (400 MPN/100 ml)

LIMITED RECREATIONAL USE: INNER HARBOR

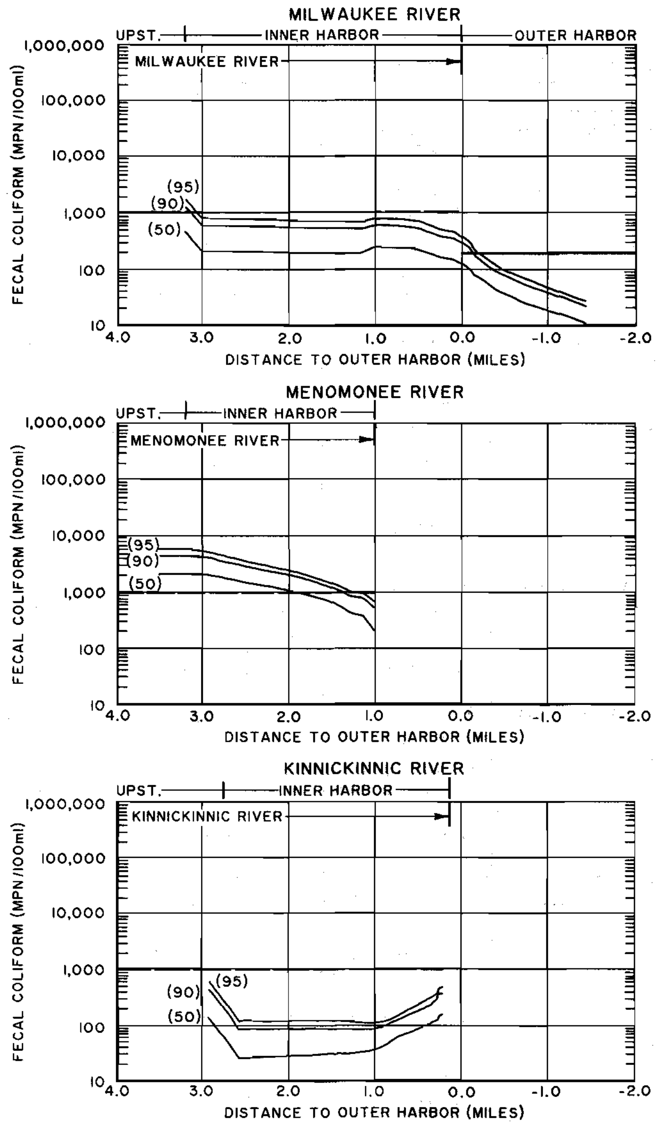
- - - LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THEN 10 PERCENT OF THE TIME (2,000 MPN/100 ml)

— — LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 2 PERCENT OF THE TIME (10,000 MPN/100 ml)

Source: HydroQual, Inc.

Figure 67

ESTIMATED FECAL COLIFORM LEVELS UNDER THE EXISTING FLUSHING TUNNELS SUBALTERNATIVE: DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF FIVE SAMPLES



LEGEND

(90) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE: OUTER HARBOR

—— LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH (200 MPN/100 ml)

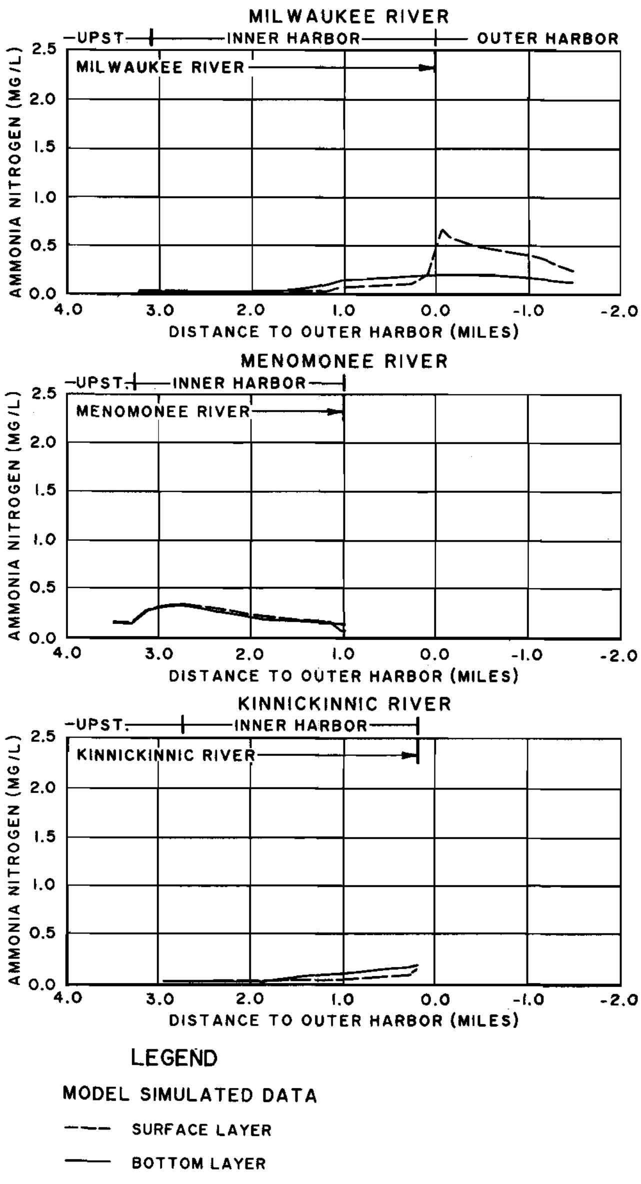
LIMITED RECREATIONAL USE: INNER HARBOR

— — LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH MORE THAN 5 PERCENT OF THE TIME (1,000 MPN/100 ml)

Source: HydroQual, Inc.

Figure 68

ESTIMATED AMMONIA NITROGEN LEVELS UNDER THE EXISTING FLUSHING TUNNELS SUBALTERNATIVE



Source: HydroQual, Inc.

Thus, under the existing flushing tunnels subalternative, the fecal coliform standards supporting limited recreational use would not be achieved in the upstream Milwaukee and Menomonee Rivers and in the Menomonee River estuary. The Milwaukee and Kinnickinnic River estuaries would achieve the fecal coliform standards supporting limited recreational use. The outer harbor would be expected to achieve the fecal coliform standards supporting full recreational use.

Ammonia Nitrogen: The existing flushing tunnels subalternative would substantially reduce ammonia nitrogen levels throughout the inner harbor and portions of the outer harbor. Simulated ammonia nitrogen concentrations under low-flow, steady-state conditions are presented in Figure 68. The greatest reductions, compared to the committed action alternative, are shown for the Milwaukee and Kinnickinnic River estuaries, but the Menomonee River estuary and the outer harbor also show marked reductions.

Table 33 sets forth the un-ionized ammonia nitrogen concentrations expected under the existing flushing tunnels subalternative, and compares these concentrations to acute and chronic toxicity standards. The un-ionized ammonia nitrogen concentrations and acute and chronic toxicity standards were calculated in accordance with the procedures described for the committed action alternative.

Under low-flow, steady-state conditions, the un-ionized ammonia nitrogen concentration would range from 0.009 to 0.022 mg/l at the upstream river stations, from 0.001 to 0.009 mg/l at the inner harbor stations, and from 0.002 to 0.009 mg/l at the outer harbor stations. No stations would violate the chronic or acute toxicity standards. Although Table 33 indicates that standard violations would probably not occur within the outer harbor, occasional violations of the chronic toxicity standards could occur within portions of the outer harbor during periods of higher pH. However, these occasional violations would be less severe than under the committed action alternative.

Lead: The existing flushing tunnels subalternative would substantially reduce lead levels in the Milwaukee and Kinnickinnic River estuaries. The statistical water quality model described in Chapter VII of Volume One of this report was used to determine the lead levels which could be expected within the estuary under this subalternative. To determine the maximum benefit that could be achieved by using the existing flushing tunnels, it was assumed for the statistical analysis that the tunnels would operate continuously.

The estimated distribution of lead concentrations in the surface and bottom water layers under the existing flushing tunnels subalternative is presented in Figure 69. The median lead levels, plus and

Table 33

COMPARISON OF ESTIMATED UN-IONIZED AMMONIA NITROGEN CONCENTRATIONS TO THE RECOMMENDED ACUTE AND CHRONIC TOXICITY STANDARDS UNDER THE EXISTING FLUSHING TUNNELS SUBALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Total Ammonia Nitrogen[b] (mg/l)	pH[c] (standard units)	Temperature (°F)	Un-ionized Ammonia Nitrogen[d] (mg/l)	Un-ionized Ammonia Nitrogen Toxicity Standards		Violation of Un-ionized Ammonia Nitrogen Toxicity Standards	
							Acute[e]	Chronic[e]	Acute	Chronic
Upstream										
Milwaukee River	North Avenue Dam (RIV-5)	DI	0.05	8.5	81	0.009	0.117	0.025	--	--
Menomonee River	S. 37th Street (RIV-10)	DI	0.15	8.5	75	0.022	0.116	0.025	--	--
Kinnickinnic River	S. 9th Place (RIV-13)	DI	0.05	8.9	84	0.019	0.121	0.025	--	--
Inner Harbor										
Milwaukee River	Walnut Street (RIV-6)	S	0.05	8.5	81	0.009	0.116	0.025	--	--
		B	0.05	8.4	81	0.008	0.115	0.025	--	--
	Wells Street (RIV-7)	S	0.05	8.0	79	0.003	0.102	0.025	--	--
		B	0.05	8.1	75	0.004	0.108	0.025	--	--
	Water Street (RIV-8)	S	0.05	7.9	79	0.003	0.098	0.025	--	--
		B	0.10	7.9	66	0.003	0.099	0.025	--	--
	C&NW Railway (RIV-15)	S	0.10	7.5	77	0.002	0.073	0.025	--	--
		B	0.15	8.1	64	0.007	0.105	0.025	--	--
Menomonee River	Muskego Avenue (RIV-11)	S	0.25	7.7	81	0.009	0.088	0.025	--	--
		B	0.20	7.5	72	0.003	0.077	0.025	--	--
	S. 2nd Street (RIV-17)	S	0.20	7.7	79	0.007	0.088	0.025	--	--
		B	0.20	7.7	72	0.005	0.090	0.025	--	--
Kinnickinnic River	S. 1st Street (RIV-14)	S	0.05	7.6	72	0.001	0.081	0.025	--	--
		B	0.05	7.6	72	0.001	0.081	0.025	--	--
	Greenfield Avenue Extended (RIV-18)	S	0.05	7.6	73	0.001	0.081	0.025	--	--
		B	0.10	7.6	64	0.002	0.081	0.025	--	--
	Jones Island (RIV-19)	S	0.10	7.6	73	0.002	0.083	0.025	--	--
		B	0.15	7.9	63	0.004	0.097	0.025	--	--
Outer Harbor	South OH (OH-11)	S	0.45	7.6	72	0.009	0.079	0.025	--	--
		B	0.20	7.6	57	0.002	0.083	0.025	--	--
	JI STP Plume (OH-2)	S	0.70	7.4	70	0.008	0.065	0.025	--	--
		B	0.20	7.9	61	0.005	0.097	0.025	--	--

NOTE: The existing Wisconsin Department of Natural Resources standard for un-ionized ammonia nitrogen specifies a maximum level of 0.04 mg/l for the full warmwater fishery and aquatic life water use objective. The Department has issued no standard for the limited fishery and aquatic life objective. The standard for the warmwater fishery and aquatic life objective is applied by the Department as a maximum not to be exceeded at any flow equal to or greater than the 7-day, 10-year minimum flow.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

[b] *As estimated in Figure 68.*

[c] *Arithmetic mean pH and temperature levels measured during Survey Period 1, July 25 through August 8, 1983, under the baseline sampling program.*

[d] *The un-ionized ammonia nitrogen concentrations were calculated using the estimated total ammonia nitrogen, pH, and temperature levels.*

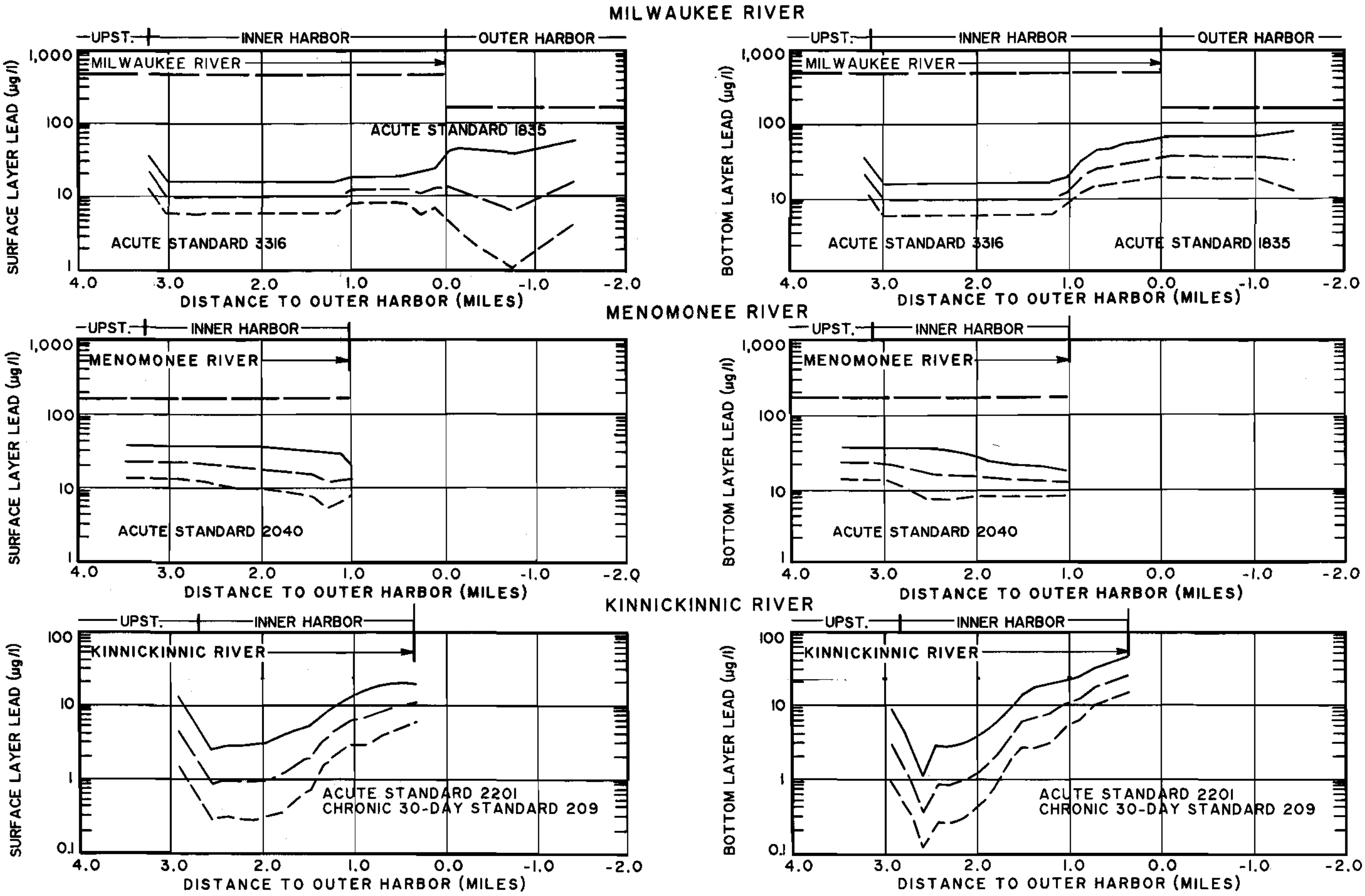
[e] *The acute and chronic toxicity standards, which vary in response to the pH and temperature of the water, were calculated in accordance with the procedures set forth in Chapter II of this volume.*

Source: SEWRPC.

minus one standard deviation of the logs of the data, are shown in the figure. The data plots show total lead concentrations. Chronic and acute toxicity standards for acid-soluble lead are also shown in the figure. Figure 69 indicates that total lead levels in both the inner and outer harbors may be expected to meet the acute and chronic standards for acid-soluble lead.

Figure 69

ESTIMATED LEAD CONCENTRATIONS UNDER THE EXISTING FLUSHING TUNNELS SUBALTERNATIVE



LEGEND

STANDARDS

- ACUTE MAXIMUM STANDARD
- CHRONIC 30 DAY MEAN MAXIMUM STANDARD

LEAD PLOTS

- MEDIAN PLUS ONE STANDARD DEVIATION OF THE LOGS (84TH PERCENTILE)
- MEDIAN (50TH PERCENTILE)
- MEDIAN MINUS ONE STANDARD DEVIATION OF THE LOGS (16TH PERCENTILE)

NOTE: THE ACUTE AND CHRONIC STANDARDS APPLY TO ACID-SOLUBLE LEAD CONCENTRATIONS, WHEREAS THE PLOTS REPRESENT TOTAL LEAD CONCENTRATIONS. THUS, VIOLATION OF THE STANDARD DOES NOT NECESSARILY INDICATE THAT TOXIC CONDITIONS WOULD EXIST. THE ACUTE AND CHRONIC STANDARDS, WHICH ARE A FUNCTION OF THE HARDNESS OF THE WATER, WERE CALCULATED USING THE BASELINE HARDNESS LEVELS MEASURED FROM 1981 THROUGH 1983 AT THE REPRESENTATIVE SAMPLING STATIONS PRESENTED IN CHAPTER VI OF VOLUME ONE OF THIS REPORT.

Source: HydroQual, Inc., and SEWRPC.

The long-term impacts of the existing flushing tunnels subalternative on lead concentrations in the inner harbor sediments are related to the anticipated reduction in total lead loadings. The dilution of the inner harbor with discharge from the flushing tunnels would result in lead loadings being slightly higher than under the committed action alternative, since the outer harbor water discharged from the flushing tunnels would contain lead. However, the higher flow velocities would also slightly reduce the settling rate of lead into the bottom sediments. Thus, overall, it was concluded that the lead concentration in the bottom sediments would be the same as under the committed action alternative. This subalternative would thus result in a reduction of approximately 53 percent in lead levels in the bottom sediments of the inner harbor. Estimated concentrations of lead in the bottom sediments would be identical to those set forth in Table 28 for the committed action alternative. The estimated lead concentrations would result in the bottom sediments in all six inner harbor stations being rated as heavily polluted.

Other Toxic Metals: The concentrations of cadmium, copper, and zinc in the bottom sediments of the inner harbor—and the pollution ratings of those sediments—under the existing flushing tunnels subalternative are expected to be the same as those set forth in Table 28 for the committed action alternative. While the metal concentrations in the bottom sediments would be affected primarily by the reduction in total metal loadings, the metal concentrations in the water column would also be influenced by the dilution with flushing tunnel discharge. Based on pollutant loading estimates set forth in Chapter VI of Volume One, this subalternative would result in a reduction of approximately 29 percent in cadmium, 8 percent in copper, and 85 percent in zinc loadings to the inner harbor.

Within the water column of the Milwaukee Harbor estuary, total metal concentrations would continue to exceed the chronic toxicity standards for acid-soluble cadmium and copper. These apparent standard violations would be substantially less severe, however, than under the committed action alternative. The chronic and acute toxicity standards for acid-soluble zinc would continue to be achieved under this subalternative.

Low Flow Augmentation: Menomonee River New Flushing Tunnel Subalternative

This subalternative calls for continued operation of the existing flushing tunnels that discharge to the Milwaukee River and Kinnickinnic River, along with a new flushing tunnel that would discharge to the upstream end of the Menomonee River estuary. All tunnels would operate during periods of critically low dissolved oxygen levels. The water quality conditions expected within the Milwaukee Harbor estuary with operation of all three flushing tunnels are presented below.

Dissolved Oxygen: A low-flow, steady-state simulation analysis was conducted to determine the effect that the operation of the three flushing tunnels would have on the critical dissolved oxygen conditions expected during low-flow and high-temperature periods. The steady-state analysis estimated dissolved oxygen levels under 7-day, 10-year recurrence interval low-flow conditions at the high temperature levels measured during Survey Period 1, July 25 to August 8, 1983. Spatial plots of low-flow, steady-state dissolved oxygen levels under the Menomonee River new flushing tunnel subalternative are shown in Figure 70. The figure compares the simulated dissolved oxygen levels to standards established for a warmwater fishery and for a limited fishery.

The comparison to the standards indicates that all standards for both warmwater and limited fisheries would be met throughout the inner harbor and outer harbor. The dissolved oxygen levels under these critical low-flow conditions would exceed 6 mg/l. The dissolved oxygen levels in the outer harbor would be about the same as those estimated under the committed action alternative.

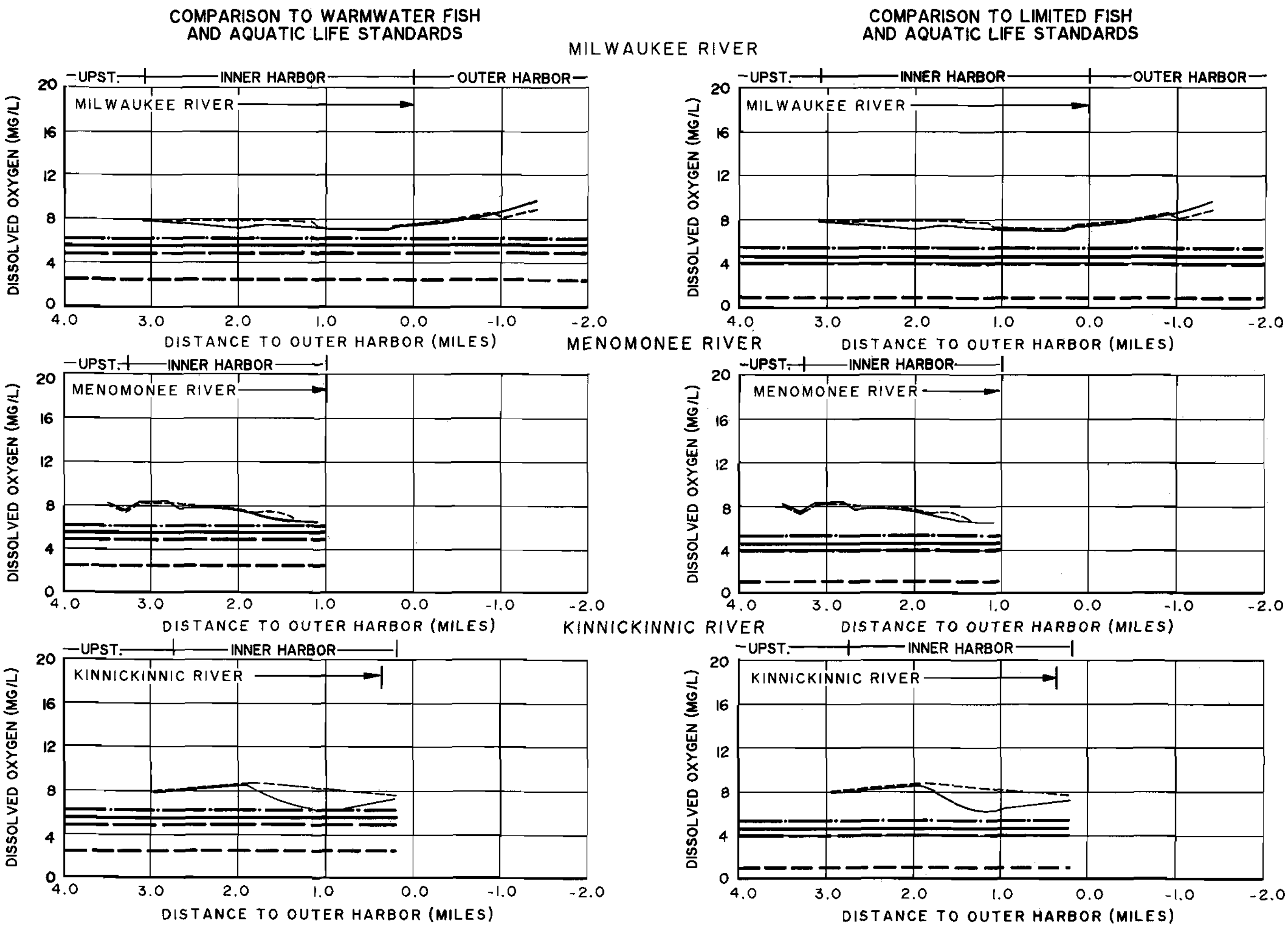
The significance of the individual sinks of oxygen under the Menomonee River new flushing tunnel subalternative can be determined by analyzing the components of the dissolved oxygen deficit. The components of the deficit that were studied in the steady-state analysis included the sediment flux of methane and ammonia, sediment oxygen demand, carbonaceous biochemical oxygen demand from upstream sources and from the Jones Island sewage treatment plant, and net photosynthesis/respiration. The computed components of the dissolved oxygen deficit under low-flow, steady-state conditions in the surface and bottom water layers are shown in Figure 71.

The total dissolved oxygen deficit would be less than 2 mg/l in the surface water layers of the Milwaukee, Menomonee, and Kinnickinnic River estuaries, and less than 3 mg/l in the bottom water layers. The largest component of the deficit would be carbonaceous biochemical oxygen demand from upstream sources. The deficits for the Milwaukee and Kinnickinnic River estuaries and for the outer harbor would be about the same as under the existing flushing tunnels subalternative.

Dissolved oxygen conditions under a series of flow and temperature conditions were evaluated to assess the improvement in dissolved oxygen levels under the Menomonee River new flushing tunnel subalternative. Estimated dissolved oxygen levels were then compared to the standards for a warmwater fishery and for a limited fishery. The expected violations of the dissolved oxygen standards are set forth in Table 34. For the surface and

Figure 70

LOW-FLOW, STEADY-STATE ANALYSIS OF DISSOLVED OXYGEN UNDER THE LOW-FLOW AUGMENTATION: MENOMONEE RIVER NEW FLUSHING TUNNEL SUBALTERNATIVE



LEGEND

MODEL SIMULATED DATA

- - - SURFACE LAYER

—— BOTTOM LAYER

STANDARDS (MG/L)	WARMWATER	LIMITED
—— 30 DAY MEAN MINIMUM STANDARD	5.5	4.5
—·— 7 DAY MEAN MINIMUM STANDARD (3/15-7/31)	6.0	5.0
— — I DAY MEAN MINIMUM STANDARD (3/15-7/31)	5.0	4.0
- - - ABSOLUTE MINIMUM STANDARD	2.5	1.5

NOTE: THE EXISTING WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS SPECIFY MINIMUM DISSOLVED OXYGEN LEVELS OF 5.0 MG/L AND 3.0 MG/L FOR THE FULL WARMWATER FISH AND AQUATIC LIFE AND THE LIMITED FISH AND AQUATIC LIFE WATER USE OBJECTIVES,RESPECTIVELY. THESE STANDARDS ARE APPLIED BY THE DEPARTMENT AS A MINIMUM NOT TO BE VIOLATED AT ANY FLOW EQUAL TO OR GREATER THAN THE 7-DAY,10-YEAR MINIMUM FLOW.

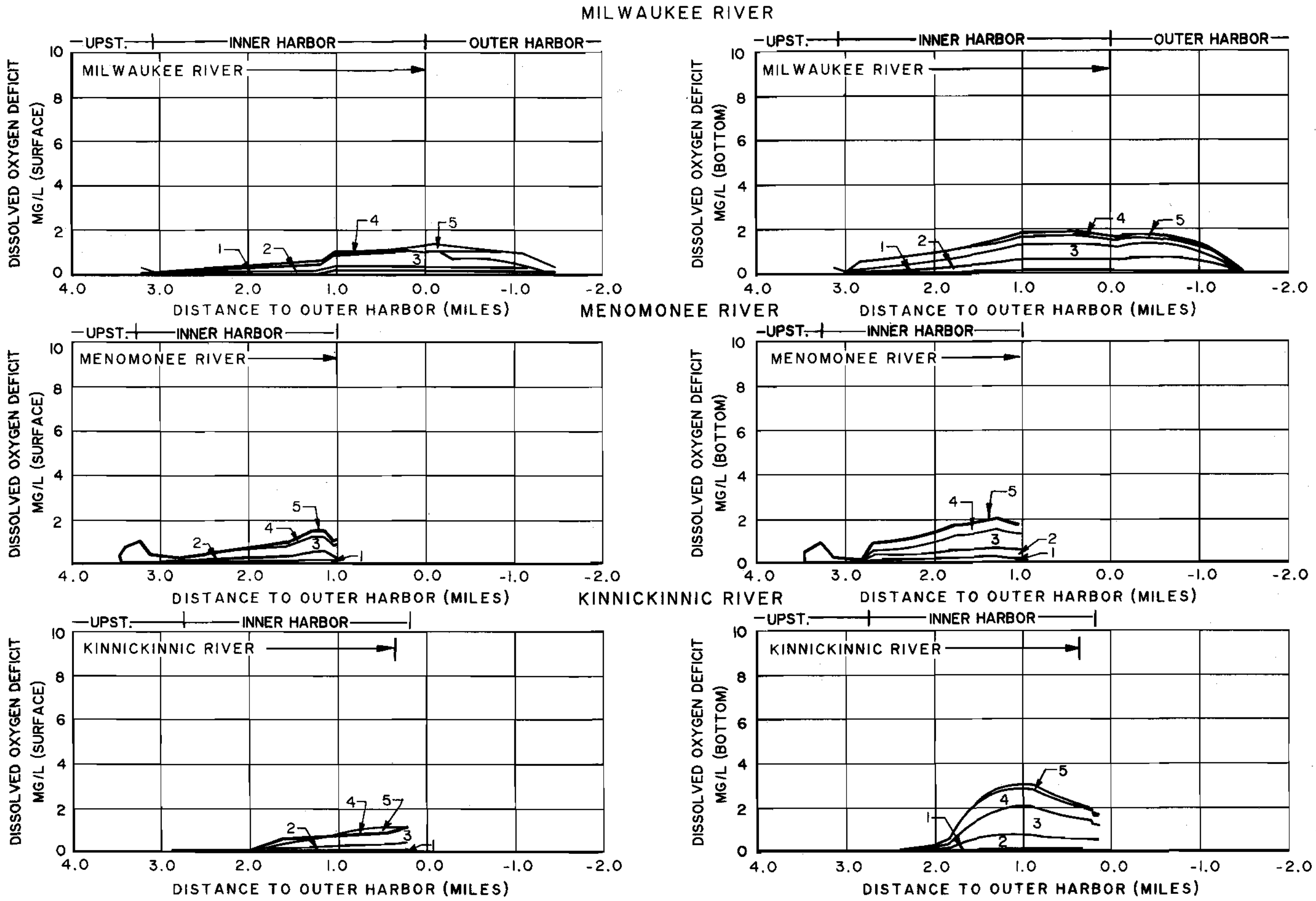
Source: HydroQual, Inc.

bottom water layers of several upstream, inner harbor, and outer harbor sampling stations, the anticipated violation of the dissolved oxygen standards is classified as slight, moderate, or severe.

In the tributary rivers upstream of the esuary, the violation of the dissolved oxygen standards would be the same as that expected under the committed action alternative. Within the Milwaukee and Menomonee River estuaries, all of the dissolved oxygen standards for both warmwater and limited fisheries would be expected to be met. Dissolved oxygen levels in the Kinnickinnic River estuary would be the same as under the existing flushing tunnels subalternative in that, with the exception of some slight violations in the bottom water layer

Figure 71

COMPONENTS OF THE DISSOLVED OXYGEN DEFICIT UNDER LOW-FLOW, STEADY-STATE CONDITIONS: MENOMONEE RIVER NEW FLUSHING TUNNEL SUBALTERNATIVE



LEGEND

1 SEDIMENT FLUX OF METHANE AND AMMONIA

2 SEDIMENT OXYGEN DEMAND

3 UPSTREAM CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND

4 NET PHOTOSYNTHESIS/RESPIRATION

5 CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND FROM THE JONES ISLAND SEWAGE TREATMENT PLANT

Source: HydroQual, Inc.

near Greenfield Avenue extended, all standards would be met. The dissolved oxygen levels in the outer harbor would remain about the same as under the committed action alternative, with a minor improvement being noted at the Hoan Bridge and near the Jones Island sewage treatment plant outfall.

Diurnal fluctuations in dissolved oxygen levels within the Milwaukee River estuary would be the same as those expected under the existing flushing tunnels subalternative. Diurnal fluctuations would continue to be very minor in the Menomonee and Kinnickinnic River estuaries, and in the outer harbor. The bottom water layers would not exhibit diurnal fluctuations in any of the water bodies.

Fecal Coliform: The operation of three flushing tunnels would substantially reduce fecal coliform levels within the entire inner harbor. The statistical water quality model described in Chapter VII of Volume One of this report was used to deter-

Table 34

VIOLATION OF DISSOLVED OXYGEN STANDARDS UNDER THE MENOMONEE RIVER NEW FLUSHING TUNNEL SUBALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Warmwater Fish and Aquatic Life: 30-Day Mean All Year 5.5 mg/l	7-Day Mean 3/15-7/31 6.0 mg/l	1-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 8/1-3/14 4.0 mg/l	Absolute Minimum All Year 2.5 mg/l	Limited Fish and Aquatic Life: 30-Day Mean All Year 4.5 mg/l	7-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 3/15-7/31 4.0 mg/l	1-Day Mean 8/1-3/14 3.0 mg/l	Absolute Minimum All Year 1.5 mg/l
Upstream												
Milwaukee River	North Avenue Dam (RIV-5)	DI	None	Moderate	None	None	None	None	None	None	None	None
Menomonee River	S. 37th Street (RIV-10)	DI	None	Moderate	None	None	None	None	None	None	None	None
Kinnickinnic River	S. 9th Place (RIV-13)	DI	None	Slight	Slight	Slight	Slight	None	Slight	Slight	Slight	None
Inner Harbor												
Milwaukee River	Walnut Street (RIV-6)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Wells Street (RIV-7)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Water Street (RIV-8)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	C&NW Railway (RIV-15)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
Menomonee River	Muskego Avenue (RIV-11)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	S. 2nd Street (RIV-17)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
Kinnickinnic River	S. 1st Street (RIV-14)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Greenfield Avenue Extended (RIV-18)	S	None	None	None	None	None	None	None	None	None	None
		B	None	Slight	Slight	None	None	None	Slight	None	None	None
	Jones Island (RIV-19)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
Outer Harbor	Hoan Bridge (OH-1)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Central OH (OH-3)	S	Slight	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	None	None	Slight	None	None	None	None
	South OH (OH-11)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	Slight	None	Slight	None	Slight	None	None	None	None
	JI STP Plume (OH-2)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	Slight	None	None	None	None	Slight	None

NOTE: Standard violations that occur up to 5 percent of the time are classified as slight; violations that occur 6 to 10 percent of the time are classified as moderate; and violations that occur more than 10 percent of the time are classified as severe. Underlined ratings indicate a significant improvement in dissolved oxygen levels over the levels expected under the committed action alternative.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

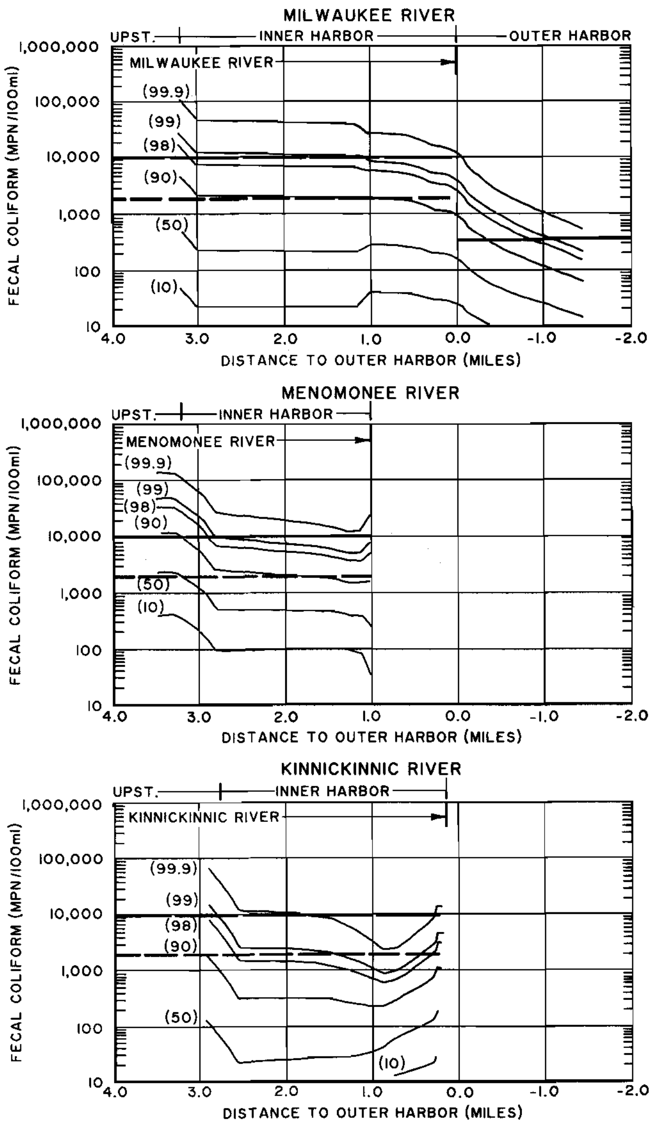
Source: HydroQual, Inc., and SEWRPC.

mine the fecal coliform levels that could be anticipated within the estuary under the Menomonee River new flushing tunnel subalternative. For the statistical analysis, it was assumed that the tunnels would operate continuously.

The estimated distribution of fecal coliform levels is presented in Figure 72. The fecal coliform levels in the Milwaukee and Kinnickinnic River estuaries and in the outer harbor would be about the same as under the existing flushing tunnels subalterna-

Figure 72

ESTIMATED FECAL COLIFORM LEVELS UNDER THE MENOMONEE RIVER NEW FLUSHING TUNNEL SUBALTERNATIVE: DISTRIBUTION OF ALL DATA



LEGEND

(99.9) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE:
OUTER HARBOR

—— LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 10 PERCENT OF THE TIME (400 MPN/100 ml)

LIMITED RECREATIONAL USE:
INNER HARBOR

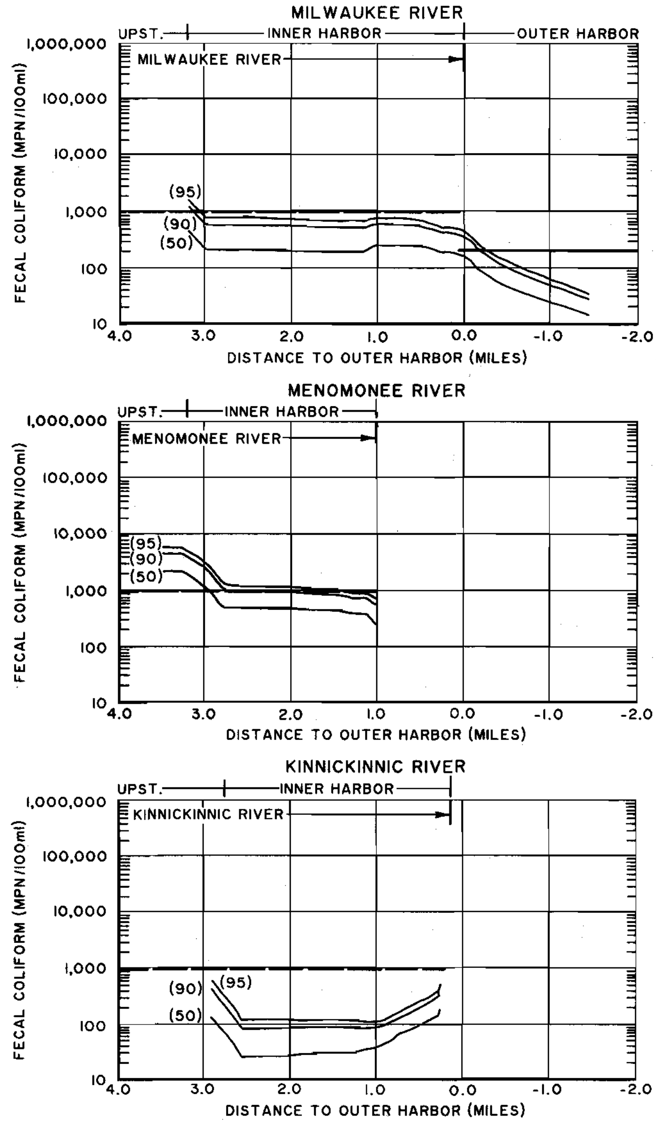
- - - LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THEN 10 PERCENT OF THE TIME (2,000 MPN/100 ml)

—— LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 2 PERCENT OF THE TIME (10,000 MPN/100 ml)

Source: HydroQual, Inc.

Figure 73

ESTIMATED FECAL COLIFORM LEVELS UNDER THE MENOMONEE RIVER NEW FLUSHING TUNNEL SUBALTERNATIVE: DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF FIVE SAMPLES



LEGEND

(90) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE:
OUTER HARBOR

—— LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH (200 MPN/100 ml)

LIMITED RECREATIONAL USE:
INNER HARBOR

—— LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH MORE THAN 5 PERCENT OF THE TIME (1,000 MPN/100 ml)

Source: HydroQual, Inc.

tive. Within the Menomonee River estuary, the 10,000 and 2,000 MPN/100 ml standards supporting limited recreational use would be violated less than the maximum 2 percent and 10 percent of the time, respectively. The fecal coliform standards supporting limited recreational use would be violated in the upstream Milwaukee and Menomonee Rivers.

Figure 73 shows the distribution of the geometric means of groups of five fecal coliform samples. This figure illustrates the achievement of the geometric mean standards. Overall, the geometric mean standard for limited recreational use would be met in the inner harbor, and the geometric mean standard for full recreational use would be met in the outer harbor.

Thus, under the Menomonee River new flushing tunnel subalternative, the fecal coliform levels in the Menomonee River estuary would be lower than under the existing flushing tunnels subalternative. The fecal coliform standards supporting limited recreational use would be achieved in the inner harbor, and the outer harbor would be expected to achieve the fecal coliform standards supporting full recreational use.

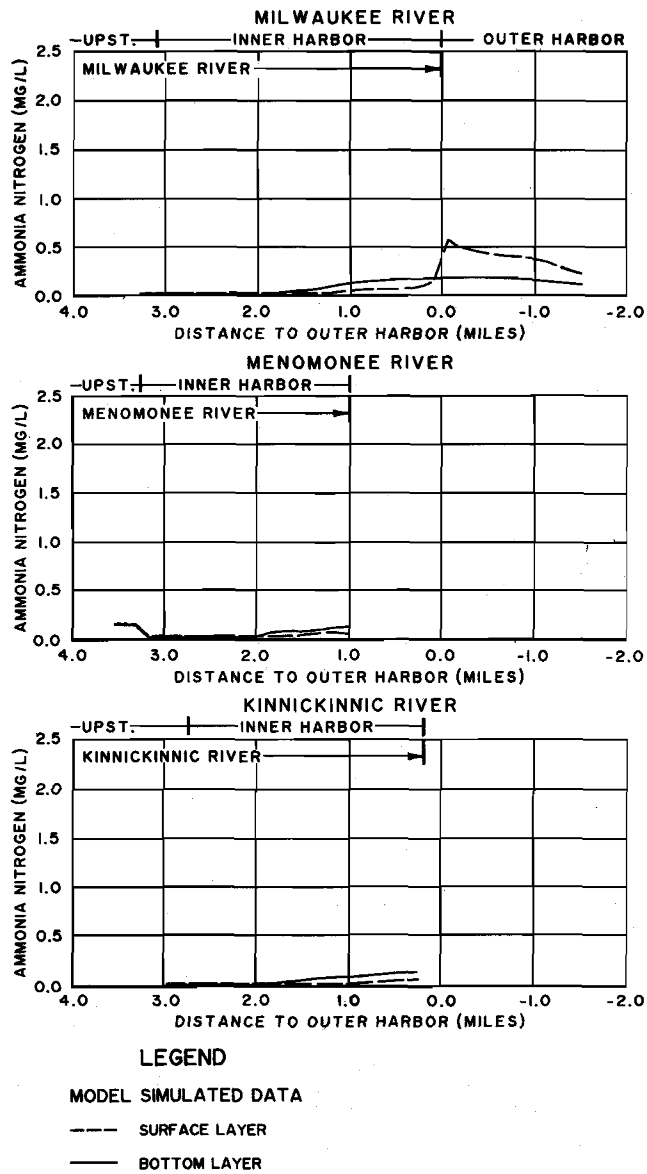
Ammonia Nitrogen: Ammonia nitrogen levels under the Menomonee River new flushing tunnel subalternative would be the same as those under the existing flushing tunnels subalternative in the Milwaukee and Kinnickinnic River estuaries and in the outer harbor. The new flushing tunnel in the Menomonee River would reduce the ammonia nitrogen concentrations in the Menomonee River estuary up to 80 percent. Simulated ammonia nitrogen concentrations under low-flow, steady-state conditions are presented in Figure 74.

The un-ionized ammonia nitrogen concentrations expected under the Menomonee River new flushing tunnel subalternative and a comparison to acute and chronic toxicity standards are set forth in Table 35. The un-ionized ammonia nitrogen concentrations and acute and chronic toxicity standards were calculated in accordance with the procedures described for the committed action alternative.

Under low-flow, steady-state conditions, the estimated un-ionized ammonia nitrogen concentration would range from 0.009 to 0.022 mg/l at the upstream river stations, from 0.001 to 0.009 mg/l at the inner harbor stations, and from 0.002 to 0.009 mg/l at the outer harbor stations. No stations would violate the chronic or acute toxicity standards. Although Table 35 indicates that standard violations would probably not occur within the outer harbor, occasional violations of the chronic toxicity standards could occur within portions of the outer harbor during periods of higher pH. However, these occasional violations would be less severe than under the committed action alternative.

Figure 74

ESTIMATED AMMONIA NITROGEN LEVELS UNDER THE MENOMONEE RIVER NEW FLUSHING TUNNEL SUBALTERNATIVE



Source: HydroQual, Inc.

Table 35

COMPARISON OF ESTIMATED UN-IONIZED AMMONIA NITROGEN CONCENTRATIONS TO THE RECOMMENDED ACUTE AND CHRONIC TOXICITY STANDARDS UNDER THE MENOMONEE RIVER NEW FLUSHING TUNNEL SUBALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Total Ammonia Nitrogen[b] (mg/l)	pH[c] (standard units)	Temperature (°F)	Un-ionized Ammonia Nitrogen[d] (mg/l)	Un-ionized Ammonia Nitrogen Toxicity Standards		Violation of Un-ionized Ammonia Nitrogen Toxicity Standards	
							Acute[e]	Chronic[e]	Acute	Chronic
Upstream										
Milwaukee River	North Avenue Dam (RIV-5)	DI	0.05	8.5	81	0.009	0.117	0.025	- -	- -
Menomonee River	S. 37th Street (RIV-10)	DI	0.15	8.5	75	0.022	0.116	0.025	- -	- -
Kinnickinnic River	S. 9th Place (RIV-13)	DI	0.05	8.9	84	0.019	0.121	0.025	- -	- -
Inner Harbor										
Milwaukee River	Walnut Street (RIV-6)	S	0.05	8.5	81	0.009	0.116	0.025	- -	- -
		B	0.05	8.4	81	0.008	0.115	0.025	- -	- -
	Wells Street (RIV-7)	S	0.05	8.0	79	0.003	0.102	0.025	- -	- -
		B	0.05	8.1	75	0.004	0.108	0.025	- -	- -
	Water Street (RIV-8)	S	0.05	7.9	79	0.003	0.098	0.025	- -	- -
		B	0.10	7.9	66	0.003	0.099	0.025	- -	- -
	C&NW Railway (RIV-15)	S	0.05	7.5	77	0.001	0.073	0.025	- -	- -
		B	0.15	8.1	64	0.007	0.105	0.025	- -	- -
Menomonee River	Muskego Avenue (RIV-11)	S	0.05	7.7	81	0.002	0.088	0.025	- -	- -
		B	0.05	7.5	72	0.001	0.077	0.025	- -	- -
	S. 2nd Street (RIV-17)	S	0.05	7.7	79	0.002	0.088	0.025	- -	- -
		B	0.10	7.7	72	0.003	0.090	0.025	- -	- -
Kinnickinnic River	S. 1st Street (RIV-14)	S	0.05	7.6	72	0.001	0.081	0.025	- -	- -
		B	0.05	7.6	72	0.001	0.081	0.025	- -	- -
	Greenfield Avenue Extended (RIV-18)	S	0.05	7.6	73	0.001	0.081	0.025	- -	- -
		B	0.10	7.6	64	0.002	0.081	0.025	- -	- -
	Jones Island (RIV-19)	S	0.10	7.6	73	0.002	0.083	0.025	- -	- -
		B	0.15	7.9	63	0.004	0.097	0.025	- -	- -
Outer Harbor	South OH (OH-11)	S	0.45	7.6	72	0.009	0.079	0.025	- -	- -
		B	0.20	7.6	57	0.002	0.083	0.025	- -	- -
	JI STP Plume (OH-2)	S	0.60	7.4	70	0.007	0.065	0.025	- -	- -
		B	0.20	7.9	61	0.005	0.097	0.025	- -	- -

NOTE: The existing Wisconsin Department of Natural Resources standard for un-ionized ammonia nitrogen specifies a maximum level of 0.04 mg/l for the full warmwater fishery and aquatic life water use objective. The Department has issued no standard for the limited fishery and aquatic life objective. The standard for the warmwater fishery and aquatic life objective is applied by the Department as a maximum not to be exceeded at any flow equal to or greater than the 7-day, 10-year minimum flow.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

[b] *As estimated in Figure 74.*

[c] *Arithmetic mean pH and temperature levels measured during Survey Period 1, July 25 through August 8, 1983, under the baseline sampling program.*

[d] *The un-ionized ammonia nitrogen concentrations were calculated using the estimated total ammonia nitrogen, pH, and temperature levels.*

[e] *The acute and chronic toxicity standards, which vary in response to the pH and temperature of the water, were calculated in accordance with the procedures set forth in Chapter II of this volume.*

Source: SEWRPC.

Lead: The operation of the three flushing tunnels would substantially reduce the lead concentrations throughout the inner harbor. The statistical water quality model described in Chapter VII of Volume One of this report was used to evaluate the lead levels which could be anticipated within the estuary under the Menomonee River new flushing tunnel subalternative. For the statistical analysis, it was assumed that the tunnels would operate continuously.

The estimated distribution of lead concentrations in the surface and bottom water layers is presented in Figure 75. The median lead levels, plus and minus one standard deviation of the logs of the data, are shown in the figure. The data plots show total lead concentrations. Chronic and acute toxicity standards for acid-soluble lead are also shown in the figure.

Figure 75 indicates that the lead levels would be about the same as under the existing flushing tunnels subalternative for the Milwaukee and Kinnickinnic River estuaries and for the outer harbor. The total lead concentrations may be expected to meet both the acute and chronic toxicity standards for acid-soluble lead throughout the Milwaukee Harbor estuary.

Lead concentrations in the bottom sediments of the inner harbor would be the same under the Menomonee River new flushing tunnel subalternative as under the committed action alternative, as set forth in Table 28. The expected lead concentrations would represent a reduction of approximately 53 percent in existing lead levels in the bottom sediments of the inner harbor. The estimated lead concentrations would result in the bottom sediments in all six inner harbor stations being rated as heavily polluted.

Other Toxic Metals: Concentrations of cadmium, copper, and zinc in the bottom sediments of the inner harbor—and the pollution rating of those sediments—under the Menomonee River new flushing tunnel subalternative are expected to be the same as those set forth in Table 28 for the committed action alternative. Based on pollutant loading estimates set forth in Chapter VI of Volume One, this subalternative would result in a reduction of approximately 29 percent in cadmium, 8 percent in copper, and 85 percent in zinc loadings to the inner harbor.

Within the water column of the Milwaukee Harbor estuary, total metal concentrations would continue to exceed the chronic toxicity standards for acid-soluble cadmium and copper. The apparent standard violations in the Menomonee River estuary would be less severe than under the existing flushing tunnels subalternative. The chronic and acute toxicity standards for acid-soluble zinc would continue to be achieved under this subalternative.

Menomonee River Instream Aeration Alternative

This alternative calls for instream aeration to increase the dissolved oxygen levels in the Menomonee River estuary. The existing flushing tunnels would continue to discharge to the Milwaukee and Kinnickinnic Rivers. The water quality conditions expected within the Milwaukee Harbor estuary under the combined operation of the existing flushing tunnels and new instream aeration facilities are presented below.

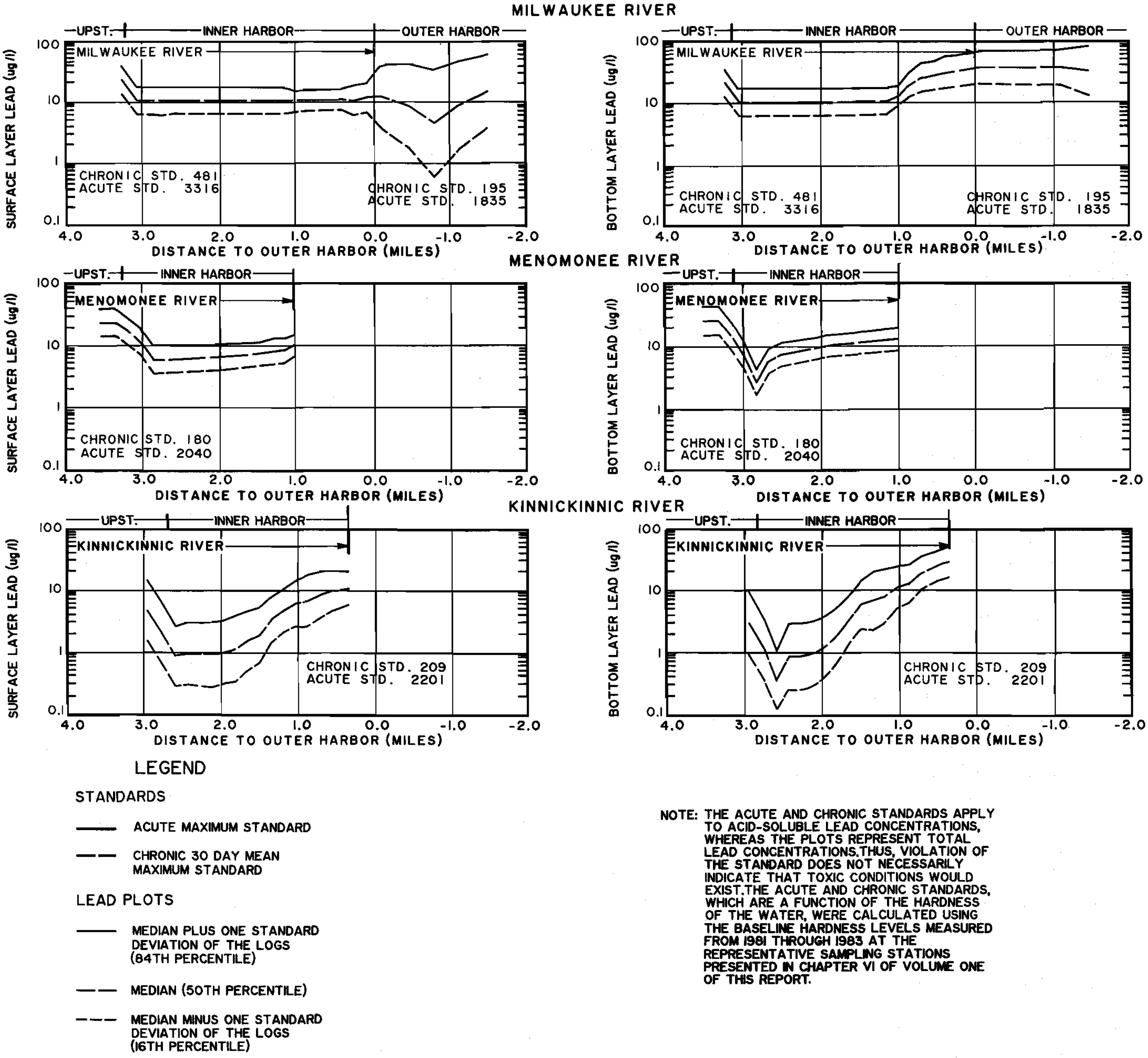
Dissolved Oxygen: A low-flow, steady-state simulation analysis was conducted to determine the effect that the Menomonee River instream aeration alternative would have on the critical dissolved oxygen conditions expected during low-flow and high-temperature periods. The steady-state analysis estimated dissolved oxygen levels under 7-day, 10-year recurrence interval low-flow conditions at the high temperature levels measured during Survey Period 1, July 25 to August 8, 1983. Spatial plots of low-flow, steady-state dissolved oxygen levels under the Menomonee River instream aeration alternative are shown in Figure 76. The figure compares the simulated dissolved oxygen levels to standards established for a warmwater fishery and for a limited fishery.

The comparison to the standards indicates that all standards for both warmwater and limited fisheries would be met within the Milwaukee, Menomonee, and Kinnickinnic River estuaries. The dissolved oxygen levels in the outer habor would be about the same as those estimated under the committed action alternative, and all standards would be met.

The significance of the individual sinks of oxygen under the Menomonee River instream aeration alternative can be determined by analyzing the components of the dissolved oxygen deficit. The components of the deficit that were studied in the steady-state analysis included the sediment flux of methane and ammonia, sediment oxygen

Figure 75

ESTIMATED LEAD CONCENTRATIONS UNDER THE MENOMONEE RIVER NEW FLUSHING TUNNEL SUBALTERNATIVE



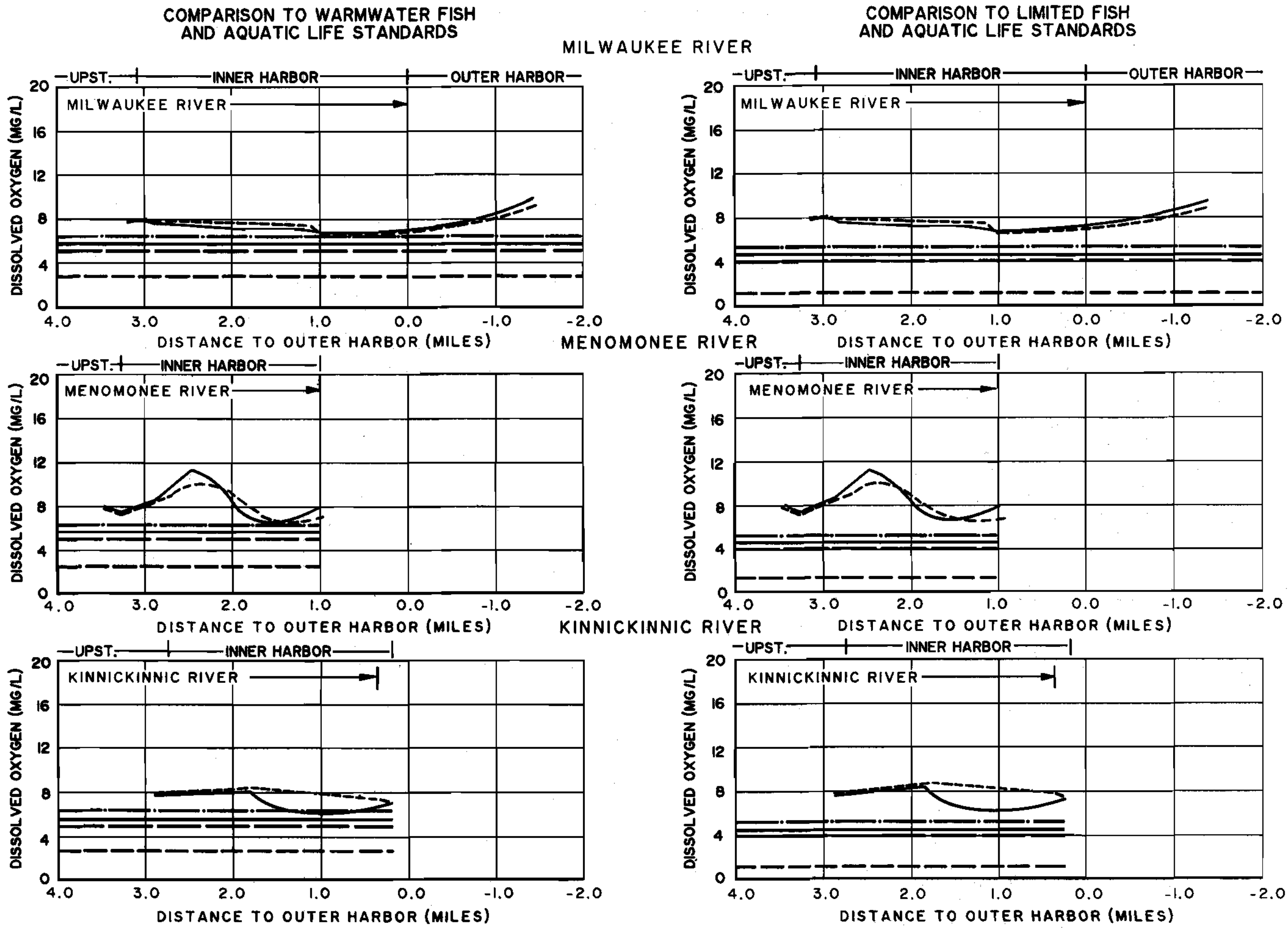
Source: HydroQual, Inc., and SEWRPC.

demand, carbonaceous biochemical oxygen demand from upstream sources and from the Jones Island sewage treatment plant, and net photosynthesis/respiration. The computed components of the dissolved oxygen deficit under low-flow, steady-state conditions in the surface and bottom water layers are shown in Figure 77.

The total dissolved oxygen deficits in the Milwaukee and Kinnickinnic River estuaries and in the outer harbor would be the same as under the existing flushing tunnels subalternative. Near the upper ends of these estuaries, the deficits would be negligible, then increase in the downstream direction. Within the Menomonee River estuary, the

Figure 76

LOW-FLOW, STEADY-STATE ANALYSIS OF DISSOLVED OXYGEN UNDER THE MENOMONEE RIVER INSTREAM AERATION ALTERNATIVE



LEGEND

MODEL SIMULATED DATA

- – – – SURFACE LAYER
- ——— BOTTOM LAYER

STANDARDS (MG/L)

		WARMWATER	LIMITED
———	30 DAY MEAN MINIMUM STANDARD	5.5	4.5
—·—	7 DAY MEAN MINIMUM STANDARD (3/15-7/31)	6.0	5.0
— —	1 DAY MEAN MINIMUM STANDARD (3/15-7/31)	5.0	4.0
– – –	ABSOLUTE MINIMUM STANDARD	2.5	1.5

NOTE: THE EXISTING WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS SPECIFY MINIMUM DISSOLVED OXYGEN LEVELS OF 5.0 MG/L AND 3.0 MG/L FOR THE FULL WARMWATER FISH AND AQUATIC LIFE AND THE LIMITED FISH AND AQUATIC LIFE WATER USE OBJECTIVES, RESPECTIVELY. THESE STANDARDS ARE APPLIED BY THE DEPARTMENT AS A MINIMUM NOT TO BE VIOLATED AT ANY FLOW EQUAL TO OR GREATER THAN THE 7-DAY,10-YEAR MINIMUM FLOW.

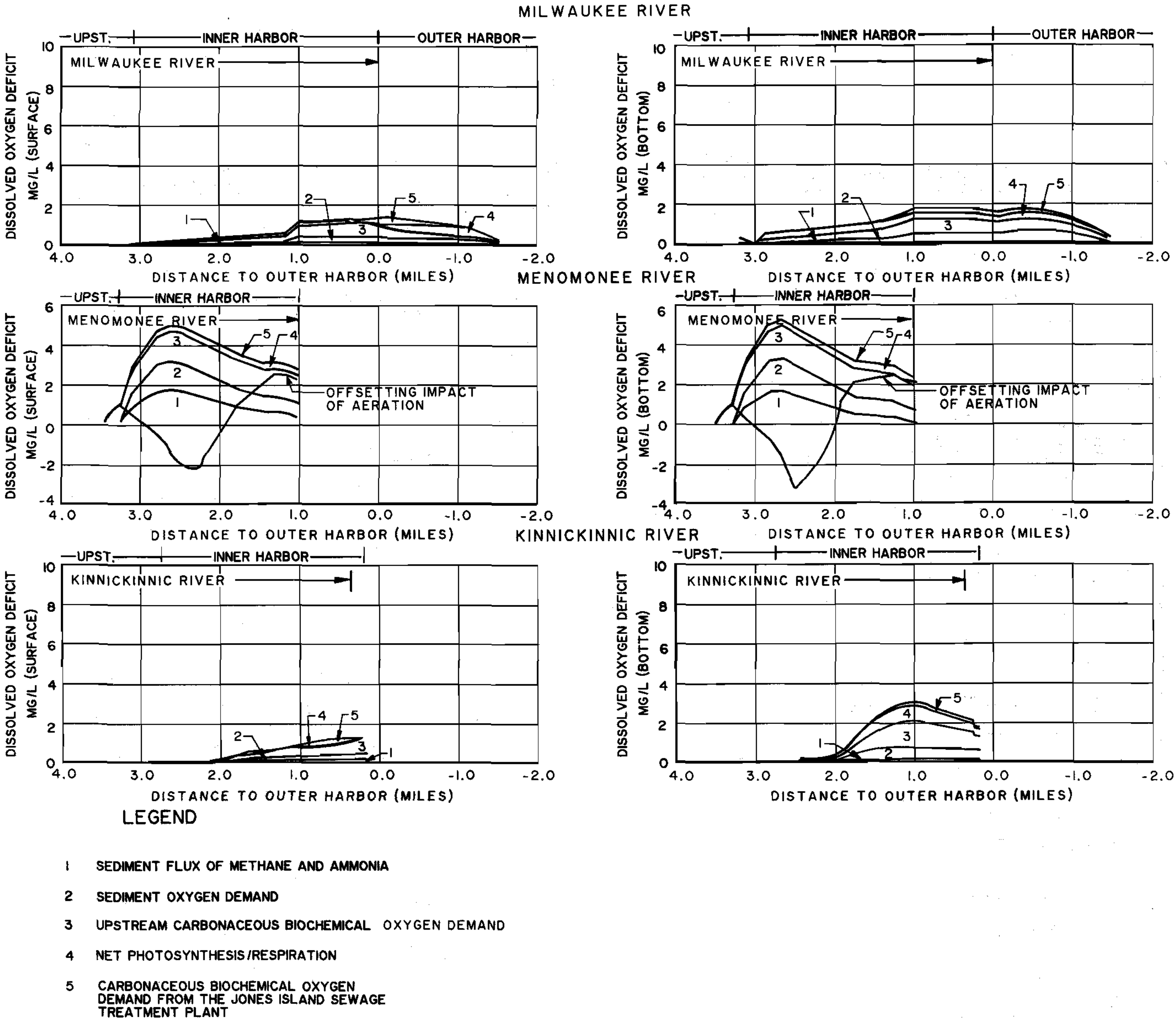
Source: HydroQual, Inc.

upper reaches would have a negative deficit—the dissolved oxygen concentrations would exceed the saturation level—which would increase rapidly in the downstream direction. Throughout the inner harbor the largest component of the deficit would be carbonaceous biochemical oxygen demand from upstream sources.

Dissolved oxygen conditions under a series of flow and temperature conditions were evaluated to assess the improvement in dissolved oxygen levels under the Menomonee River instream aeration alternative. Estimated dissolved oxygen levels were then compared to the standards for a warmwater fishery and for a limited fishery. The expected

Figure 77

COMPONENTS OF THE DISSOLVED OXYGEN DEFICIT UNDER LOW-FLOW, STEADY-STATE CONDITIONS: MENOMONEE RIVER INSTREAM AERATION ALTERNATIVE



Source: HydroQual, Inc.

violations of the dissolved oxygen standards are set forth in Table 36. For the surface and bottom water layers of several upstream, inner harbor, and outer harbor sampling stations, the anticipated violation of the dissolved oxygen standards is classified as slight, moderate, or severe.

Within the tributary rivers upstream of the estuary, the Milwaukee and Kinnickinnic River estuaries, and the outer harbor, the achievement of the dissolved oxygen standards would be about the same as that expected under the existing flushing tunnels subalternative. The Menomonee River estuary would experience improved dissolved oxygen levels, with all standards for both a warmwater fishery and a limited fishery being met.

Diurnal fluctuations in dissolved oxygen levels within the Milwaukee River estuary would be the same as those expected under the existing flushing

Table 36

VIOLATION OF DISSOLVED OXYGEN STANDARDS UNDER THE MENOMONEE RIVER INSTREAM AERATION ALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Warmwater Fish and Aquatic Life					Limited Fish and Aquatic Life				
			30-Day Mean All Year 5.5 mg/l	7-Day Mean 3/15-7/31 6.0 mg/l	1-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 8/1-3/14 4.0 mg/l	Absolute Minimum All Year 2.5 mg/l	30-Day Mean All Year 4.5 mg/l	7-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 3/15-7/31 4.0 mg/l	1-Day Mean 8/1-3/14 3.0 mg/l	Absolute Minimum All Year 1.5 mg/l
Upstream												
Milwaukee River	North Avenue Dam (RIV-5)	DI	None	Moderate	None	None	None	None	None	None	None	None
Menomonee River	S. 37th Street (RIV-10)	DI	None	Moderate	None	None	None	None	None	None	None	None
Kinnickinnic River	S. 9th Place (RIV-13)	DI	None	Slight	Slight	Slight	Slight	None	Slight	Slight	Slight	None
Inner Harbor												
Milwaukee River	Walnut Street (RIV-6)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Wells Street (RIV-7)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Water Street (RIV-8)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	C&NW Railway (RIV-15)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
Menomonee River	Muskego Avenue (RIV-11)	S	Moderate	Moderate	None	None	None	None	None	None	None	None
		B	Moderate	Moderate	None	None	None	None	None	None	None	None
	S. 2nd Street (RIV-17)	S	Moderate	Moderate	None	None	None	None	None	None	None	None
		B	Moderate	Moderate	None	Moderate	None	None	None	None	None	None
Kinnickinnic River	S. 1st Street (RIV-14)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Greenfield Avenue Extended (RIV-18)	S	None	None	None	None	None	None	None	None	None	None
		B	None	Slight	Slight	None	None	None	Slight	None	None	None
	Jones Island (RIV-19)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
Outer Harbor	Hoan Bridge (OH-1)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Central OH (OH-3)	S	Slight	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	None	None	Slight	None	None	None	None
	South OH (OH-11)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	Slight	None	Slight	None	Slight	None	None	None	None
	JI STP Plume (OH-2)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	Slight	None	Slight	None	None	Slight	None

NOTE: Standard violations that occur up to 5 percent of the time are classified as slight; violations that occur 6 to 10 percent of the time are classified as moderate; and violations that occur more than 10 percent of the time are classified as severe. Underlined ratings indicate a significant improvement in dissolved oxygen levels over the levels expected under the committed action alternative.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

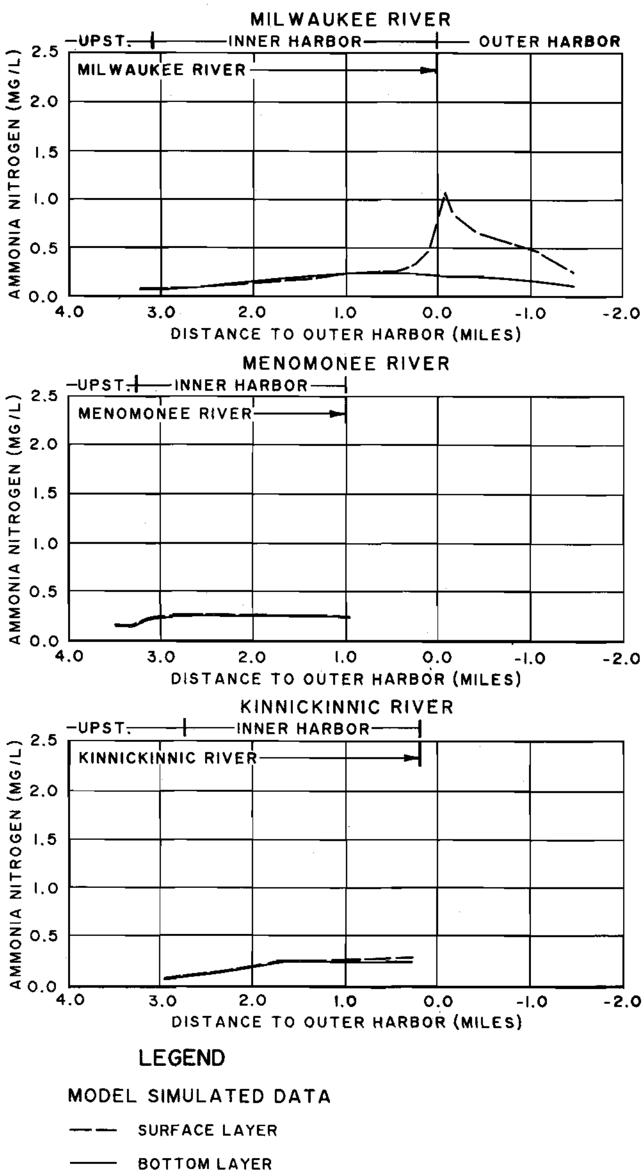
Source: HydroQual, Inc., and SEWRPC.

tunnels subalternative. Diurnal fluctuations would continue to be very minor in the Menomonee and Kinnickinnic River estuaries, and in the outer harbor. The bottom water layers would not exhibit diurnal fluctuations in any of the water bodies.

Fecal Coliform: The fecal coliform levels may be expected to be about the same as under the existing flushing tunnels subalternative. The distribution of all fecal coliform data would be about the same as that shown in Figure 66, and the distribution of

Figure 78

ESTIMATED AMMONIA NITROGEN LEVELS UNDER THE MENOMONEE RIVER INSTREAM AERATION ALTERNATIVE



Source: HydroQual, Inc.

geometric means of groups of five consecutive samples would be about the same as shown in Figure 67.

Under the Menomonee River instream aeration alternative, the fecal coliform levels in the Menomonee River estuary would exceed the standards supporting limited recreational use. The Milwaukee and Kinnickinnic River estuaries would be expected to meet the fecal coliform standards supporting limited recreational use, and the outer harbor would be expected to achieve the standards supporting full recreational use.

Ammonia Nitrogen: Ammonia nitrogen concentrations under the Menomonee River instream aeration alternative would be about the same as under the existing flushing tunnels subalternative, except in the Menomonee River estuary. In the Menomonee River estuary, the concentrations of ammonia nitrogen under the instream aeration alternative would be lower in the upstream reaches and higher in the downstream reaches. Simulated ammonia nitrogen concentrations under low-flow, steady-state conditions are shown in Figure 78.

The un-ionized ammonia nitrogen concentrations expected under the Menomonee River instream aeration alternative and a comparison to acute and chronic toxicity standards are set forth in Table 37. The un-ionized ammonia nitrogen concentrations and acute and chronic toxicity standards were calculated in accordance with the procedures described for the committed action alternative.

Under low-flow, steady-state conditions, the un-ionized ammonia nitrogen concentration would range from 0.009 to 0.022 mg/l at the upstream river stations, from 0.001 to 0.011 mg/l at the inner harbor stations, and from 0.002 to 0.009 mg/l at the outer harbor stations. The chronic and acute toxicity standards for un-ionized ammonia nitrogen would not be violated at any station. Although Table 37 indicates that standard violations would probably not occur within the outer harbor, occasional violations of the chronic toxicity standards could occur within portions of the outer harbor during periods of higher pH. However, these occasional violations would be less severe than under the committed action alternative.

Lead: The lead concentrations in the water column of the inner harbor may be expected to be about the same as under the existing flushing tunnels subalternative. The estimated distribution of lead concentrations in the surface and bottom water layers would be the same as set forth in Figure 69. The estimated total lead concentrations in the inner harbor may be expected to meet both the acute and chronic toxicity standards for acid-soluble lead. The lead concentration in the bottom sediments would be about the same as under the committed action alternative, as set forth in Table 28. The bottom sediments would be classified as heavily polluted based on their lead content.

Table 37

COMPARISON OF ESTIMATED UN-IONIZED AMMONIA NITROGEN CONCENTRATIONS TO THE RECOMMENDED ACUTE AND CHRONIC TOXICITY STANDARDS UNDER THE MENOMONEE RIVER INSTREAM AERATION ALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Total Ammonia Nitrogen[b] (mg/l)	pH[c] (standard units)	Temperature[c] (°F)	Un-ionized Ammonia Nitrogen[d] (mg/l)	Un-ionized Ammonia Nitrogen Toxicity Standards		Violation of Un-ionized Ammonia Nitrogen Toxicity Standards	
							Acute[e]	Chronic[e]	Acute	Chronic
Upstream										
Milwaukee River	North Avenue Dam (RIV-5)	DI	0.05	8.5	81	0.009	0.117	0.025	- -	- -
Menomonee River	S. 37th Street (RIV-10)	DI	0.15	8.5	75	0.022	0.116	0.025	- -	- -
Kinnickinnic River	S. 9th Place (RIV-13)	DI	0.05	8.9	84	0.019	0.121	0.025	- -	- -
Inner Harbor										
Milwaukee River	Walnut Street (RIV-6)	S B	0.05 0.05	8.5 8.4	81 81	0.009 0.008	0.116 0.115	0.025 0.025	- - - -	- - - -
	Wells Street (RIV-7)	S B	0.05 0.05	8.0 8.1	79 75	0.003 0.004	0.102 0.108	0.025 0.025	- - - -	- - - -
	Water Street (RIV-8)	S B	0.05 0.10	7.9 7.9	79 66	0.003 0.003	0.098 0.099	0.025 0.025	- - - -	- - - -
	C&NW Railway (RIV-15)	S B	0.10 0.15	7.5 8.1	77 64	0.002 0.007	0.073 0.105	0.025 0.025	- - - -	- - - -
Menomonee River	Muskego Avenue (RIV-11)	S B	0.30 0.30	7.7 7.5	81 72	0.011 0.004	0.088 0.077	0.025 0.025	- - - -	- - - -
	S. 2nd Street (RIV-17)	S B	0.25 0.25	7.7 7.7	79 72	0.009 0.007	0.088 0.090	0.025 0.025	- - - -	- - - -
Kinnickinnic River	S. 1st Street (RIV-14)	S B	0.05 0.05	7.6 7.6	72 72	0.001 0.001	0.081 0.081	0.025 0.025	- - - -	- - - -
	Greenfield Avenue Extended (RIV-18)	S B	0.05 0.10	7.6 7.6	73 64	0.001 0.002	0.081 0.081	0.025 0.025	- - - -	- - - -
	Jones Island (RIV-19)	S B	0.10 0.15	7.6 7.9	73 63	0.002 0.004	0.083 0.097	0.025 0.025	- - - -	- - - -
Outer Harbor	South OH (OH-11)	S B	0.45 0.20	7.6 7.6	72 57	0.009 0.002	0.079 0.083	0.025 0.025	- - - -	- - - -
	JI STP Plume (OH-2)	S B	0.70 0.20	7.4 7.9	70 61	0.008 0.005	0.065 0.097	0.025 0.025	- - - -	- - - -

NOTE: The existing Wisconsin Department of Natural Resources standard for un-ionized ammonia nitrogen specifies a maximum level of 0.04 mg/l for the full warmwater fishery and aquatic life water use objective. The Department has issued no standard for the limited fishery and aquatic life objective. The standard for the warmwater fishery and aquatic life objective is applied by the Department as a maximum not to be exceeded at any flow equal to or greater than the 7-day, 10-year minimum flow.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

[b] *As estimated in Figure 78.*

[c] *Arithmetic mean pH and temperature levels measured during Survey Period 1, July 25 through August 8, 1983, under the baseline sampling program.*

[d] *The un-ionized ammonia nitrogen concentrations were calculated using the estimated total ammonia nitrogen, pH, and temperature levels.*

[e] *The acute and chronic toxicity standards, which vary in response to the pH and temperature of the water, were calculated in accordance with the procedures set forth in Chapter II of this volume.*

Source: SEWRPC.

Other Toxic Metals: The concentrations of cadmium, copper, and zinc in the bottom sediments of the inner harbor—and the pollution ratings of those sediments—under the Menomonee River instream aeration alternative are expected to be the same as those set forth in Table 28 for the committed action alternative. Based on pollutant loading estimates set forth in Chapter VI of Volume One, this alternative would result in a reduction of approximately 29 percent in cadmium, 8 percent in copper, and 85 percent in zinc loadings to the inner harbor.

Within the water column of the Milwaukee Harbor estuary, total metal concentrations would continue to exceed the chronic toxicity standards for acid-soluble cadmium and copper. The apparent standard violations in the Menomonee River estuary would be about the same as under the existing flushing tunnels subalternative. The chronic and acute toxicity standards for acid-soluble zinc would continue to be achieved under this alternative.

Abatement of Nonpoint Sources of Pollution Alternative

This alternative would result in substantial reductions in pollutant loadings from nonpoint sources located upstream of the estuary. Based on the estimated pollutant removal effectiveness of nonpoint source abatement measures, and the expected level of implementation, the Milwaukee River Priority Watersheds Program can be expected to result in a reduction of 40 to 45 percent in fecal coliform organisms; of 15 percent in carbonaceous biochemical oxygen demand, phosphorus, and suspended solids; and of 10 percent in lead, and a relatively low reduction in nitrogen loadings, from nonpoint sources to the estuary. Under existing conditions, the most significant sources of dissolved oxygen deficits in the Milwaukee Harbor estuary are sediment related, as shown in Chapter VII of Volume One. Carbonaceous biochemical oxygen demand and net algal photosynthesis, however, are also important contributing sources to these deficits—each typically accounting for 1 to 2 mg/l of deficit during critical low-flow, warm-weather periods. Both of these components of the dissolved oxygen deficit could be reduced by implementing upstream nonpoint source water pollution control. However, the water quality monitoring data, including the plots of chlorophyll-a, nitrogen, and phosphorus concentrations presented in Chapter VI of Volume One, indicate that the production of algae in the Milwaukee River upstream of the estuary may be nitrogen-limited, rather than phosphorus-limited. Accordingly, reductions in nitrogen levels may be expected to result directly in algal growth reductions, while reductions in phosphorus levels may not significantly change the production of algae.

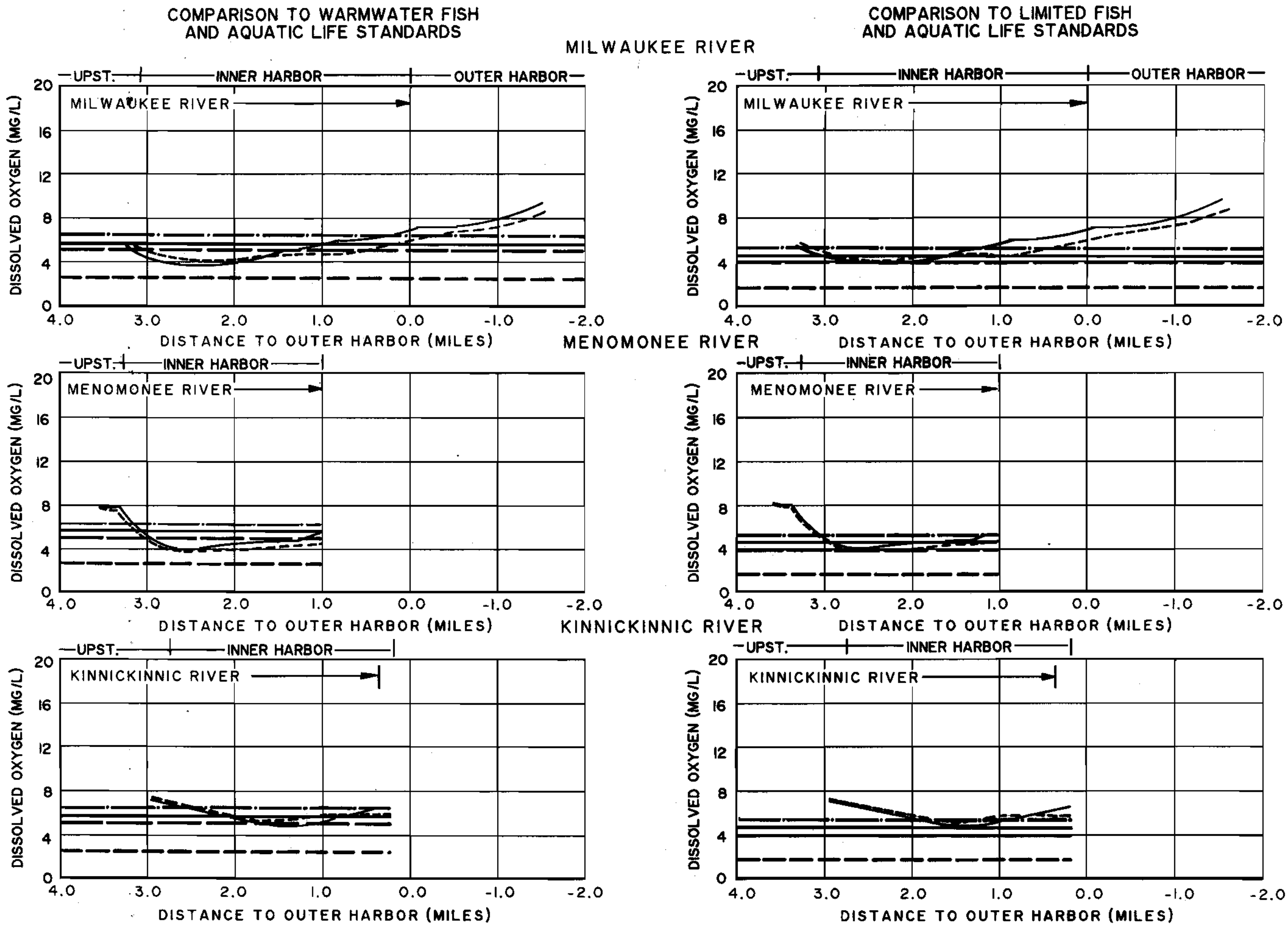
The effectiveness of nonpoint source pollution abatement measures has historically been expressed in terms of phosphorus and sediment removal efficiencies. The data on the removal efficiencies of such measures on nitrogen, and to a lesser degree carbonaceous biochemical oxygen demand, are limited. Conventional nonpoint source control measures may be expected to have minimal effects on nitrogen levels because most of the nitrogen is transported in a dissolved state. Thus, the actual amount of reduction in nitrogen loadings that would result from the provision of nonpoint source pollution abatement measures under this alternative is uncertain, but is likely less than 5 percent. If algae growth is indeed nitrogen limited, the reduction in the dissolved oxygen deficit resulting from algal respiration may be expected to be minimal for the Milwaukee River portion of the estuary.

This alternative consists of the implementation of additional control measures to achieve a maximum level of nonpoint source control. It is estimated that this maximum level of control would result in approximately double the aforecited reductions in pollutant loadings. This high level of nonpoint source control was evaluated in an attempt to identify the highest potential effectiveness of such nonpoint source control measures. Subsequent evaluation and incorporation as a component of the recommended plan would then be based upon refinements of this alternative, perhaps providing for a lower level of control. The water quality conditions expected within the Milwaukee Harbor estuary if the maximum level of nonpoint source control is achieved are presented below.

Dissolved Oxygen: A low-flow, steady-state simulation analysis was conducted to determine the effect that a reduction in pollutant loadings from nonpoint sources would have on the critical dissolved oxygen conditions expected during low-flow and high-temperature periods. The steady-state analysis estimated dissolved oxygen levels under 7-day, 10-year recurrence interval low-flow conditions at the high temperature levels measured during Survey Period 1, July 25 to August 8, 1983. Spatial plots of low-flow, steady-

Figure 79

LOW-FLOW, STEADY-STATE ANALYSIS OF DISSOLVED OXYGEN UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE



LEGEND

MODEL SIMULATED DATA

- - - SURFACE LAYER

—— BOTTOM LAYER

STANDARDS (MG/L)	WARMWATER	LIMITED
—— 30 DAY MEAN MINIMUM STANDARD	5.5	4.5
—·— 7 DAY MEAN MINIMUM STANDARD (3/15-7/31)	6.0	5.0
— — I DAY MEAN MINIMUM STANDARD (3/15-7/31)	5.0	4.0
- - - ABSOLUTE MINIMUM STANDARD	2.5	1.5

NOTE: THE EXISTING WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS SPECIFY MINIMUM DISSOLVED OXYGEN LEVELS OF 5.0 MG/L AND 3.0 MG/L FOR THE FULL WARMWATER FISH AND AQUATIC LIFE AND THE LIMITED FISH AND AQUATIC LIFE WATER USE OBJECTIVES,RESPECTIVELY. THESE STANDARDS ARE APPLIED BY THE DEPARTMENT AS A MINIMUM NOT TO BE VIOLATED AT ANY FLOW EQUAL TO OR GREATER THAN THE 7-DAY,10-YEAR MINIMUM FLOW.

Source: HydroQual, Inc.

state dissolved oxygen levels under the abatement of nonpoint sources of pollution alternative are shown in Figure 79. The figure compares the simulated dissolved oxygen levels to standards established to support warmwater fish and aquatic life and to support limited fish and aquatic life.

In order to estimate the maximum benefits that abatement of nonpoint sources would have on dissolved oxygen levels, the steady-state analysis was conducted assuming that upstream loadings of biochemical oxygen demand and chlorophyll-a would be reduced by 50 percent. As already noted, this level of reduction appeared to be unachievable but was nevertheless evaluated to determine the maximum potential water quality benefits. The figure indicates that dissolved oxygen levels would be up to 3 mg/l higher under this alternative than under the committed action alternative in portions of the Milwaukee River estuary, and up to 1 mg/l higher in portions of the Menomonee River estuary. The dissolved oxygen levels in the Kinnickinnic River estuary and the outer harbor would be about the same as under the committed action alternative.

The 7-day mean standards supporting both warmwater and limited fish and aquatic life and the 30-day mean and 1-day mean standards supporting warmwater fish and aquatic life would be violated in portions of all three estuaries. The dissolved oxygen levels in the Milwaukee and Menomonee River estuaries would be less than the 30-day mean standard for a limited fishery. The 1-day mean standard for a limited fishery would be met—although just barely—in all three estuaries. The absolute minimum standards would be met.

The significance of the individual sinks of oxygen under the abatement of nonpoint sources of pollution alternative can be determined by analyzing the components of the dissolved oxygen deficit. The components of the deficit that were studied in the steady-state analysis included the sediment flux of methane and ammonia, sediment oxygen demand, carbonaceous biochemical oxygen demand from upstream sources and from the Jones Island sewage treatment plant, and net photosynthesis/respiration. The computed components of the dissolved oxygen deficit under low-flow, steady-state conditions in the surface and bottom water layers are shown in Figure 80.

The total dissolved oxygen deficit in the inner harbor is lower under the abatement of nonpoint sources of pollution alternative than under the committed action alternative as a result of the lower dissolved oxygen deficit associated with carbonaeous biochemical oxygen demand and, in the case of the Milwaukee River estuary, net photosynthesis/respiration. The dissolved oxygen deficit in the outer harbor would be about the same as under the committed action alternative.

Dissolved oxygen conditions under a series of flow and temperature conditions were evaluated to assess the improvement in dissolved oxygen levels under this alternative. Estimated dissolved oxygen levels were then compared to the standards for a warmwater fishery and for a limited fishery. The expected violations of the dissolved oxygen standards are set forth in Table 38. For the surface and bottom water layers of several upstream, inner harbor, and outer harbor sampling stations, the anticipated violation of the dissolved oxygen standards is classified as slight, moderate, or severe.

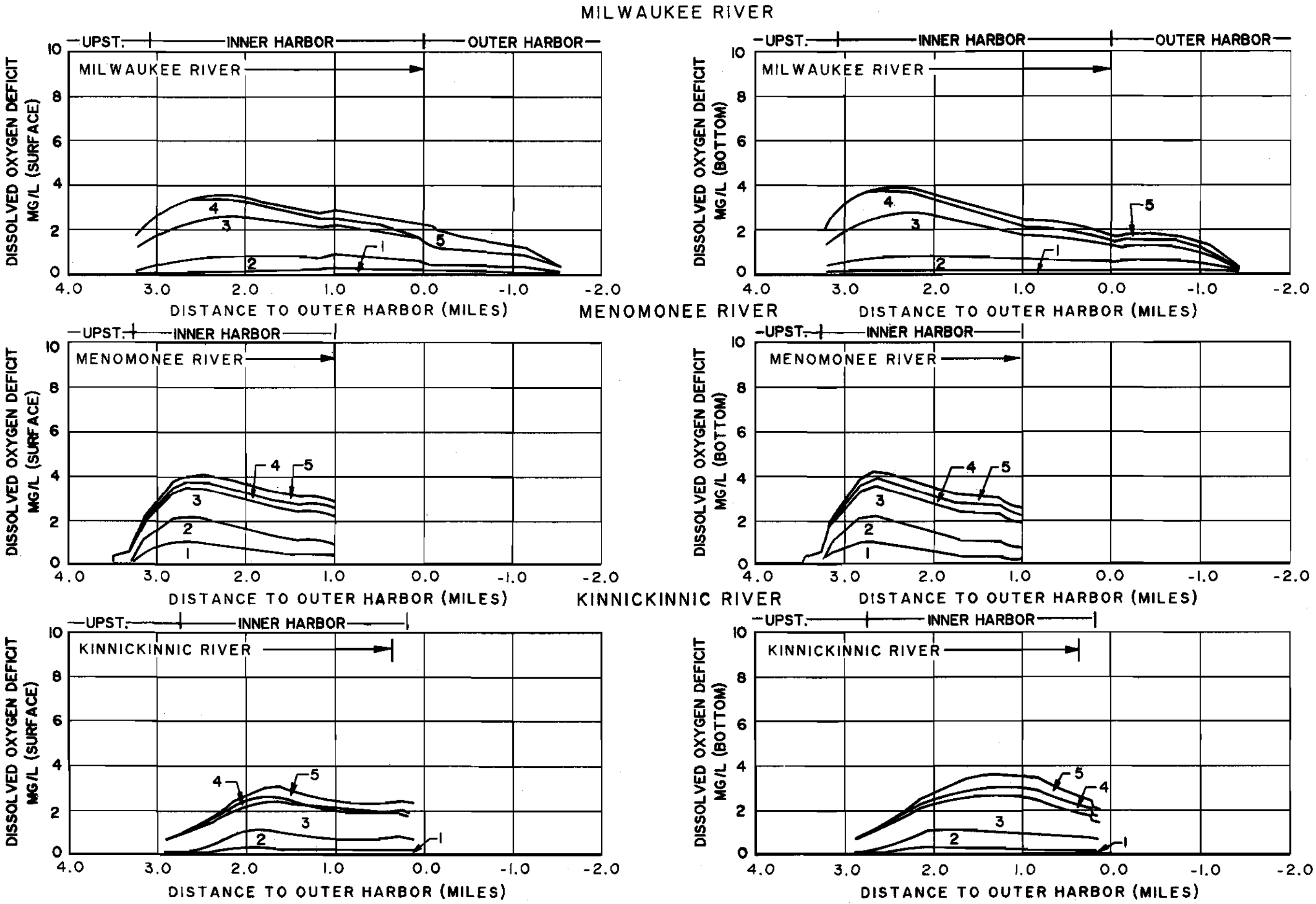
The violation of the dissolved oxygen standards in the inner harbor would be less severe than under the committed action alternative. Within the Milwaukee River estuary, all violations of the 30-day mean, 7-day mean, and 1-day mean standards would be expected to be slight. Those standards of 4 mg/l or less would be expected to be met consistently in the Milwaukee River estuary. The Menomonee and Kinnickinnic River estuaries would experience moderate violations of many of the dissolved oxygen standards for both warmwater and limited fisheries. The dissolved oxygen levels in the outer harbor would likely be about the same as under the committed action alternative.

Diurnal fluctuations in dissolved oxygen levels within the Milwaukee River estuary would be less than those expected under the committed action alternative, and violations of the absolute minimum dissolved oxygen standards would probably not occur at night. Diurnal fluctuations in dissolved oxygen concentrations would continue to be very minor in the Menomonee and Kinnickinnic River estuaries, and in the outer harbor. The bottom water layers would not exhibit diurnal fluctuations in any of the water bodies.

Fecal Coliform: A substantial reduction in fecal coliform levels—both within and upstream of the estuary—may be expected to result from the abatement of nonpoint sources of pollution, combined sewer overflows, and separate sanitary sewer flow relief devices. For the tributary rivers upstream of the inner harbor, the frequency distribution plots shown in Figures 81, 82, and 83 compare the existing fecal coliform data to those levels which may be expected to occur under the abatement of nonpoint sources of pollution alternative. The solid line plots—A and C—show the distribution of all data, and can be compared to the 2,000 and 10,000 MPN/100 ml standards. The dashed line plots—A^1 and C^1—show the distribution of the geometric means of groups of five consecutive samples, and can be compared to the geometric mean standard of 1,000 MPN/100 ml. The existing data plots—A and A^1—were described under the committed action alternative discussion.

Figure 80

COMPONENTS OF THE DISSOLVED OXYGEN DEFICIT UNDER LOW-FLOW, STEADY-STATE CONDITIONS: ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE



LEGEND

- 1 SEDIMENT FLUX OF METHANE AND AMMONIA
- 2 SEDIMENT OXYGEN DEMAND
- 3 UPSTREAM CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND
- 4 NET PHOTOSYNTHESIS/RESPIRATION
- 5 CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND FROM THE JONES ISLAND SEWAGE TREATMENT PLANT

Source: HydroQual, Inc.

Fecal coliform levels which may be expected upstream of the inner harbor under the abatement of nonpoint sources of pollution alternative are shown as plots C and C^1. It was reported in SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975, that nearly 60 percent of the nonpoint source fecal coliform loadings to the Milwaukee and Menomonee Rivers was contributed by livestock operations and malfunctioning septic tank systems. These sources can be effectively controlled by nonpoint source abatement programs. The reported effectiveness of nonpoint source control measures in reducing fecal coliform levels is presented in Table 39. A high level of reduction in nonpoint source fecal coliform loadings would be more difficult to achieve for the Kinnickinnic River, where urban land runoff is the primary contributor of nonpoint source fecal coliform loadings.

Combined with the 50 percent reduction in fecal coliform levels which would be expected to result from the abatement of combined sewer overflows and separate sanitary sewer flow relief devices, it

Table 38

VIOLATION OF DISSOLVED OXYGEN STANDARDS UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Warmwater Fish and Aquatic Life: 30-Day Mean All Year 5.5 mg/l	7-Day Mean 3/15-7/31 6.0 mg/l	1-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 8/1-3/14 4.0 mg/l	Absolute Minimum All Year 2.5 mg/l	Limited Fish and Aquatic Life: 30-Day Mean All Year 4.5 mg/l	7-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 3/15-7/31 4.0 mg/l	1-Day Mean 8/1-3/14 3.0 mg/l	Absolute Minimum All Year 1.5 mg/l
Upstream												
Milwaukee River	North Avenue Dam (RIV-5)	DI	None	None	None	None	None	None	None	None	None	None
Menomonee River	S. 37th Street (RIV-10)	DI	None	None	None	None	None	None	None	None	None	None
Kinnickinnic River	S. 9th Place (RIV-13)	DI	None	Slight	Slight	None	None	None	Slight	None	None	None
Inner Harbor												
Milwaukee River	Walnut Street (RIV-6)	S	None	None	None	None	None	None	None	None	None	None
		B	None	Slight	Slight	None	None	None	Slight	None	None	None
	Wells Street (RIV-7)	S	Slight	Slight	Slight	None	None	Slight	Slight	None	None	None
		B	Slight	Slight	Slight	None	None	None	Slight	None	None	None
	Water Street (RIV-8)	S	Slight	Slight	Slight	None	None	Slight	Slight	None	None	None
		B	Slight	Slight	Slight	None	None	Slight	Slight	None	None	None
	C&NW Railway (RIV-15)	S	Slight	Slight	None	None	None	None	None	None	None	None
		B	Slight	Slight	None	None	None	Slight	None	None	None	None
Menomonee River	Muskego Avenue (RIV-11)	S	Moderate	Moderate	Moderate	Moderate	None	Moderate	Moderate	Moderate	Slight	None
		B	Moderate	Moderate	Moderate	Slight	None	Moderate	Moderate	Moderate	None	None
	S. 2nd Street (RIV-17)	S	Moderate	Moderate	Moderate	Moderate	None	Moderate	Moderate	Moderate	None	None
		B	Moderate	Moderate	None	Moderate	None	Slight	None	None	None	None
Kinnickinnic River	S. 1st Street (RIV-14)	S	Moderate	Moderate	Moderate	Moderate	None	Moderate	Moderate	Moderate	Moderate	None
		B	Moderate	Moderate	Moderate	Moderate	None	Moderate	Moderate	Moderate	Moderate	None
	Greenfield Avenue Extended (RIV-18)	S	None	Moderate	Moderate	None	None	None	Moderate	None	None	None
		B	Slight	Moderate	Moderate	Slight	None	Slight	Moderate	Moderate	None	None
	Jones Island (RIV-19)	S	None	Moderate	Moderate	None	None	None	Moderate	None	None	None
		B	Slight	Moderate	None	None	None	Slight	None	None	None	None
Outer Harbor	Hoan Bridge (OH-1)	S	Slight	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	None	None	Slight	None	None	None	None
	Central OH (OH-3)	S	Slight	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	None	None	Slight	None	None	None	None
	South OH (OH-11)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	Slight	None	Slight	None	Slight	None	None	None	None
	JI STP Plume (OH-2)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	Slight	None	Slight	None	None	Slight	None

NOTE: Standard violations that occur up to 5 percent of the time are classified as slight; violations that occur 6 to 10 percent of the time are classified as moderate; and violations that occur more than 10 percent of the time are classified as severe. Underlined ratings indicate a significant improvement in dissolved oxygen levels over the levels expected under the committed action alternative.

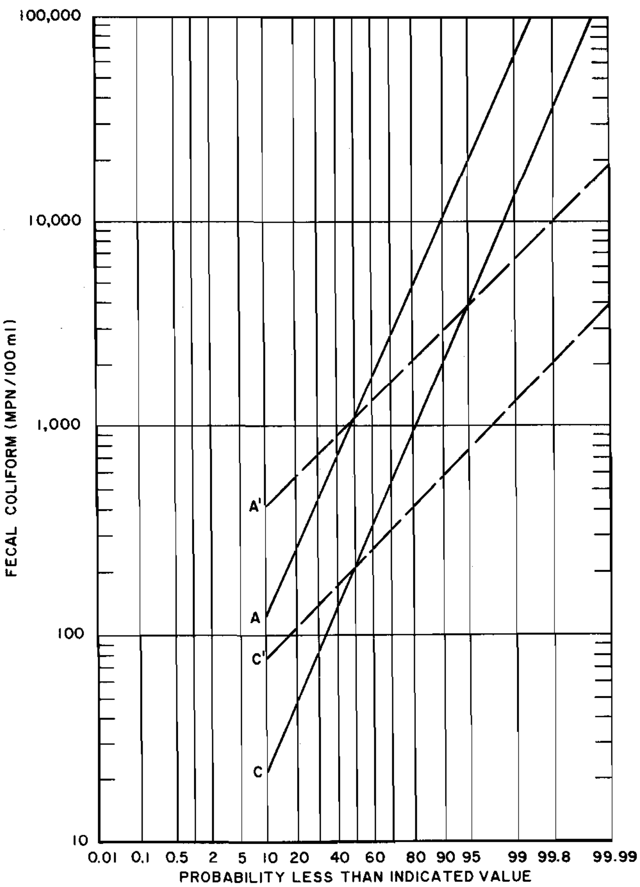
[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

Source: HydroQual, Inc., and SEWRPC.

was concluded that the abatement of nonpoint sources of pollution would result in fecal coliform levels that are 75 to 95 percent lower than the existing levels observed in the tributary rivers upstream of the inner harbor. To determine the distribution of fecal coliform levels under this alternative, it was assumed that the variability of the data—as expressed by the standard deviation of the natural logs of the data—would be the same as the existing variability, and that the proposed fecal coliform standards supporting limited recreational use would be met.

Figure 81

FREQUENCY-DISTRIBUTION OF FECAL COLIFORM LEVELS IN THE MILWAUKEE RIVER AT THE NORTH AVENUE DAM UNDER EXISTING CONDITIONS AND UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE



LEGEND

DISTRIBUTION OF ALL DATA

A - EXISTING CONDITIONS

C - FUTURE CONDITIONS UNDER THE NONPOINT SOURCE ABATEMENT ALTERNATIVE

DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF 5 SAMPLES

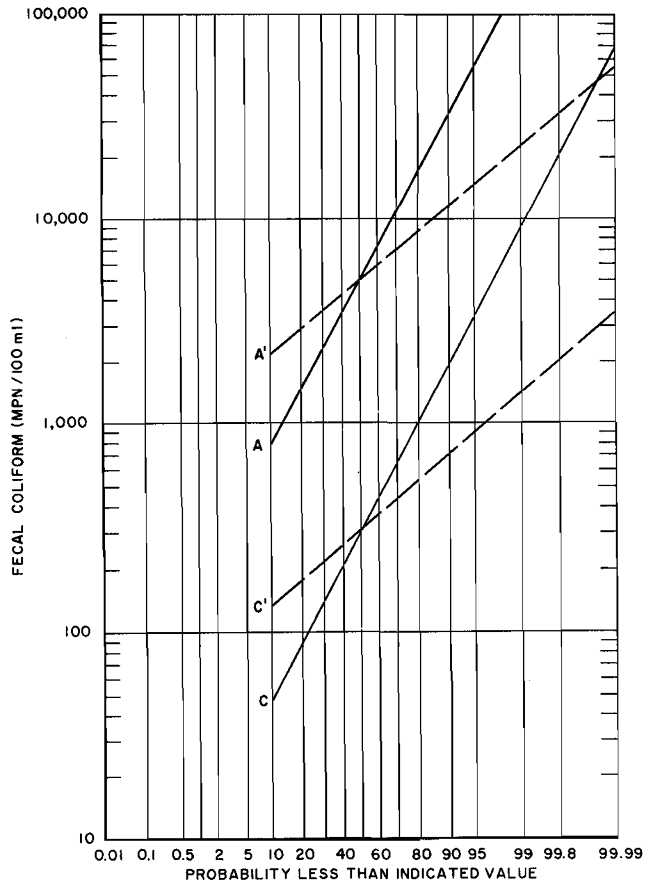
A' - EXISTING CONDITIONS

C' - FUTURE CONDITIONS UNDER THE NONPOINT SOURCE ABATEMENT ALTERNATIVE

Source: SEWRPC.

Figure 82

FREQUENCY-DISTRIBUTION OF FECAL COLIFORM LEVELS IN THE MENOMONEE RIVER AT S. 37TH STREET UNDER EXISTING CONDITIONS AND UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE



LEGEND

DISTRIBUTION OF ALL DATA

A - EXISTING CONDITIONS

C - FUTURE CONDITIONS UNDER THE NONPOINT SOURCE ABATEMENT ALTERNATIVE

DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF 5 SAMPLES

A' - EXISTING CONDITIONS

C' - FUTURE CONDITIONS UNDER THE NONPOINT SOURCE ABATEMENT ALTERNATIVE

Source: SEWRPC.

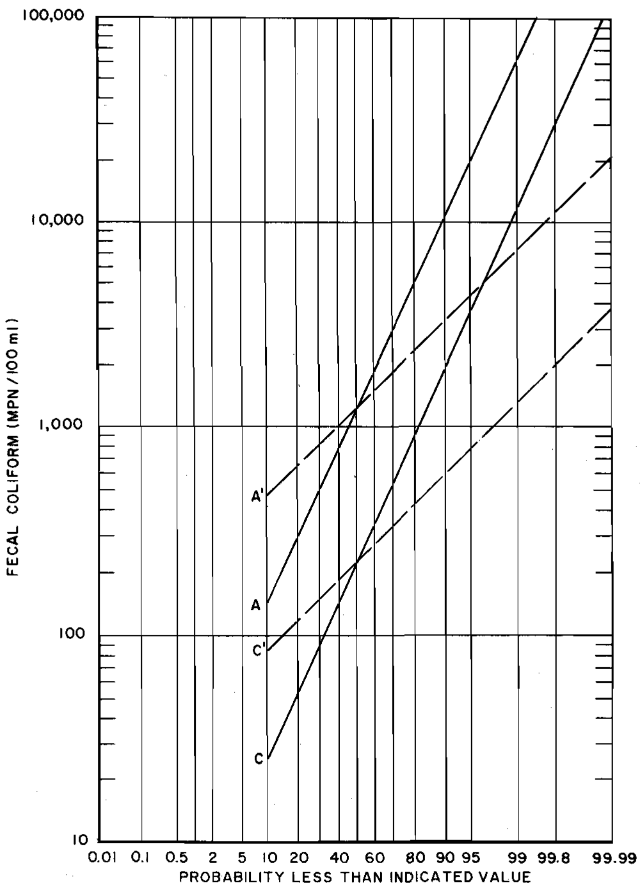
The percent reductions in fecal coliform levels expected to be achieved upstream of the inner harbor by the abatement of nonpoint sources of pollution alternative are set forth in Table 40. This alternative would be expected to result in a reduction in fecal coliform levels of about 80 percent in the Milwaukee River, 94 percent in the Menomonee River, and 82 percent in the Kinnickinnic River.

With these reductions in fecal coliform levels, the tributary rivers upstream of the inner harbor would be suitable for limited recreational uses.

The statistical water quality model described in Chapter VII of Volume One of this report was used to determine the fecal coliform levels that could be anticipated under the abatement of nonpoint

Figure 83

FREQUENCY-DISTRIBUTION OF FECAL COLIFORM LEVELS IN THE KINNICKINNIC RIVER AT S. 1ST STREET UNDER EXISTING CONDITIONS AND UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE



LEGEND

DISTRIBUTION OF ALL DATA

A - EXISTING CONDITIONS

C - FUTURE CONDITIONS UNDER THE NONPOINT SOURCE ABATEMENT ALTERNATIVE

DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF 5 SAMPLES

A' - EXISTING CONDITIONS

C' - FUTURE CONDITIONS UNDER THE NONPOINT SOURCE ABATEMENT ALTERNATIVE

Source: SEWRPC.

sources of pollution alternative within the estuary. The estimated distribution of fecal coliform levels is presented in Figure 84. The distribution plots show that all of the fecal coliform standards supporting limited recreational use in the inner harbor, and full recreational use in the outer harbor, would be met the required percentage of the time. Specifically, the limited recreational use standard of 10,000 MPN/100 ml would be violated less than 2 percent of the time, and the standard of 2,000 MPN/100 ml would be violated less than 10 percent of the time throughout the inner harbor. The full recreational use standard of 400 MPN/100 ml would be violated less than 10 percent of the time within the outer harbor.

Figure 85 shows the distribution of the geometric means of groups of five fecal coliform samples. This figure illustrates the achievement of the geometric mean standards. The geometric mean standard of 1,000 MPN/100 ml which would support limited recreational use in the inner harbor would be violated less than the recommended maximum of 5 percent of the time. The geometric mean standard of 200 MPN/100 ml which would support full recreational use would not be expected to be violated at all within the outer harbor.

Ammonia Nitrogen: The abatement of nonpoint sources of pollution would not substantially reduce the levels of ammonia nitrogen within the estuary. Thus, under the abatement of nonpoint sources of pollution alternative, simulated low-flow, steady-state ammonia nitrogen concentrations would be about the same as under the committed action alternative, as presented in Figure 57. The un-ionized ammonia nitrogen concentrations expected under the abatement of nonpoint sources of pollution alternative, and the results of a comparison to acute and chronic toxicity standards, would also be about the same as under the committed action alternative, as set forth in Table 27.

Lead: It was estimated in Chapter VI of Volume One of this report that nonpoint sources of pollution that discharge upstream of the estuary contribute 59,000 pounds of lead to the inner harbor annually, or about 45 percent of the total loading. Under this alternative, the maximum level of control of nonpoint sources of pollution, along with the abatement of combined sewer overflows and separate sanitary sewer flow relief devices, would be expected to reduce lead loadings to the inner harbor from upstream sources by about 50 percent, and to reduce total lead loadings to the inner harbor—including direct discharges—by about 85 percent. The statistical water quality model described in Chapter VII of Volume One of this report was used to evaluate the lead levels that could be anticipated within the estuary under the abatement of nonpoint sources of pollution alternative.

Table 39

LITERATURE SUMMARY OF THE EFFECTIVENESS OF NONPOINT SOURCE POLLUTION ABATEMENT MEASURES IN REDUCING FECAL COLIFORM LEVELS IN SURFACE WATERS

Abatement Measures	Effect of Measure of Fecal Coliform Levels	Reference
Street Sweeping	Maximum level of fecal coliform reduction is about 15 percent in a residential area. For individual storms, up to a 35 percent level of reduction could be achieved	Pitt, Robert, Urban Bacteria Sources and Control By Street Cleaning in the Lower Rideau River Watershed, 1983
Catch Basin Cleaning	Since about 10 percent of the total bacteria in urban runoff is contained within catch basins, catch basin cleaning would result in less than a 10 percent reduction in urban bacterial loadings	Pitt, 1983
Stormwater Storage—Wet Basins	Maximum reductions of 90 percent or more are possible	Pitt, 1983
	Wet basin designed for 75 to 90 percent solids removal for a one-year, 24-hour storm may remove 60 to 70 percent of the fecal coliform organisms	Pitt, Robert, and Roger Bannerman, Management Alternatives for Urban Stormwater, Nonpoint Source Pollution Abatement Symposium, Milwaukee, Wisconsin, April 23-25, 1985
	A 3.3-foot-deep wet basin in Long Island achieved an average reduction in fecal coliform levels of 91 percent over eight storm events	U. S. Environmental Protection Agency, Results of the Nationwide Urban Runoff Program, Vol. I, Final Report, 1983
Dog Waste Control	May result in up to a 35 percent reduction in fecal coliform loadings	Pitt, 1983
Infiltration and Swale Systems	Systems may result in a 16 to 30 percent reduction in fecal coliform levels, which would approximate the corresponding reduction in flow volume and rate	Pitt and Bannerman, 1985
Stormwater Treatment	May result in more than a 75 percent reduction in fecal coliform levels	Pitt, 1983
	Treatment with disinfection can reduce fecal coliform levels to 10 MFFCC/100 ml	Davis, E. H., Maximum Utilization of Water Resources in a Planned Community. Bacterial Characteristics of Stormwaters in Developing Rural Areas, 1979
	A 99.99 percent reduction can be achieved by disinfection	Pitt, 1983
Septic Tank System Management	Elimination of malfunctioning septic tank systems may reduce fecal coliform concentrations during low streamflows by 17 percent, and during high streamflows by 87 percent. In subsurface tile drainage flow, elimination of malfunctioning septic tank systems may reduce fecal coliform concentrations during low flows by more than 99 percent, and during high flows by 83 percent	Dudley, D. R. and J. R. Karr, "Concentration and Sources of Fecal and Organic Pollution in an Agricultural Watershed," Water Resources Bulletin, Vol. 15, No. 4, August 1979, pp. 911-923
Livestock Waste Control	Livestock waste management runoff controls are not effective in reducing fecal coliform levels below about 1,000 organisms/100 ml	Crane, S. R., J. A. Moore, M. E. Grismer, and J. R. Miner, "Bacterial Pollution from Agricultural Sources: A Review," Trans. ASAE, 1983, pp. 858-872
	Low density pasture systems present a minimal contribution of bacteria to surface runoff	
	As much as 2 to 23 percent of the fecal coliforms deposited by livestock may be transported by runoff, although transport rates as low as 0.007 percent may occur under optimal conditions	
	Buffer strips may remove 96 to 99 percent of overflowing fecal coliform organisms during the summer and 65 percent during the winter. Other studies indicate no removal by buffer strips. Vegetative buffer strips are effective only in removing bacteria from overland flow at very high concentrations of bacteria	
	Subsurface injection or plow under injection of wastes should virtually eliminate bacterial losses in surface runoff, although a potential for groundwater contamination would exist	

Source: SEWRPC.

Table 40

REDUCTIONS IN FECAL COLIFORM LEVELS EXPECTED IN THE TRIBUTARY RIVERS JUST UPSTREAM OF THE MILWAUKEE HARBOR ESTUARY UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE

Upstream River Station	Existing Fecal Coliform Level[a]	Abatement of Nonpoint Sources of Pollution Alternative: Level of Fecal Coliform[b]	Abatement of Nonpoint Sources of Pollution Alternative: Percent Reduction in Existing Levels
Milwaukee River at North Avenue Dam			
Geometric Mean[c]	1,070	210	80
Level Exceeded 10 Percent of Time[d]. . . .	10,160	2,000	80
Menomonee River at S. 37th Street			
Geometric Mean[c]	5,020	310	94
Level Exceeded 10 Percent of Time[d]. . . .	32,110	2,000	94
Kinnickinnic River at S. 11th Street			
Geometric Mean[c]	1,240	225	82
Level Exceeded 10 Percent of Time[d]. . . .	10,860	2,000	82

NOTE: All fecal coliform levels are in MPN/100 ml.

[a]*Shown as plot A in Figures 81, 82, and 83.*

[b]*Shown as plot C in Figures 81, 82, and 83.*

[c]*The geometric mean is the 50 percentile level shown on the frequency distribution plots in Figures 81, 82, and 83.*

[d]*The fecal coliform level exceeded 10 percent of the time is the 90 percentile level shown on the frequency distribution plots in Figures 81, 82, and 83.*

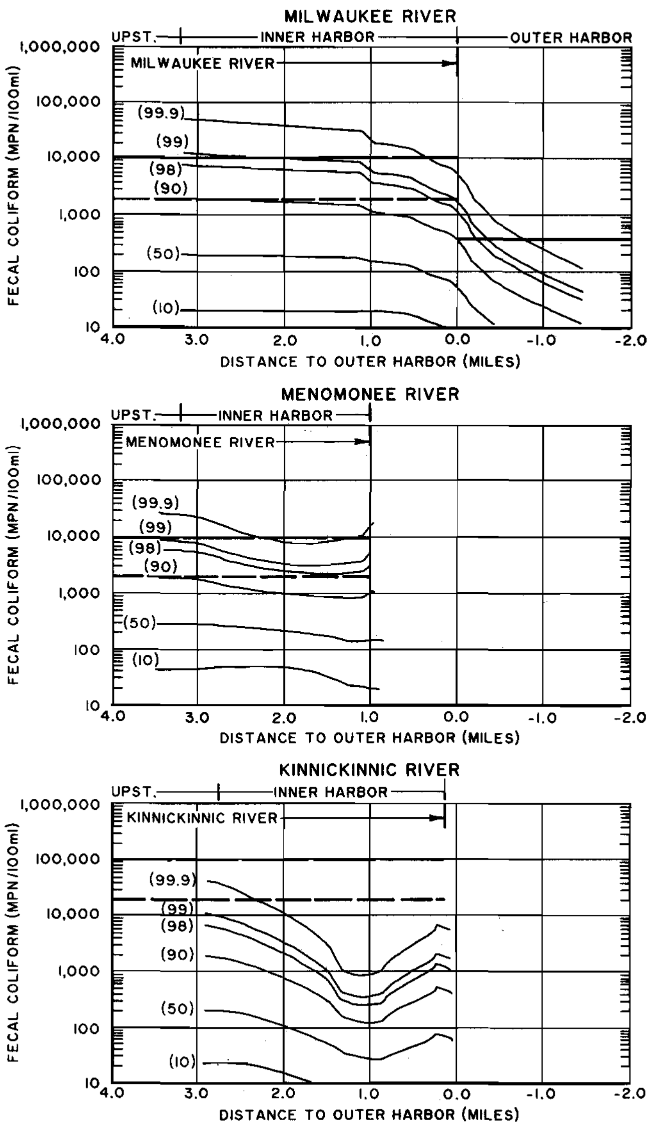
Source: SEWRPC.

The estimated distribution of lead concentrations in the surface and bottom water layers is presented in Figure 86. The median lead levels, plus and minus one standard deviation of the logs of the data, are shown in the figure. The data plots show total lead concentrations. Chronic and acute toxicity standards for acid-soluble lead are also shown in the figure.

The estimated concentrations of lead in both the inner harbor and the outer harbor are substantially lower than under the committed action alternative, but the reductions in concentrations are not as great as the 85 percent reduction in loadings. Since the vast majority of the existing loadings are contributed during storm events, the effect of reduced loadings on the estuary concentrations

Figure 84

ESTIMATED FECAL COLIFORM LEVELS UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE: DISTRIBUTION OF ALL DATA



LEGEND

(99.9) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE: OUTER HARBOR

——— LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 10 PERCENT OF THE TIME (400 MPN/100 ml)

LIMITED RECREATIONAL USE: INNER HARBOR

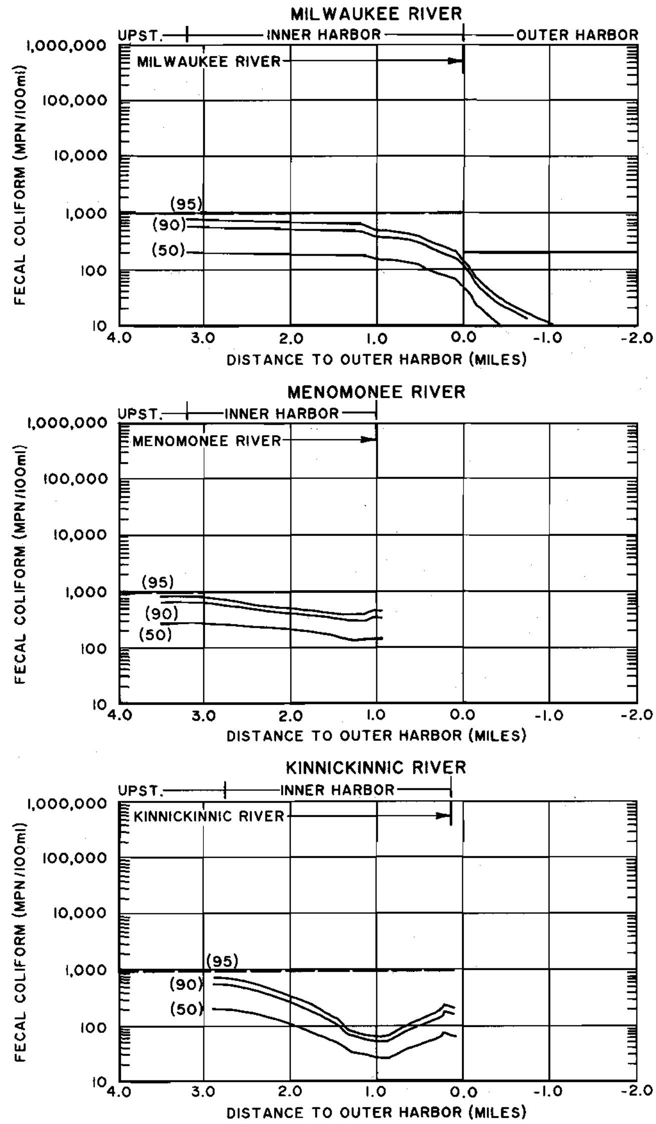
– – – LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THEN 10 PERCENT OF THE TIME (2,000 MPN/100 ml)

— — LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 2 PERCENT OF THE TIME (10,000 MPN/100 ml)

Source: HydroQual, Inc.

Figure 85

ESTIMATED FECAL COLIFORM LEVELS UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE: DISTRIBUTION OF THE GEOMETRIC MEANS OF GROUPS OF FIVE SAMPLES



LEGEND

(90) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE: OUTER HARBOR

——— LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH (200 MPN/100 ml)

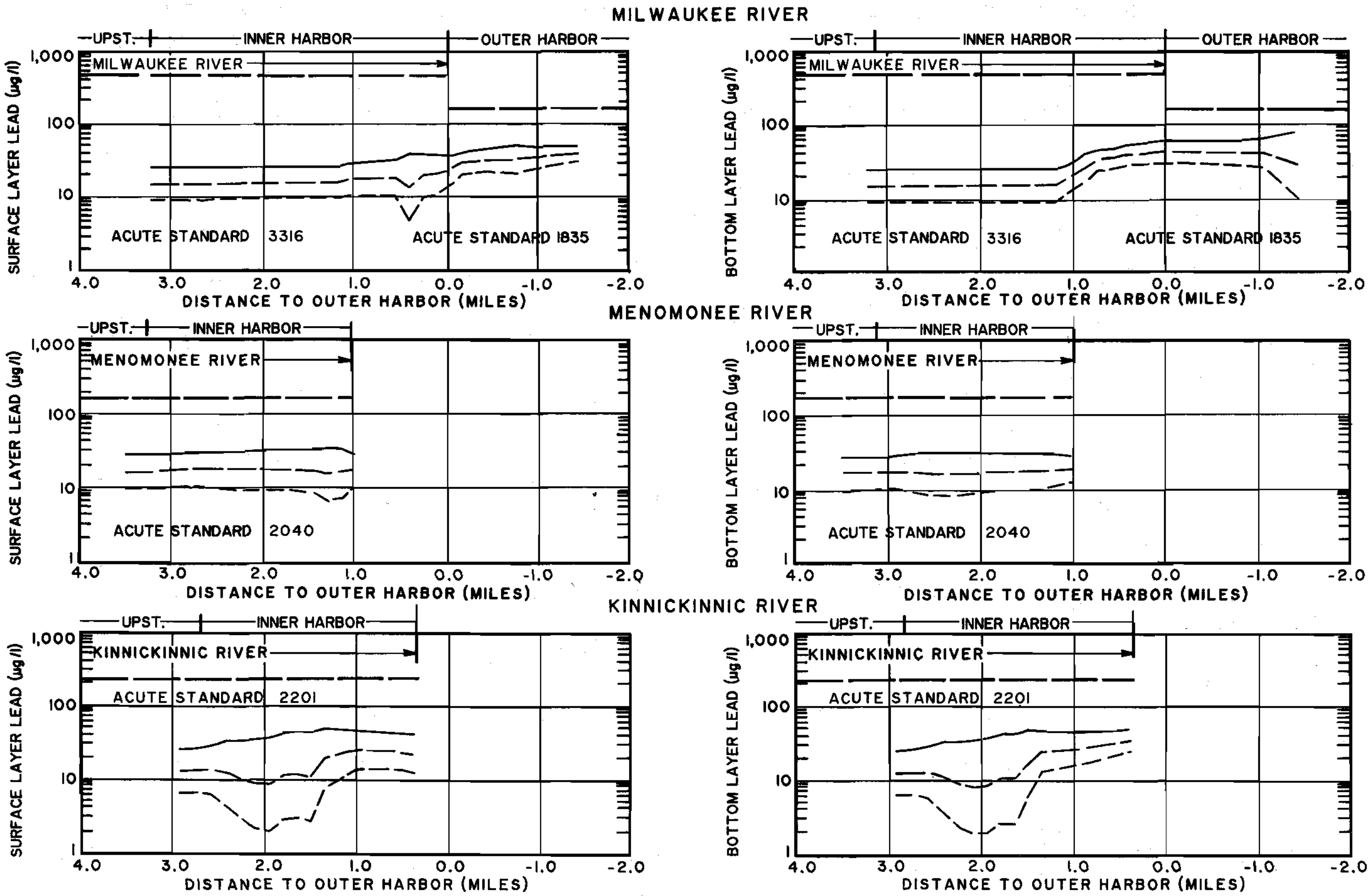
LIMITED RECREATIONAL USE: INNER HARBOR

— — LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH MORE THAN 5 PERCENT OF THE TIME (1,000 MPN/100 ml)

Source: HydroQual, Inc.

Figure 86

ESTIMATED LEAD CONCENTRATIONS UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE



LEGEND

STANDARDS

- ACUTE MAXIMUM STANDARD
- CHRONIC 30 DAY MEAN MAXIMUM STANDARD

LEAD PLOTS

- MEDIAN PLUS ONE STANDARD DEVIATION OF THE LOGS (84TH PERCENTILE)
- MEDIAN (50TH PERCENTILE)
- MEDIAN MINUS ONE STANDARD DEVIATION OF THE LOGS (16TH PERCENTILE)

NOTE: THE ACUTE AND CHRONIC STANDARDS APPLY TO ACID-SOLUBLE LEAD CONCENTRATIONS, WHEREAS THE PLOTS REPRESENT TOTAL LEAD CONCENTRATIONS.THUS, VIOLATION OF THE STANDARD DOES NOT NECESSARILY INDICATE THAT TOXIC CONDITIONS WOULD EXIST.THE ACUTE AND CHRONIC STANDARDS, WHICH ARE A FUNCTION OF THE HARDNESS OF THE WATER, WERE CALCULATED USING THE BASELINE HARDNESS LEVELS MEASURED FROM 1981 THROUGH 1983 AT THE REPRESENTATIVE SAMPLING STATIONS PRESENTED IN CHAPTER VI OF VOLUME ONE OF THIS REPORT.

Source: HydroQual, Inc., and SEWRPC.

would be evident primarily during wet-weather conditions. Figure 86 indicates that total lead levels in both the inner harbor and the outer harbor may be expected to meet the acute and chronic toxicity standards for acid-soluble lead under this alternative.

To assess the long-term impacts of the abatement of nonpoint sources of pollution alternative on lead concentrations in the inner harbor sediments, it was assumed that the concentrations would be reduced proportionately to the anticipated reduction in total lead loadings. This alternative would

Table 41

ESTIMATED METAL CONCENTRATIONS IN THE BOTTOM SEDIMENTS OF THE INNER HARBOR UNDER THE ABATEMENT OF NONPOINT SOURCES OF POLLUTION ALTERNATIVE

Metal	U. S. Environmental Protection Agency Sediment Quality Classification			Milwaukee River				Menomonee River				Kinnickinnic River			
				Broadway Street		C&NW Railway		Muskego Avenue		Burnham Canal		S. 1st Street		Greenfield Avenue Extended	
	Nonpolluted	Moderately Polluted	Heavily Polluted	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating	Mean Concentration	Pollution Rating
Cadmium	--[a]	--[a]	>6	1.8	--[a]	4.1	--[a]	5.9	--[a]	3.3	--[a]	3.3	--[a]	5.0	--[a]
Copper	<25	25-50	>50	51	H	74	H	98	H	70	H	84	H	84	H
Lead	<40	40-60	>60	108	H	59	M	77	H	41	M	87	H	57	M
Zinc	<90	90-200	>200	22	N	43	N	45	N	45	N	64	N	53	N

NOTES: All units are in milligrams per kilogram on a dry-weight basis. The metal concentrations measured in the sediment core samples presented in Chapter VI of Volume One were reduced in proportion to the reduction in total metal loadings expected under the abatement of nonpoint sources of pollution alternative.

Pollution Ratings: N-Nonpolluted; M-Moderately Polluted; H-Heavily Polluted

[a] *Cadmium ranges for a nonpolluted or moderately polluted classification have not been established by the U. S. Environmental Protection Agency.*

Source: SEWRPC.

thus result in a reduction of approximately 85 percent in existing lead levels in the bottom sediments of the inner harbor. Estimated concentrations of lead in the bottom sediments are set forth in Table 41. The estimated lead concentrations would result in the bottom sediments at the three stations located in the upper portions of the inner harbor being rated as heavily polluted, and the sediments at the three stations located in the lower portions of the inner harbor being rated as moderately polluted.

Other Toxic Metals: To provide a general assessment of the long-term impacts of the abatement of nonpoint sources of pollution alternative, it was assumed that the metal concentrations in both the bottom sediments and the water column would be reduced proportionately to the reduction in total pollutant loadings. Based on pollutant loading estimates set forth in Chapter VI of Volume One, this alternative would result in a reduction of approximately 50 percent in cadmium, 30 percent in copper, and 90 percent in zinc levels in the inner harbor bottom sediments and water column.

Estimated concentrations of cadmium, copper, and zinc in the bottom sediments of the inner harbor under the abatement of nonpoint sources of pollution alternative are set forth in Table 41. The metal concentrations in the bottom sediments—especially cadmium and copper—would be significantly lower than those estimated under the committed action alternative. The anticipated reductions would affect the existing pollution ratings for cadmium and zinc in the bottom sediments. None of the inner harbor stations would be classified as heavily polluted based on the cadmium concentrations. The estimated zinc concentrations would result in a nonpolluted rating at all six inner harbor stations.

Within the water column of the Milwaukee Harbor estuary, total cadmium concentrations would exceed the chronic toxicity standards for acid-soluble cadmium. This apparent violation of the chronic standards would be less severe than under the committed action alternative. The chronic and acute toxicity standards for acid-soluble zinc and copper would be achieved under this alternative.

Reduction in Point Source Phosphorus Loadings Alternative

This alternative would reduce phosphorus loadings from public sewage treatment plants that discharge to surface waters in the Milwaukee River watershed upstream of the estuary by approximately 90 percent. The impact of the reduced phosphorus loadings on chlorophyll-a and dissolved oxygen levels in the Milwaukee River upstream of the estuary was investigated. The water quality effects of this alternative are discussed below.

Dissolved Oxygen: Phosphorus levels may affect the dissolved oxygen content of the water by stimulating excessive growths of algae and rooted macrophytes. When the plants die and decompose, oxygen is consumed. Although the provision of additional phosphorus removal at public sewage treatment plants would result in a substantial reduction in the phosphorus load from point sources, the total phosphorus loading to the Milwaukee River would be only modestly reduced. It was reported in Chapter VI of Volume One of this report that point sources of pollution that discharge to surface waters in the Milwaukee River watershed upstream of the estuary contributed about 14,800 pounds of phosphorus annually. It was also reported in Chapter VI that the Milwaukee River contributes about 183,000 pounds of phosphorus annually to the estuary. Thus, point sources of pollution account for only about 8 percent of the total phosphorus load to the Milwaukee River. A 90 percent reduction in the point source phosphorus load would result in only about a 7 percent reduction in the total phosphorus load discharged to the estuary from the Milwaukee River. Under future conditions with abatement of combined sewer overflows that discharge upstream of the estuary, a 90 percent reduction in the point source phosphorus load would still represent less than a 10 percent reduction in the total phosphorus load.

However, point sources of pollution generally have their greatest impact on water quality during dry-weather periods, when dilution with river water would be lowest. It was reported in Chapter VI of Volume One that the total phosphorus loading carried by the Milwaukee River during dry-weather periods—which occur about 45 percent of the time—was about 61,700 pounds per year. The total phosphorus loading from point sources during dry-weather periods is about 6,600 pounds per year. A 90 percent reduction in this dry-weather point source phosphorus load would result in a reduction of approximately 10 percent in the total Milwaukee River dry-weather loading.

These relatively small reductions in the total Milwaukee River phosphorus loadings would result in even smaller reductions in chlorophyll-a, an indicator of algal biomass. In Chapter VI of Volume One, time versus concentration plots of chlorophyll-a, inorganic nitrogen, and soluble phosphorus in the Milwaukee River suggested that algal growth was seldom limited by phosphorus. Thus, reducing the phosphorus levels may not result in a proportional reduction in algal biomass. Analyses conducted by the Commission staff indicate that reductions in phosphorus loadings would result in a less than 5 percent reduction in chlorophyll-a levels in the Milwaukee River.

Because reduced phosphorus loadings would be expected to have a minimal effect on algal biomass levels, it was concluded that the reduction in point source phosphorus loadings alternative would have a negligible impact on dissolved oxygen levels. Thus, the effect on dissolved oxygen levels would be about the same as presented for the committed action alternative in Figures 49, 50, and 51, and Table 25.

<u>Fecal Coliform</u>: Under this alternative, the fecal coliform levels may be expected to be about the same as under the committed action alternative. The distribution of all fecal coliform data would be about the same as indicated in Figure 55, and the distribution of geometric means of groups of five consecutive samples may be expected to be about the same as shown in Figure 56. Under the reduction in point source phosphorus loadings alternative, the inner harbor as a whole would not be able to fully achieve the fecal coliform standards supporting limited recreational use. However, the lower reaches of the harbor would have substantially lower levels of fecal coliform than would the upper reaches, and the lower reaches of the Kinnickinnic River estuary in particular could achieve the standards supporting limited recreational use. The outer harbor would be expected to achieve the fecal coliform standards supporting full recreational use.

<u>Ammonia Nitrogen</u>: Both ammonia nitrogen and un-ionized ammonia nitrogen concentrations would be expected to be about the same as under the committed action alternative, as presented in Figure 57 and Table 27. The chronic and acute toxicity standards would not be violated during low-flow, steady-state conditions, although occasional violations of the chronic toxicity standards could occur within portions of the outer harbor during periods of higher pH.

<u>Lead:</u> Lead concentrations in both the water column and the bottom sediments would be about the same as under the committed action alternative, as presented in Figure 58 and Table 28. Total lead levels in both the inner harbor and the outer harbor may be expected to meet the acute and chronic toxicity standards for acid-soluble lead. The lead concentrations in the bottom sediments would result in a heavily polluted classification based on U. S. Environmental Protection Agency sediment quality guidelines.

Other Toxic Metals: This alternative would be expected to have the same effect as the committed action alternative on the levels of cadmium, copper, and zinc in the inner harbor. Cadmium levels in the bottom sediments would result in a heavily polluted classification at two of six sampling stations. The estimated zinc concentrations in the sediments would result in a nonpolluted rating at five stations, and a moderately polluted rating at the remaining station. At all six stations, the copper concentrations would result in a heavily polluted rating.

Total cadmium and copper concentrations in the water column may exceed the chronic toxicity standards for acid-soluble cadmium and copper. The standards for zinc would be met under this alternative.

Modification/Relocation of the WEPCo Valley Power Plant Outfalls Alternative

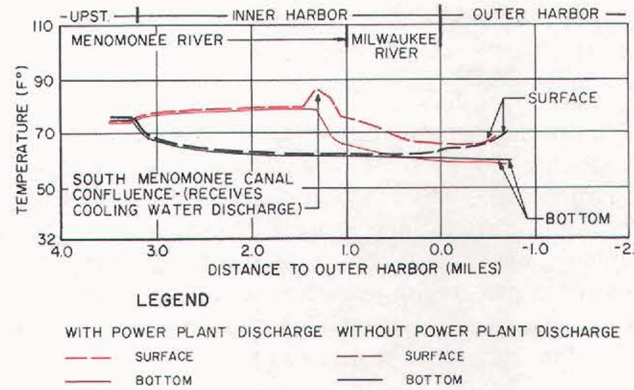
Under this alternative, high temperature condenser cooling water would no longer be discharged to the South Menomonee Canal from the Wisconsin Electric Power Company valley power plant. The discharge of heated water could be eliminated by one of three subalternatives: construction of a cooling tower, diversion of the outfall to the outer harbor, or discharge of the cooling water to the Milwaukee Metropolitan Sewerage District's deep tunnel. The water quality effects of these three subalternatives, as discussed below, would be similar.

Temperature: The effect of eliminating the power plant discharge on the temperature of the Menomonee River, lower Milwaukee River, and outer harbor was estimated for the low-flow, high-temperature conditions present during Survey Period 1. Surface and bottom temperature profiles, with and without the power plant discharge, are shown in Figure 87. Elimination of the power plant discharge may be expected to reduce the temperature of the Menomonee River estuary by 10° to 15°F, and the temperature of the lower Milwaukee River estuary by 5° to 10°F. These temperature changes would extend for some distance upstream of the power plant discharge site because of the circulation of water within the inner harbor.

The ecological significance of these temperature changes can be assessed by reviewing the general effects that temperature has on life processes and the energy cycles within the estuary. Even with the power plant discharges, the temperatures of

Figure 87

ESTIMATED WATER TEMPERATURE WITH AND WITHOUT THE WEPCO VALLEY POWER PLANT CONDENSER COOLING DISCHARGE



Source: HydroQual, Inc.

the receiving waters are not high enough to be lethal to aquatic organisms, since the maximum temperature standard of 89°F is not exceeded. Fish are particularly sensitive to sudden drops in temperature, however. The elimination of the power plant discharges could therefore be expected to prevent some fish from dying, especially during cooler months, since deaths can result if the elevated temperature is suddenly dropped to the ambient river temperature, as when the power plant discharge temporarily ceases, or if the fish are driven out of the elevated temperature plume. As discussed in more detail in the dissolved oxygen section below, higher water temperatures increase the respiration rate of aquatic organisms, which increases the amount of energy and material the organisms need for life processes. The temperature of the water also affects the types of aquatic organisms present, the incidence of disease, fish reproduction success, fish growth rates, the bacterial die-off rate, and the growth of algae and rooted macrophytes. Higher water temperatures also increase the oxidation rate of organic matter, thus affecting the stabilization of the highly organic inner harbor bottom sediments.

An increase in water temperatures can also increase the accumulation of toxic substances in the tissue of fish.[22] As the metabolic and respiration rates increase, more oxygen is required, and thus more water—and more toxic substances—passes over the

[22] *U. S. Environmental Protection Agency, Quality Criteria for Water, 1976.*

gill tissue. Greater amounts of toxic substances are thereby transmitted into the bloodstream. Fish also feed more at higher water temperatures, thus increasing their accumulation of toxic substances. Thus, elimination of the power plant discharge could reduce the accumulation of toxic substances in the tissue of the fish in the Menomonee River estuary.

Elimination of the power plant discharge may be expected to increase the diurnal fluctuation in temperature, which would have a favorable effect on aquatic organisms. Thermal tolerance is enhanced when organisms exist in a diurnally fluctuating temperature regime, rather than at a constant temperature.[23] Diurnal fluctuations also reduce the duration of exposure to extreme temperatures.

Dissolved Oxygen: The temperature of the water strongly influences the severity of dissolved oxygen problems. Because high temperatures and low dissolved oxygen levels often occur simultaneously, the likelihood of the synergistic effects of these two stresses on aquatic organisms is an important consideration in determining the achievement of water use objectives. Organisms require more oxygen for respiration at higher temperatures, but the solubility of oxygen in the water is reduced as the water temperature increases. Thus, less oxygen is available for the increased respiratory need. An increase in water temperature of 20°F can result in a two- to three-fold increase in oxygen consumption[24] and a 15 to 20 percent decrease in the solubility of oxygen.[25] The effect of increased temperature on metabolism and the attendant consumption of oxygen is therefore one of the most important factors causing fishkills during warm-weather periods. Temperature also affects the tolerance of organisms to low dissolved oxygen levels. The minimum dissolved oxygen level that fish can tolerate increases with a rise in temperature, particularly near the upper lethal thermal limit.

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[23] *Ibid.*

[24] *R. J. Hoffman, and R. C. Averett, "Influences of Water Temperature on Aquatic Biota," Biota and Biological Principles of the Aquatic Environment, ed. P. E. Greeson, U. S. Geological Survey Circular 848-A, 1982.*

[25] *J. C. Davis, "Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: A Review," Journal of Fisheries Research Board of Canada, 32(12), 1975, pp. 2295-2332.*

A low-flow, steady-state simulation analysis was conducted to determine the effect that the modification/relocation of the WEPCo valley power plant outfalls alternative would have on the critical dissolved oxygen conditions expected during low-flow and high-temperature periods. The steady-state analysis estimated dissolved oxygen levels under 7-day, 10-year recurrence interval low-flow conditions at the high temperature levels measured during Survey Period 1, July 25 to August 8, 1983. Spatial plots of low-flow, steady-state dissolved oxygen levels under the modification/relocation of the WEPCo valley power plant outfalls alternative are shown in Figure 88. The figure compares the simulated dissolved oxygen levels to standards established for a warmwater fishery and for a limited fishery.

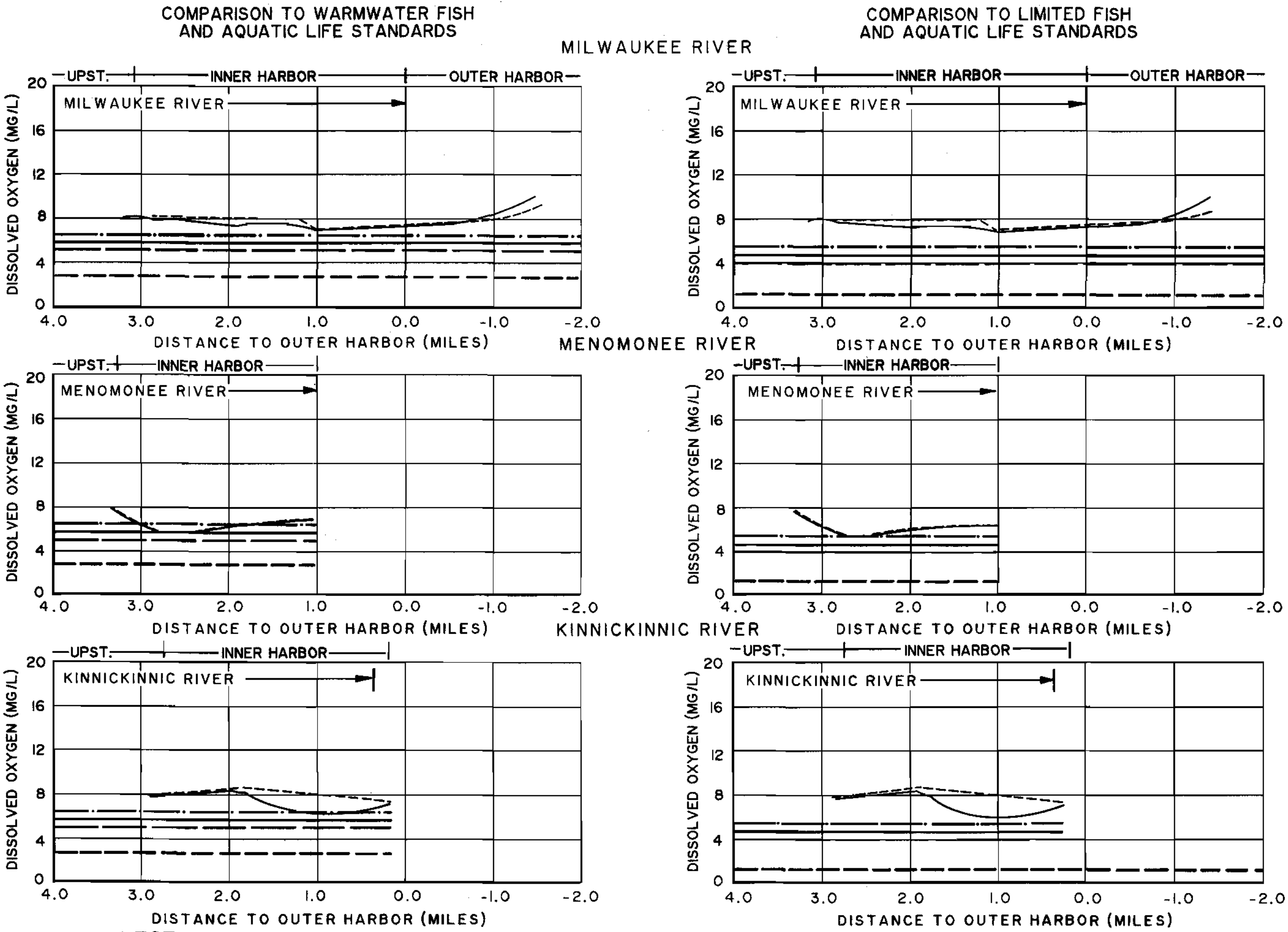
The analysis indicated that standards for the maintenance of both a warmwater fishery and a limited fishery may be expected to be met within the Milwaukee and Kinnickinnic River estuaries, but that the 30-day mean and 7-day mean standards for a warmwater fishery may be expected to be violated within the Menomonee River estuary. However, all other dissolved oxygen standards for a warmwater fishery and all standards for a limited fishery may be expected to be achieved in the Menomonee River estuary. The substantial improvement in dissolved oxygen levels in the Menomonee River over the levels achieved under the committed action alternative suggests that the existing thermal discharges from the power plant have a significant adverse effect on dissolved oxygen levels in the Menomonee River. The dissolved oxygen levels in the outer harbor would be about the same as those estimated under the committed action alternative, and all standards would be met.

Dissolved oxygen conditions under a series of flow and temperature conditions were evaluated to assess the improvement in dissolved oxygen levels under the modification/relocation of the WEPCo valley power plant outfalls alternative. Estimated dissolved oxygen levels were then compared to the standards for a warmwater fishery and for a limited fishery. The expected violations of the dissolved oxygen standards are set forth in Table 42. For the surface and bottom water layers of several upstream, inner harbor, and outer harbor sampling stations, the anticipated violations of the dissolved oxygen standards were classified as slight, moderate, or severe.

Within the tributary rivers upstream of the estuary, the Milwaukee and Kinnickinnic River estuaries, and the outer harbor, the violation of the dissolved

Figure 88

LOW-FLOW, STEADY-STATE ANALYSIS OF DISSOLVED OXYGEN UNDER THE MODIFICATION/RELOCATION OF THE WEPCO VALLEY POWER PLANT OUTFALLS ALTERNATIVE



LEGEND

MODEL SIMULATED DATA

- - - SURFACE LAYER

—— BOTTOM LAYER

STANDARDS (MG/L)	WARMWATER	LIMITED
—— 30 DAY MEAN MINIMUM STANDARD	5.5	4.5
—·— 7 DAY MEAN MINIMUM STANDARD (3/15-7/31)	6.0	5.0
— — I DAY MEAN MINIMUM STANDARD (3/15-7/31)	5.0	4.0
- - - ABSOLUTE MINIMUM STANDARD	2.5	1.5

NOTE: THE EXISTING WISCONSIN DEPARTMENT OF NATURAL RESOURCES STANDARDS SPECIFY MINIMUM DISSOLVED OXYGEN LEVELS OF 5.0 MG/L AND 3.0 MG/L FOR THE FULL WARMWATER FISH AND AQUATIC LIFE AND THE LIMITED FISH AND AQUATIC LIFE WATER USE OBJECTIVES,RESPECTIVELY. THESE STANDARDS ARE APPLIED BY THE DEPARTMENT AS A MINIMUM NOT TO BE VIOLATED AT ANY FLOW EQUAL TO OR GREATER THAN THE 7-DAY,10-YEAR MINIMUM FLOW.

Source: HydroQual, Inc.

oxygen standards would be about the same as under the existing flushing tunnels subalternative. The Menomonee River estuary would likely experience some violations of the 7-day mean dissolved oxygen standard for a warmwater fishery. All other standards would be expected to be met within the Menomonee River estuary.

Diurnal fluctuations in dissolved oxygen levels within the Milwaukee River estuary would be about the same as those expected under the existing flushing tunnels subalternative. Diurnal fluctuations in dissolved oxygen concentrations would continue to be minor in the Menomonee and Kinnickinnic River estuaries, and in the outer

Table 42

VIOLATION OF DISSOLVED OXYGEN STANDARDS UNDER THE MODIFICATION/ RELOCATION OF THE WEPCO VALLEY POWER PLANT OUTFALLS ALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Warmwater Fish and Aquatic Life: 30-Day Mean All Year 5.5 mg/l	7-Day Mean 3/15-7/31 6.0 mg/l	1-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 8/1-3/14 4.0 mg/l	Absolute Minimum All Year 2.5 mg/l	Limited Fish and Aquatic Life: 30-Day Mean All Year 4.5 mg/l	7-Day Mean 3/15-7/31 5.0 mg/l	1-Day Mean 3/15-7/31 4.0 mg/l	1-Day Mean 8/1-3/14 3.0 mg/l	Absolute Minimum All Year 1.5 mg/l
Upstream												
Milwaukee River	North Avenue Dam (RIV-5)	DI	None	Moderate	None	None	None	None	None	None	None	None
Menomonee River	S. 37th Street (RIV-10)	DI	None	Moderate	None	None	None	None	None	None	None	None
Kinnickinnic River	S. 9th Place (RIV-13)	DI	None	Slight	Slight	Slight	Slight	None	Slight	Slight	Slight	None
Inner Harbor												
Milwaukee River	Walnut Street (RIV-6)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Wells Street (RIV-7)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Water Street (RIV-8)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	C&NW Railway (RIV-15)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
Menomonee River	Muskego Avenue (RIV-11)	S	None	Slight	None	None	None	None	None	None	None	None
		B	None	Slight	None	None	None	None	None	None	None	None
	S. 2nd Street (RIV-17)	S	None	Slight	None	None	None	None	None	None	None	None
		B	None	Slight	None	None	None	None	None	None	None	None
Kinnickinnic River	S. 1st Street (RIV-14)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Greenfield Avenue Extended (RIV-18)	S	None	None	None	None	None	None	None	None	None	None
		B	None	Slight	Slight	None	None	None	Slight	None	None	None
	Jones Island (RIV-19)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
Outer Harbor	Hoan Bridge (OH-1)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	None	None	None	None	None	None	None
	Central OH (OH-3)	S	Slight	None	None	None	None	None	None	None	None	None
		B	Slight	None	None	None	None	Slight	None	None	None	None
	South OH (OH-11)	S	None	None	None	None	None	None	None	None	None	None
		B	Slight	Slight	None	Slight	None	Slight	None	None	None	None
	JI STP Plume (OH-2)	S	None	None	None	None	None	None	None	None	None	None
		B	None	None	None	Slight	None	None	None	None	Slight	None

NOTE: Standard violations that occur up to 5 percent of the time are classified as slight; violations that occur 6 to 10 percent of the time are classified as moderate; and violations that occur more than 10 percent of the time are classified as severe. Underlined ratings indicate a significant improvement in dissolved oxygen levels over the levels expected under the committed action alternative.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

Source: HydroQual, Inc., and SEWRPC.

harbor. The bottom water layers would not exhibit diurnal fluctuations in any of the water bodies.

Review of the temperature and fecal coliform data for the modification/relocation of the WEPCo valley power plant outfalls alternative indicates that there would be a slight change in the fecal coliform levels in that at cooler temperatures, the coliform organisms would grow at a slower rate and die off less quickly; thus, the fecal coliform levels may be expected to increase somewhat under this alternative. As noted previously, the temperatures in the Menomonee River portion of the estuary could be expected to be reduced by 10° to 15°F, with the temperature in the lower Milwaukee River estuary being reduced by 5° to 10°F, with modification of the WEPCo power plant outfall. These temperature reductions may be expected to result in an increase in the fecal coliform levels of less than 20 percent. Detailed simulation modeling has not been developed for fecal coliform levels for this alternative since levels of fecal coliform organisms in the system are expected to be only slightly higher than those shown in Figures 66 and 67.

Under the modification/relocation of the WEPCo valley power plant outfalls alternative, the fecal coliform levels in the Menomonee River estuary would exceed the standards supporting limited recreational use. The Milwaukee and Kinnickinnic River estuaries would be expected to meet the fecal coliform standards supporting limited recreational use, and the outer harbor would be expected to achieve the standards supporting full recreational use.

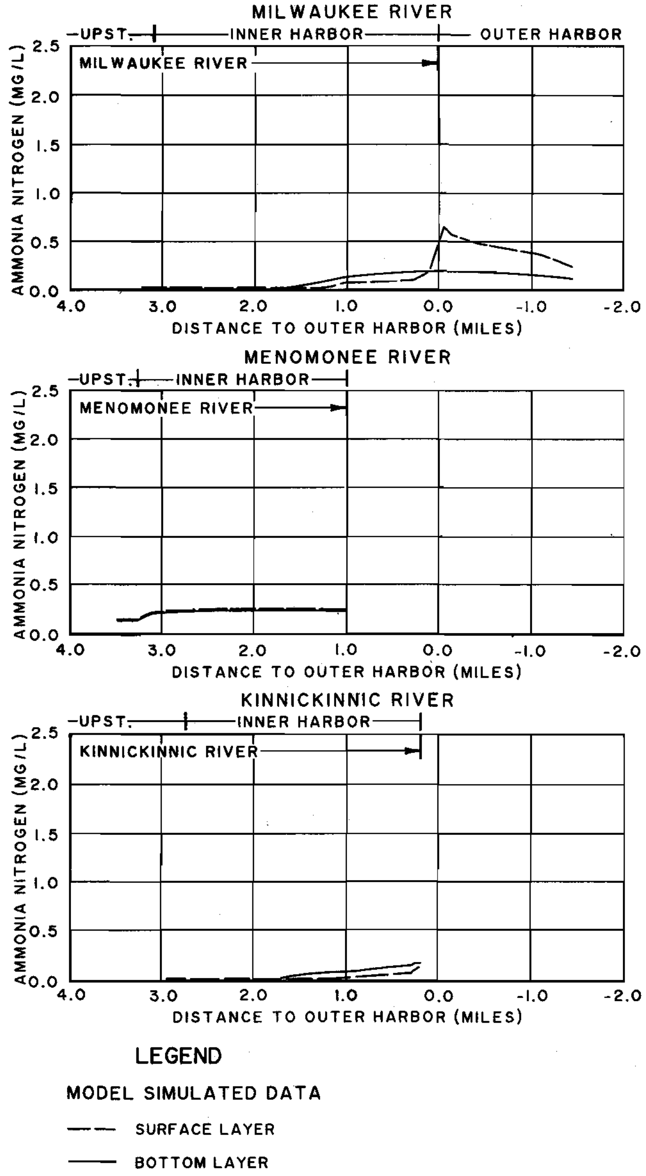
Ammonia Nitrogen: The modification/relocation of the WEPCo valley power plant outfalls alternative would result in ammonia nitrogen concentrations that are about the same as those under the existing flushing tunnels subalternative, except in the Menomonee River. In the Menomonee River, the concentrations of ammonia nitrogen under this alternative would be lower in the upstream reaches. Simulated ammonia nitrogen concentrations under low-flow, steady-state conditions are shown in Figure 89.

Table 43 sets forth the un-ionized ammonia nitrogen concentrations expected under the modification/relocation of the WEPCo valley power plant outfalls alternative, along with a comparison of these concentrations to acute and chronic toxicity standards. The un-ionized ammonia nitrogen concentrations and acute and chronic toxicity standards were calculated in accordance with the procedures described for the committed action alternative.

Under low-flow, steady-state conditions, the un-ionized ammonia nitrogen concentration would range from 0.009 to 0.022 mg/l at the upstream river stations, from 0.001 to 0.009 mg/l at the inner harbor stations, and from 0.002 to 0.009 mg/l at the outer harbor stations. The chronic and acute toxicity standards would not be violated during low-flow, steady-state conditions, although occasional violations of the chronic toxicity standards could occur within portions of the outer harbor during periods of higher pH.

Figure 89

ESTIMATED AMMONIA NITROGEN LEVELS UNDER THE MODIFICATION/RELOCATION OF THE WEPCO VALLEY POWER PLANT OUTFALLS ALTERNATIVE



Source: HydroQual, Inc.

Lead: Lead concentrations in both the water column and bottom sediments would be about the same as under the committed action alternative, as presented in Figure 58 and Table 28. Total lead levels in both the inner harbor and the outer harbor may be expected to meet the acute and chronic toxicity standards for acid-soluble lead. The lead concentrations in the bottom sediments would result in a heavily polluted classification based on U. S. Environmental Protection Agency sediment quality guidelines.

Table 43

COMPARISON OF ESTIMATED UN-IONIZED AMMONIA NITROGEN CONCENTRATIONS TO THE RECOMMENDED ACUTE AND CHRONIC TOXICITY STANDARDS UNDER THE MODIFICATION/RELOCATION OF THE WEPCO VALLEY POWER PLANT OUTFALLS ALTERNATIVE

Water Body	Baseline Sampling Station	Water Layer[a]	Total Ammonia Nitrogen[b] (mg/l)	pH[c] (standard units)	Temperature (°F)	Un-ionized Ammonia Nitrogen[d] (mg/l)	Un-ionized Ammonia Nitrogen Toxicity Standards		Violation of Un-ionized Ammonia Nitrogen Toxicity Standards	
							Acute[e]	Chronic[e]	Acute	Chronic
Upstream										
Milwaukee River	North Avenue Dam (RIV-5)	DI	0.05	8.5	81	0.009	0.117	0.025	--	--
Menomonee River	S. 37th Street (RIV-10)	DI	0.15	8.5	75	0.022	0.116	0.025	--	--
Kinnickinnic River	S. 9th Place (RIV-13)	DI	0.05	8.9	84	0.019	0.121	0.025	--	--
Inner Harbor										
Milwaukee River	Walnut Street (RIV-6)	S	0.05	8.5	81	0.009	0.116	0.025	--	--
		B	0.05	8.4	81	0.008	0.115	0.025	--	--
	Wells Street (RIV-7)	S	0.05	8.0	79	0.003	0.102	0.025	--	--
		B	0.05	8.1	75	0.004	0.108	0.025	--	--
	Water Street (RIV-8)	S	0.05	7.9	62	0.001	0.098	0.025	--	--
		B	0.10	7.9	61	0.003	0.099	0.025	--	--
	C&NW Railway (RIV-15)	S	0.10	7.5	62	0.001	0.073	0.025	--	--
		B	0.15	8.1	61	0.006	0.105	0.025	--	--
Menomonee River	Muskego Avenue (RIV-11)	S	0.25	7.7	62	0.005	0.088	0.025	--	--
		B	0.25	7.5	62	0.002	0.077	0.025	--	--
	S. 2nd Street (RIV-17)	S	0.20	7.7	61	0.003	0.088	0.025	--	--
		B	0.20	7.7	61	0.003	0.090	0.025	--	--
Kinnickinnic River	S. 1st Street (RIV-14)	S	0.05	7.6	72	0.001	0.081	0.025	--	--
		B	0.05	7.6	72	0.001	0.081	0.025	--	--
	Greenfield Avenue Extended (RIV-18)	S	0.05	7.6	73	0.001	0.081	0.025	--	--
		B	0.10	7.6	64	0.002	0.081	0.025	--	--
	Jones Island (RIV-19)	S	0.10	7.6	73	0.002	0.083	0.025	--	--
		B	0.15	7.9	63	0.004	0.097	0.025	--	--
Outer Harbor	South OH (OH-11)	S	0.45	7.6	72	0.009	0.079	0.025	--	--
		B	0.20	7.6	57	0.002	0.083	0.025	--	--
	JI STP Plume (OH-2)	S	0.70	7.4	70	0.008	0.065	0.025	--	--
		B	0.20	7.9	61	0.005	0.097	0.025	--	--

NOTE: The existing Wisconsin Department of Natural Resources standard for un-ionized ammonia nitrogen specifies a maximum level of 0.04 mg/l for the full warmwater fishery and aquatic life water use objective. The Department has issued no standard for the limited fishery and aquatic life objective. The standard for the warmwater fishery and aquatic life objective is applied by the Department as a maximum not to be exceeded at any flow equal to or greater than the 7-day, 10-year minimum flow.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

[b] *As estimated in Figure 89.*

[c] *Arithmetic mean pH and temperature levels measured during Survey Period 1, July 25 through August 8, 1983, under the baseline sampling program.*

[d] *The un-ionized ammonia nitrogen concentrations were calculated using the estimated total ammonia nitrogen, pH, and temperature levels.*

[e] *The acute and chronic toxicity standards, which vary in response to the pH and temperature of the water, were calculated in accordance with the procedures set forth in Chapter II of this volume.*

Source: SEWRPC.

Other Toxic Metals: This alternative would be expected to have the same effect as the committed action alternative on the levels of cadmium, copper, and zinc in the inner harbor. Cadmium levels in the bottom sediments would result in a heavily polluted classification at two of six sampling stations. The estimated zinc concentrations in the sediments would result in a nonpolluted rating at five stations, and a moderately polluted rating at the remaining station. At all six stations, the copper concentrations would result in a heavily polluted rating.

Total cadmium and copper concentrations in the water column might exceed the chronic toxicity standards for acid-soluble cadmium and copper. The standards for zinc would be met under this alternative.

Economic Analysis

To compare the costs and evaluate the financial feasibility of the alternative water quality management plans, an economic analysis was conducted. Table 44 sets forth the capital cost, average annual operation and maintenance cost, 50-year present worth, and equivalent annual cost of each of the alternative plans.

The costs of these alternative plans must be viewed in terms of the substantial water quality benefits they provide for the waterways in the most highly urbanized area of the Region. It must be recognized that all of the alternative plans do not provide equivalent water quality benefits, although all, to some degree, help achieve the recommended water use objectives. It must also be recognized that the abatement of nonpoint sources of pollution alternative and the reduction in point source phosphorus loadings alternative would provide benefits not only for the surface waters of the estuary, but also for surface waters located upstream of the estuary.

With respect to the four economic indicators presented in the table, the existing flushing tunnels subalternative has the lowest cost, entailing a capital cost of about $300,000, an annual operation and maintenance cost of about $70,000, a 50-year present worth of about $1.85 million, and an equivalent annual cost of about $110,000. Of all the alternatives other than the committed action alternative, the elimination of combined sewer overflows alternative has the highest overall cost, with a capital cost of about $350 million, an annual operation and maintenance cost of about $1.0 million, a 50-year present worth of about $258 million, and an equivalent annual cost of about $16.3 million.

Summary Evaluation of Alternative Plans

The foregoing section described the costs and anticipated impacts on water quality conditions of each of the alternative water quality management plans considered under the Milwaukee Harbor estuary study. The costs and impacts were evaluated to identify the most cost-effective means of achieving those water quality conditions that can be practicably achieved within the estuary. Table 45 summarizes the water quality impacts on the inner harbor and the annual costs of the alternative plans.

The committed action alternative may be expected to result in continued violations of the dissolved oxygen standards for both a warmwater fishery and a limited fishery, and of the fecal coliform standards for limited recreational use, throughout the inner harbor. The capital and operation costs of the committed action alternative are considered to be previously committed.

Under the committed action alternative, contributions of metal loadings to the estuary are expected to be reduced by 8 to 85 percent, depending on the pollutant. The chronic and acute column toxicity standards for lead would not be violated. While the chronic water column standards for cadmium and copper would be exceeded at times, the exceedance would be less severe than under existing conditions. The anticipated reduction in metals would tend to reduce the concentrations in the sediments. However, portions of the estuary would continue to be classified as heavily polluted based upon EPA dredged material disposal guidelines for copper and cadmium levels. All of the alternatives would result in similar sediment quality conditions with the exception of the abatement of nonpoint sources of pollution alternative, under which the estimated concentrations of cadmium and copper in the bottom sediments would be significantly lower, and thus none of the sediments would be classified as heavily polluted based on metal concentrations. Within the water column of the Milwaukee Harbor estuary, total cadmium concentrations would exceed the chronic toxicity standards for acid-soluble cadmium. This apparent violation of the chronic standards would be less severe than under the committed action alternative. The chronic and acute toxicity standards for acid-soluble copper would be achieved under this alternative.

Table 44

ESTIMATED COSTS OF ALTERNATIVE WATER QUALITY MANAGEMENT PLANS FOR THE MILWAUKEE HARBOR ESTUARY

Alternative Plan	Capital Cost: 1986-2000 (millions)	Annual Operation and Maintenance Cost	50-Year Present Worth[a] (millions)	Equivalent Annual Cost
Committed Action.	$338.4	$1,540,000	$303.4	$19,250,000
Elimination of Combined Sewer Overflows	350.0	1,000,000	258.0	16,340,000
Low Flow Augmentation: Existing Flushing Tunnels	0.3	70,000	1.85	110,000
Low Flow Augmentation: Menomonee River New Flushing Tunnel	24.3	95,000	4.55	290,000
Menomonee River Instream Aeration	0.6	80,000	1.97	120,000
Abatement of Nonpoint Sources of Pollution.	185.5[b]	3,650,000[b]	184.4[b]	11,700,000[b]
Reduction in Point Source Phosphorus Loadings	23.2	1,840,000	46.3	2,940,000
Modification/Relocation of WEPCo Valley Power Plant Outfalls: Cooling Tower	3.2	350,000	8.33	530,000
Modification/Relocation of WEPCo Valley Power Plant Outfalls: Outfall Diversion.	16.3	80,000	16.21	1,030,000
Modification/Relocation of WEPCo Valley Power Plant Outfalls: Deep Tunnel Discharge	6.4	180,000	9.89	620,000

[a] *The present worth was calculated at an interest rate of 6 percent.*

[b] *The costs for the abatement of nonpoint sources of pollution alternative do not include those costs associated with the implementation of the Milwaukee River Priority Watersheds Program, which is intended to provide water quality benefits for those surface waters located upstream of the estuary. The implementation of the priority watersheds program is expected to entail a capital cost of about $196 million, and an annual operation and maintenance cost of $3,850,000. The costs presented for this alternative are those associated with the implementation of additional nonpoint source abatement measures to achieve the maximum level of control practicable.*

Source: SEWRPC.

Table 45

SUMMARY EVALUATION OF ALTERNATIVE WATER QUALITY MANAGEMENT PLANS FOR THE MILWAUKEE HARBOR ESTUARY

Alternative	Description	Water Quality Effects—Achievement of Recommended Standards in Inner Harbor							Equivalent Annual Cost	Implementability	Comments
		Dissolved Oxygen Warmwater Fish and Aquatic Life	Dissolved Oxygen Limited Fish and Aquatic Life	Fecal Coliform Limited Recreational Use	Un-ionized Ammonia Nitrogen Warmwater and Limited Fish and Aquatic Life	Lead-Warmwater and Limited Fish and Aquatic Life					
						Acute-Water	Chronic-Water	Bottom Sediment Rating			
Committed Action	Committed Measures Only: o Abatement of combined sewer overflows at a 0.7-year level of protection o Elimination of separate sanitary sewer flow relief devices o Dredging to maintain navigation	Violated	Violated	Violated	Met	Met	Met	Heavily polluted	$19,250,000	All measures are currently being conducted or are under construction	Abatement of combined sewer overflows provided by storage system sized to accommodate infiltration and inflow from separate sewered areas. Measures are acceptable and well known to public officials. Protects public health and provides improved water quality. Combined sewer overflows would still occur about every 0.7 year
Elimination of Combined Sewer Overflows	Same as committed action, except combined sewer overflows would be virtually eliminated by providing additional overflow storage volume	Violated	Violated	Violated	Met	Met	Met	Heavily polluted	$16,340,000	Unlikely to receive high degree of public acceptance; difficult to implement because of high cost and only marginal long-term water quality benefits	Adverse water quality impacts which occur during infrequent combined sewer overflow discharges would be avoided
Low Flow Augmentation: Existing Flushing Tunnels Subalternative	Same as committed action, plus continued operation of the existing Milwaukee River and Kinnickinnic River flushing tunnels	Met in Milwaukee and Kinnickinnic River estuaries; violated only in Menomonee River estuary	Met in Milwaukee and Kinnickinnic River estuaries; violated only in Menomonee River estuary	Met in Milwaukee and Kinnickinnic River estuaries; violated only in Menomonee River estuary	Met	Met	Met	Heavily polluted	$ 110,000	Readily implementable since flushing tunnels concerned are currently in operation	Relatively low cost. May be expected to virtually eliminate dissolved oxygen problems, to significantly reduce concentrations of nearly all other pollutants, and to improve aesthetics by increasing water clarity and by flushing debris from the Milwaukee and Kinnickinnic River estuaries. Prevention of anaerobic conditions may reduce the release of metals and nutrients from the bottom sediments to the overlying water column. The oxidation of bottom sediments would be increased. Undesirable odors would be eliminated
Low Flow Augmentation: Menomonee River New Flushing Tunnel Subalternative	Same as committed action, plus continued operation of the existing Milwaukee River and Kinnickinnic River flushing tunnels and construction and operation of a new flushing tunnel which would discharge to the Menomonee River at about N. 25th Street	Met	Met	Met	Met	Met	Met	Heavily polluted	$ 290,000	Relatively high cost would impede implementation	The benefits described for the existing flushing tunnels subalternative would also be provided to the Menomonee River estuary

Table 45 (continued)

Alternative	Description	Water Quality Effects—Achievement of Recommended Standards in Inner Harbor							Equivalent Annual Cost	Implementability	Comments
						Lead-Warmwater and Limited Fish and Aquatic Life					
		Dissolved Oxygen Warmwater Fish and Aquatic Life	Dissolved Oxygen Limited Fish and Aquatic Life	Fecal Coliform Limited Recreational Use	Un-ionized Ammonia Nitrogen Warmwater and Limited Fish and Aquatic Life	Acute-Water	Chronic-Water	Bottom Sediment Rating			
Menomonee River Instream Aeration	Same as committed action, plus continued operation of the existing Milwaukee River and Kinnickinnic River flushing tunnels; and installation and operation of four 25-horsepower mechanical surface aerators in the Menomonee River estuary. The aerators, which would operate about 1,200 hours per year, would provide up to about 180 pounds of dissolved oxygen per hour of operation to the river	Met	Met	Met in Milwaukee and Kinnickinnic River estuaries; violated in Menomonee River estuary	Met	Met	Met	Heavily polluted	$ 120,000	Readily implementable	The aerators would be ancored to the downstream side of existing bridge piers to minimize any interference with navigation
Abatement of Nonpoint Sources of Pollution	Same as committed action, plus implementation of nonpoint source pollution control measures upstream of the combined sewer service area to achieve the maximum level of nonpoint source pollution control practicable	Violated	Violated	Met	Met	Met	Met	Moderately polluted	$11,700,000	Rural nonpoint source control measures and construction erosion control measures are more likely to be implemented than urban nonpoint source control measures. In developed urban areas, the most effective nonpoint source control measures will be particularly difficult and costly to implement	Upstream surface waters would also benefit from improved water quality. This alternative consists of the implementation of control measures in addition to those measures expected to be implemented under the Milwaukee River Priority Watersheds Program
Reduction in Point Source Phosphorus Loadings	Same as committed action, plus a high level of phosphorus removal at all existing and proposed public sewage treatment plants, reducing point source phosphorus loadings by 90 percent	Violated	Violated	Violated	Met	Met	Met	Heavily polluted	$ 2,940,000	Implementation of high levels of phosphorus removal may be controversial	Would provide less than a 10 percent decrease in chlorophyll-a levels in the Milwaukee River, and only negligible improvement in dissolved oxygen levels in the Milwaukee River estuary. No benefits would be provided to the Menomonee or Kinnickinnic River estuaries. The upstream Milwaukee River would receive marginal benefits from improved water quality conditions

Table 45 (continued)

Alternative	Description	Water Quality Effects—Achievement of Recommended Standards in Inner Harbor							Equivalent Annual Cost	Implementability	Comments
		Dissolved Oxygen Warmwater Fish and Aquatic Life	Dissolved Oxygen Limited Fish and Aquatic Life	Fecal Coliform Limited Recreational Use	Un-ionized Ammonia Nitrogen Warmwater and Limited Fish and Aquatic Life	Lead-Warmwater and Limited Fish and Aquatic Life: Acute-Water	Lead-Warmwater and Limited Fish and Aquatic Life: Chronic-Water	Lead-Warmwater and Limited Fish and Aquatic Life: Bottom Sediment Rating			
Modification and/or Relocation of the WEPCo Valley Power Plant Outfalls: Cooling Tower Subalternative	Same as committed action, plus installation and operation of a cooling tower for the valley power plant to reduce the temperature of spent condenser cooling water prior to discharge to the South Menomonee Canal. Continued operation of the Milwaukee River and Kinnickinnic River flushing tunnels	Met in Milwaukee and Kinnickinnic River estuaries; violated in Menomonee River estuary	Met	Met in Milwaukee and Kinnickinnic River estuaries; violated in Menomonee River estuary	Met	Met	Met	Heavily polluted	$ 530,000[a]	Implementation may be opposed by Power Company because of cost, and may involve Public Service Commission regulation. Implementation may be opposed by the public because vapor from the cooling process may be a hazard for traffic carried on the IH 94 high level bridge over the Menomonee River Valley	Adverse thermal effects on dissolved oxygen content and on aquatic life would be reduced
Modification and/or Relocation of the WEPCo Valley Power Plant Outfalls: Outfall Diversion Subalternative	Same as committed action, plus diversion of the spent cooling water of the valley power plant to the outer harbor at the Henry W. Maier festival grounds; continued operation of the existing Milwaukee River and Kinnickinnic River flushing tunnels	Met in Milwaukee and Kinnickinnic River estuaries; violated in Menomonee River estuary	Met	Met in Milwaukee and Kinnickinnic River estuaries; violated in Menomonee River estuary	Met	Met	Met	Heavily polluted	$ 1,030,000	Implementation likely to be opposed by Power Company because of cost, and may involve Public Service Commission regulation	Adverse thermal effects on dissolved oxygen content and on aquatic life would be reduced. Removal of the outfalls from the South Menomonee Canal may induce more inflow of Lake Michigan water into the Menomonee River estuary
Modification and/or Relocation of the WEPCo Valley Power Plant Outfalls: Deep Tunnel Discharge Subalternative	Same as committed action, plus spent cooling water of the valley power plant would be discharged to the Milwaukee Metropolitan Sewerage District inline storage tunnel during dry-weather periods and be pumped out to the outer harbor, and from the existing outfalls during wet-weather periods; continued operation of the existing Milwaukee River and Kinnickinnic River flushing tunnels	Met in Milwaukee and Kinnickinnic River estuaries; violated in Menomonee River estuary	Met	Met in Milwaukee and Kinnickinnic River estuaries; violated in Menomonee River estuary	Met	Met	Met	Heavily polluted	$ 620,000	Implementation likely to be opposed by Power Company because of cost, and may involve Public Service Commission regulation	Adverse thermal effects on dissolved oxygen content and on aquatic life would be reduced. Removal of the outfalls from the South Menomonee Canal may induce more inflow of Lake Michigan water into the Menomonee River estuary

[a] *Cost estimates for operation and maintenance assume that no pretreatment of river water is required and do not include an allowance for any power production cost increases which may result from using a cooling tower.*

Source: SEWRPC.

The elimination of combined sewer overflows alternative may be expected to achieve slightly better water quality conditions in the inner harbor than the committed action alternative. This alternative has a high cost, the equivalent annual cost totaling about $16.3 million.

The existing flushing tunnels subalternative may be expected to meet all water quality standards supporting limited recreational use and both a warmwater fishery and a limited fishery for the Milwaukee and Kinnickinnic River estuaries. The dissolved oxygen standards for both a warmwater fishery and a limited fishery, and the fecal coliform standards for limited recreational use, may be expected to continue to be violated in the Menomonee River estuary. This alternative has a relatively low cost, the equivalent annual cost being about $110,000.

Under the Menomonee River new flushing tunnel subalternative, all water quality standards supporting limited recreational use and both a warmwater fishery and a limited fishery would be met within the inner harbor. This alternative has a moderate cost, with an equivalent annual cost of about $290,000.

Under the Menomonee River instream aeration alternative, water quality conditions in the Menomonee River estuary would not be quite as good as under the Menomonee River new flushing tunnel subalternative. The fecal coliform standards for limited recreational use may be expected to be violated within the Menomonee River estuary. This alternative has a low cost, the equivalent annual cost being about $120,000.

The abatement of nonpoint sources of pollution alternative would allow the achievement of the fecal coliform standards for limited recreational use throughout the inner harbor, but the dissolved oxygen standards for both a warmwater fishery and a limited fishery would be violated within the inner harbor. This alternative has a high cost, the equivalent annual cost being about $11.7 million.

The reduction in point source phosphorus loadings alternative would provide only minimal water quality benefits, with the dissolved oxygen standards for both a warmwater fishery and a limited fishery, and the fecal coliform standards for limited recreational use, being violated throughout the inner harbor. This alternative has a high cost, with the equivalent annual cost being about $2.9 million.

The three subalternatives under the modification/relocation of the WEPCo valley power plant outfalls alternative—the cooling tower, outfall diversion, and deep tunnel discharge subalternatives—would all provide similar water quality benefits. The water temperature of the Menomonee River estuary and of the lower Milwaukee River estuary downstream of its confluence with the Menomonee River would be substantially reduced, which would help improve dissolved oxygen levels. Within the Menomonee River estuary, the dissolved oxygen standards for a warmwater fishery, and the fecal coliform standards for limited recreational use, would continue to be violated. These subalternatives all have a moderate cost, with the equivalent annual costs ranging from $530,000 to $1,030,000.

RECOMMENDED WATER QUALITY MANAGEMENT PLAN ELEMENT

Introduction

Based upon the inventories, analyses, and alternative plan evaluations presented in this report, a recommended water quality management plan for the Milwaukee Harbor estuary was developed. The selection of the recommended plan was based upon careful consideration of the technical feasibility, economic viability, water quality impacts, potential public acceptance, and practicability of the alternative plans considered.

The identification of a recommended plan, which necessarily involves both objective technical and subjective nontechnical considerations, was the responsibility of the Technical Advisory Committee created to guide the conduct of the study. Accordingly, the plan selection process actively involved representatives of various units and agencies of government, and of the private interest groups concerned with the management of the water quality of the Milwaukee Harbor estuary.

The selection of the recommended plan focused primarily upon the degree to which the water use objectives could be expected to be satisfied and upon the accompanying costs. This section describes the recommended plan components, evaluates the ability of the recommended plan to meet the initially recommended water use objectives, and assesses the potential of the recommended plan to achieve higher water use objectives.

Recommended Plan Components

The recommended water quality management plan for the Milwaukee Harbor estuary is the Menomonee River instream aeration alternative, along with three auxiliary plan elements. The recommended plan includes the abatement of combined sewer overflows at a 0.7-year level of protection, and the elimination of virtually all separate sanitary sewer flow relief devices, as described for the committed action alternative. These measures have already been committed. The recommended plan also includes the implementation of rural nonpoint source pollution abatement measures to a level approximating 50 percent of the maximum achievable level, as described under the abatement of nonpoint sources of pollution alternative. With regard to nonpoint source pollution controls in the urban areas, it was concluded that only construction erosion control measures should be included in the recommended plan because of the modest costs entailed and the effectiveness in improving water quality within the estuary. However, it is recognized that the ongoing nonpoint source planning work being conducted by the Wisconsin Department of Natural Resources as part of the Milwaukee and Menomonee River priority watershed programs may lead to the implementation of urban nonpoint source pollution abatement measures to achieve desired water use objectives in the surface waters upstream of the estuary and in Lake Michigan. In this event, improvement of water quality conditions in the estuary would be a secondary benefit. The degree of water quality improvement associated with the urban nonpoint source controls is discussed further in the following section of this chapter. In addition, the recommended plan includes the continued operation of the existing flushing tunnels that discharge to the Milwaukee and Kinnickinnic Rivers. An aeration system would also be installed in the Menomonee River estuary to improve the dissolved oxygen levels in that waterway.

Pollutant loadings from combined sewer overflows would be reduced by about 97 percent by the provision of about 1,140 acre-feet of storage volume in the Milwaukee Metropolitan Sewerage District's deep tunnel inline storage system. The stored wastewater would be treated at the District's sewage treatment plants. Separate sanitary sewer flow relief devices would be virtually eliminated by the expansion and upgrading of the Jones Island and South Shore sewage treatment plants, new sewer construction, and the construction of the deep tunnel. These measures are described in the District's facilities plans.

It is recommended that the existing flushing tunnels be operated at existing capacities—600 cfs for the Milwaukee River flushing tunnel, and 350 cfs for the Kinnickinnic River flushing tunnel—whenever it appears that the instream dissolved oxygen standards for a warmwater fishery would be otherwise violated. The decision to operate the Milwaukee River flushing tunnel should be based on continuous water quality monitoring data collected by the Milwaukee Metropolitan Sewerage District for the Milwaukee River at St. Paul Avenue. The decision to operate the Kinnickinnic River flushing tunnel should be based on the continuous water quality monitoring data collected by the District for the Kinnickinnic River at S. 1st Street. Based on projected dissolved oxygen levels, the flushing tunnels would need to be operated about 20 percent of the time, or about 740 hours per year.

To increase the dissolved oxygen levels in the Menomonee River estuary, it is recommended that four 25-horsepower mechanical aerators be placed in the Menomonee River—one at the former Chicago, Milwaukee, St. Paul & Pacific Railroad Company, now Soo Line, bridge just upstream of N. 25th Street, one at N. 25th Street, and two at N. 16th Street. The aerators could be anchored to the downstream side of existing bridge piers. The aerators would operate about 1,200 hours per year, supplying up to 180 pounds of oxygen per hour to the river. The aerators would be operated whenever it appeared that the instream dissolved oxygen standards for a warmwater fishery would be otherwise violated. The decision to operate the aerators should be based on the continuous water quality monitoring data collected by the District for the Menomonee River at Muskego Avenue.

Under the Milwaukee River Priority Watersheds Program, cost-share funds and technical and planning assistance are being provided to encourage the implementation of nonpoint source abatement measures within the Milwaukee and Menomonee River watersheds. It must be recognized that implementation of nonpoint source abatement measures under the Milwaukee River Priority Watersheds Program would not alone result in water quality conditions in the estuary that would meet the standards for a warmwater fishery or for a limited fishery. Such measures would, however, contribute to the improvement of the water quality of surface waters located upstream of the estuary, as well as of the estuary itself. The most significant benefits may be expected to result from reductions in sediment, phosphorus, and fecal coliform loadings to the estuary.

Auxiliary Plan Recommendations: The following recommendations relate to additional actions which should be undertaken to help ensure the achievement of the water use objectives in the Milwaukee Harbor estuary under the recommended water quality management plan. These additional recommendations address the issues of salt and scrap metal storage, toxic substances, and water quality and sediment monitoring.

Salt and Scrap Metal Storage: To eliminate contaminated stormwater runoff and seepage from salt storage piles and scrap metal and other material storage yards located on the docks and other areas within the area directly tributary to the estuary, it is recommended that all uncovered salt storage piles and all scrap metal and other material storage piles within the direct drainage area either be eliminated, be isolated from contact with rainfall and stormwater runoff, or be provided with pollutant removal facilities such as retention storage ponds to treat runoff from the sites, or that the drainage system serving the area be connected to the combined sewer system. All salt storage piles in the direct drainage area should be covered by structures, or the salt removed to covered storage facilities in outlying areas closer to the areas of utilization. It is recommended that the best alternatives for each area determined to need modification be developed in a detailed second level planning effort to be conducted as part of the Wisconsin Department of Natural Resources Priority Watersheds Program in cooperation with the affected landowners and facility operators. This action should eliminate high loadings of salt and associated pollutants such as chromium and lead, which, as documented in Chapter VI of Volume One, may be carried in runoff from these storage piles. Scrap metal storage piles in the direct drainage area should be covered by structures and provided with means to divert runoff around the sites, or pollutant runoff control measures implemented to reduce the discharge of metals and other toxic substances into the estuary. Estimated metal loadings from industrial storage sites in the direct drainage area are about twice as high as loadings from typical industrial land areas, and about 10 times higher than loadings from typical residential land areas. To estimate the cost of this recommendation, it was assumed that about 60 acres of salt and scrap metal storage area within the direct tributary drainage area would need to be controlled. The cost of material storage runoff control would be about $10,000 per acre, for a total capital cost of about $600,000.

Toxic Substances: Chapter VI of Volume One of this report summarized the extensive data base on toxic substances collated for, or collected under, the Milwaukee Harbor estuary study, including data on metal and chlorinated hydrocarbon concentrations in the bottom sediments, the water column, and the tissue of fish. A review of these data indicated that the bottom sediments are polluted with metals and chlorinated hydrocarbons.

To the extent that this pollution may enter the biota and water column, it may have chronic toxic effects on fish life. It is accordingly recommended that further studies of the sources, transport, fate, and effects of certain toxic metals and chlorinated hydrocarbon substances be conducted for the Milwaukee Harbor estuary. These studies should address three issues: 1) the adoption of in-place sediment quality standards; 2) the risk of the release of toxic substances in the sediments into the biota and water column; and 3) the sources of the toxic substances present in the sediments. An outline of a toxic study for the estuary is set forth in Chapter VII of this report. The recommended study would entail a capital cost of about $3.2 million.

The recommended study would supplement, and fully utilize, the results of more comprehensive studies, such as the mass balance study involving the modeling of selected toxic substances in Green Bay initiated in 1987 by the U. S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and University of Wisconsin Sea Grant Program. These more general studies are helping to define and quantify those processes and factors that affect the presence of toxic substances in the Great Lakes environment, and that determine the severity of the toxic substance pollution problem.

Water Quality and Sediment Monitoring: The above-recommended plan components should provide substantially improved water quality conditions within the Milwaukee Harbor estuary. It is also important that a sound program for continuing water quality monitoring be established to document the extent to which desired water use objectives are being met over time. The intent of the monitoring program would be to analyze the achievement of the water quality standards supporting the recommended water use objectives, as well as the potential to raise those objectives; to help characterize any long-term trends in water quality conditions; and to demonstrate the specific benefits of the recommended operation of the existing flushing tunnels and proposed instream aerators.

Table 46

RECOMMENDED WATER SAMPLING STATIONS FOR A CONTINUOUS WATER QUALITY MONITORING PROGRAM

Sampling Station Designation	Water Body	Location	River Mile
RIV-5	Upstream Milwaukee River	North Avenue Dam	3.10
RIV-10	Upstream Menomonee River	S. 38th Street	2.78
RIV-13	Upstream Kinnickinnic River	S. 9th Place	3.08
RIV-6	Milwaukee River Estuary	Walnut Street	2.25
RIV-7	Milwaukee River Estuary	Wells Street	1.41
RIV-8	Milwaukee River Estuary	Broadway Street	0.63
RIV-15	Milwaukee River Estuary	C&NW Railway	0.44
RIV-11	Menomonee River Estuary	Muskego Avenue	0.92
RIV-17	Menomonee River Estuary	S. 2nd Street	0.06
RIV-14	Kinnickinnic River Estuary	S. 1st Street	1.43
RIV-18	Kinnickinnic River Estuary	Greenfield Avenue Extended	0.57
RIV-19	Kinnickinnic River Estuary	Jones Island Ferry	0.15
OH-1	Inner Harbor Channel to Outer Harbor	Hoan Bridge	0.00
OH-3	Outer Harbor	Central Portion	- -
OH-5	Outer Harbor	Breakwater-North Fairwater Gap	- -
OH-9	Outer Harbor	Breakwater-South Fairwater Gap	- -

Source: SEWRPC.

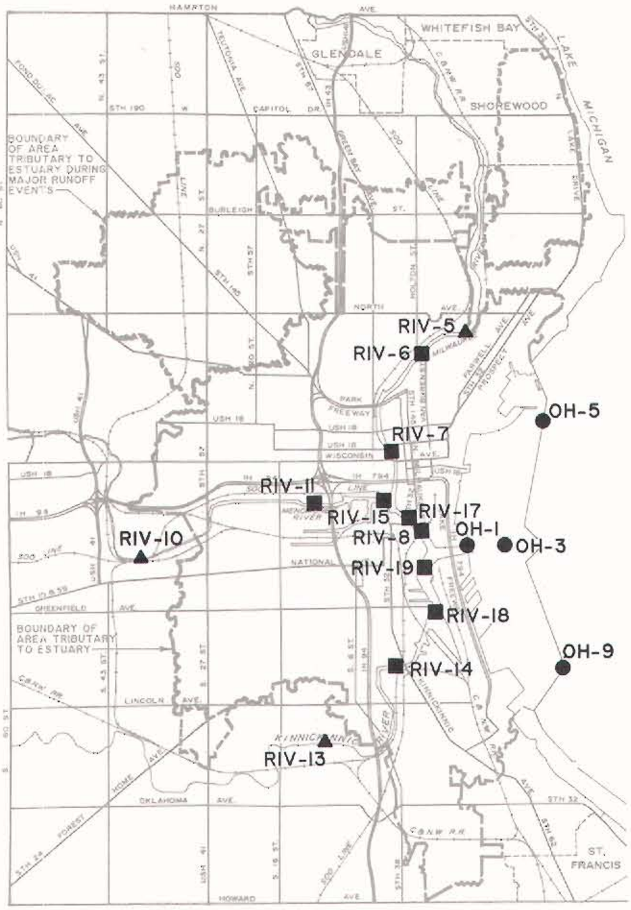
It is recommended that the baseline water quality sampling program which was conducted by the Milwaukee Metropolitan Sewerage District from 1981 through 1984 be continued in order to monitor the impacts of the recommended plan on the Milwaukee Harbor estuary. This water quality sampling program should be coordinated with similar sampling programs which may be developed to assess the water quality conditions of surface waterways upstream of the estuary, and to evaluate the impacts of discharges from the District's sewage treatment plants on the outer harbor and Lake Michigan. The sampling should be conducted at the three upstream river stations, nine inner harbor stations, and four outer harbor stations, listed in Table 46 and shown on Map 12. The sampling should be conducted on a monthly basis from October through April—except when precluded by ice conditions—and on a weekly basis from May through September. All samples should be analyzed for temperature, pH, dissolved oxygen, fecal coliform organisms, total solids, total suspended solids, volatile suspended solids, total phosphorus, soluble phosphorus, ammonia nitrogen, 5-day biochemical oxygen demand, chlorophyll-a, cadmium, copper, lead, and zinc. Both acid-soluble and total concentrations of the metals should be measured. Mid-depth water samples should be collected at the upstream stations, and surface, mid-depth, and bottom water samples should be collected at the inner harbor and outer harbor stations.

It is also recommended that at five-year intervals a more intensive monitoring program be conducted. Under this program, all 34 baseline sampling stations listed in Chapter IV of Volume One of this report would be sampled on a weekly basis for a one-year period. These samples would be analyzed for all of the water quality and biological indicators listed for the baseline sampling program. In addition, it is recommended that the bottom sediments be sampled at five-year intervals. Sediment core samples would be collected at the eight inner harbor stations and the two outer harbor stations listed in Table 47 and shown on Map 13. All sediment core samples should be analyzed for total solids, total volatile solids, total organic carbon, chemical oxygen demand, total Kjeldahl nitrogen, ammonia nitrogen, total phosphorus, lead, zinc, copper, cadmium, and polychlorinated biphenyls (PCB's).

In addition to the water quality monitoring recommendations set forth above, it is recommended that at five-year intervals a biological monitoring

Map 12

RECOMMENDED SAMPLING STATIONS FOR A CONTINUOUS WATER QUALITY MONITORING PROGRAM



LEGEND

▲ UPSTREAM STATION

■ INNER HARBOR STATION

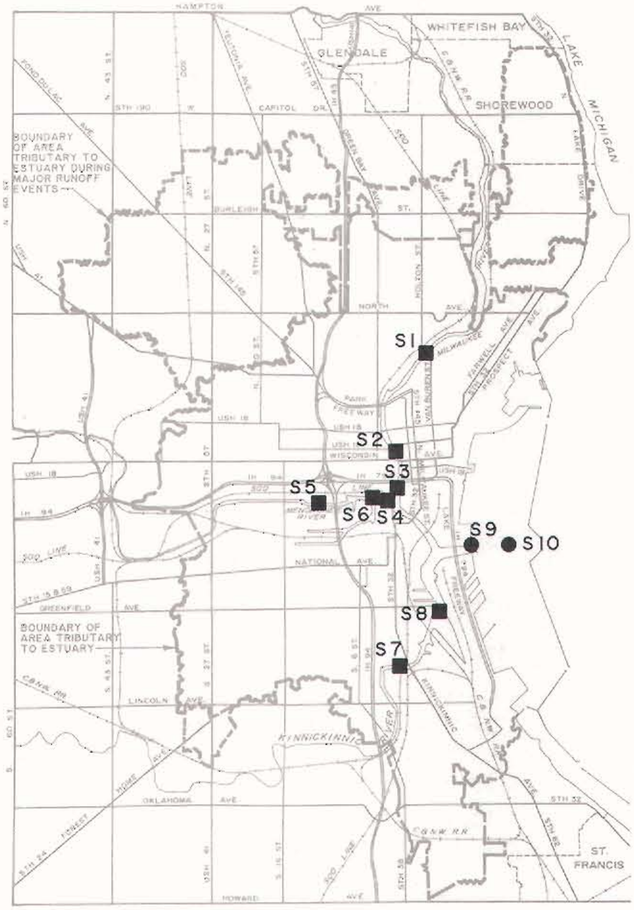
● OUTER HARBOR STATION

To help monitor the achievement of the recommended water quality standards, to help characterize any long-term trends in water quality conditions, and to demonstrate the specific benefits of the recommended water quality management measures, it is recommended that a water quality sampling and reporting program be continued at three upstream river stations, nine inner harbor stations, and four outer harbor stations. The sampling should be conducted on a monthly basis from October through April, and on a weekly basis from May through September. The proposed sampling station locations are listed in Table 46. In addition, a sediment and biological monitoring and reporting program is recommended to be implemented.

Source: SEWRPC.

Map 13

RECOMMENDED BOTTOM SEDIMENT SAMPLING STATIONS FOR THE INTENSIVE MONITORING PROGRAM AT FIVE-YEAR INTERVALS



LEGEND

■ INNER HARBOR STATION

● OUTER HARBOR STATION

The stabilization of the bottom sediments, once combined sewer overflows are abated, as well as the concentrations of important contaminants in the sediments, should be evaluated on a periodic basis. It is recommended that sediment core samples be collected and analyzed at five-year intervals at eight inner harbor stations and at two outer harbor stations, with reports prepared summarizing the data. The station locations are listed in Table 47. In addition to sediment monitoring, a water quality and biological conditions monitoring and reporting program is recommended to be implemented.

Source: SEWRPC.

Table 47

RECOMMENDED BOTTOM SEDIMENT SAMPLING STATIONS FOR THE MILWAUKEE HARBOR ESTUARY

Sampling Station Designation	Water Body	Location	River Mile
S1	Milwaukee River Estuary	Walnut Street	2.25
S2	Milwaukee River Estuary	Wells Street	1.41
S3	Milwaukee River Estuary	St. Paul Avenue	1.08
S4	Milwaukee River Estuary	C&NW Railway Bridge	0.44
S5	Menomonee River Estuary	Muskego Avenue	0.92
S6	Menomonee River Estuary	Burnham Canal	0.08
S7	Kinnickinnic River Estuary	S. 1st Street	1.43
S8	Kinnickinnic River Estuary	Greenfield Avenue Extended	0.53
S9	Inner Harbor Channel to Outer Harbor	Hoan Bridge	0.00
S10	Outer Harbor	Central Portion	- -

Source: SEWRPC.

program be conducted. This program would consist of the conduct of a fishery survey and of an inventory of the other biota, including benthic invertebrates, zooplankton, and algae; and a review of the habitat characteristics of the estuary, including stream bank vegetation, bottom scouring and deposition, and bottom substrate. The fish and other biota surveys should be conducted in the areas of the locations used in the fish survey described in Chapters IV and VI of Volume One of this report. Habitat evaluation should be conducted throughout the estuary. The total recommended water quality monitoring program would entail a capital cost of about $200,000, and an annual operation and maintenance cost of about $110,000.

Ability of the Recommended Plan to Meet the Water Use Objectives and Supporting Water Quality Standards

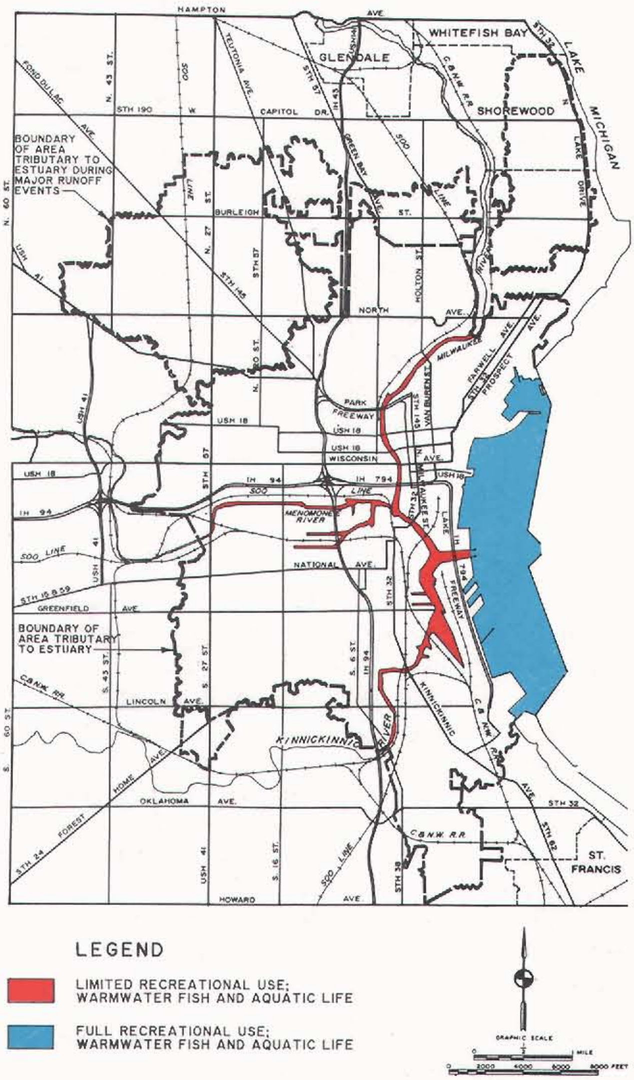
An initially recommended set of water use objectives and supporting water quality standards for the Milwaukee Harbor estuary was set forth in Chapter II of this volume. The initially recommended objectives were: full recreational use and maintenance of a warmwater fishery for the Milwaukee River portion of the inner harbor and for the outer harbor, and maintenance of limited recreational use and of a limited fishery in the Menomonee and Kinnickinnic River portions of the inner harbor. Quantitative analyses of the ability of the alternative plans to achieve these objectives, as well as fully "fishable-swimmable" water use objectives, were conducted using the water quality simulation models developed under the study. Initial analyses of the potential to achieve the supporting standards associated with the water use objectives resulted in the conclusion that the fecal coliform standards associated with the full recreational use objective were not achievable in the inner harbor portion of the estuary. Thus, the subsequent detailed analyses of the alternative plans evaluated the achievement of standards supporting limited recreational use within the inner harbor, and full recreational use within the outer harbor.

In order to evaluate the water use objectives being considered on a uniform basis, the achievement of standards for both a warmwater fishery and a limited fishery was also determined for all portions of the estuary.

Further quantitative analyses of the water quality conditions expected to be provided under the recommended water water quality management plan indicated that the plan would allow the general achievement of limited recreational use and the maintenance of a warmwater fishery in the Milwaukee River estuary, Menomonee River estuary, and Kinnickinnic River estuary; and of full recreational use and the maintenance of a warmwater fishery in the outer harbor. The final water use objectives for the Milwaukee Harbor estuary attendant to the recommended plan are shown on Map 14.

Map 14

FINAL RECOMMENDED WATER USE OBJECTIVES FOR THE MILWAUKEE HARBOR ESTUARY



Based upon the findings of this study, the initial water use objectives shown on Map 11 were reconsidered and revised. The final recommended water use objectives envision the maintenance of full—or whole body contact—recreational use and the maintenance of a healthy warmwater fishery only for the outer harbor. The maintenance of limited recreational use—fishing and boating—and the maintenance of a healthy warmwater fishery was recommended for the inner harbor. The study concluded that the recommended fecal coliform standards supporting full recreational use could not—as a practical matter—be met within the inner harbor because of high bacterial loadings from upstream sources. The attainment of these recommended objectives would represent a major improvement in water quality conditions in the Milwaukee Harbor estuary.

Source: SEWRPC.

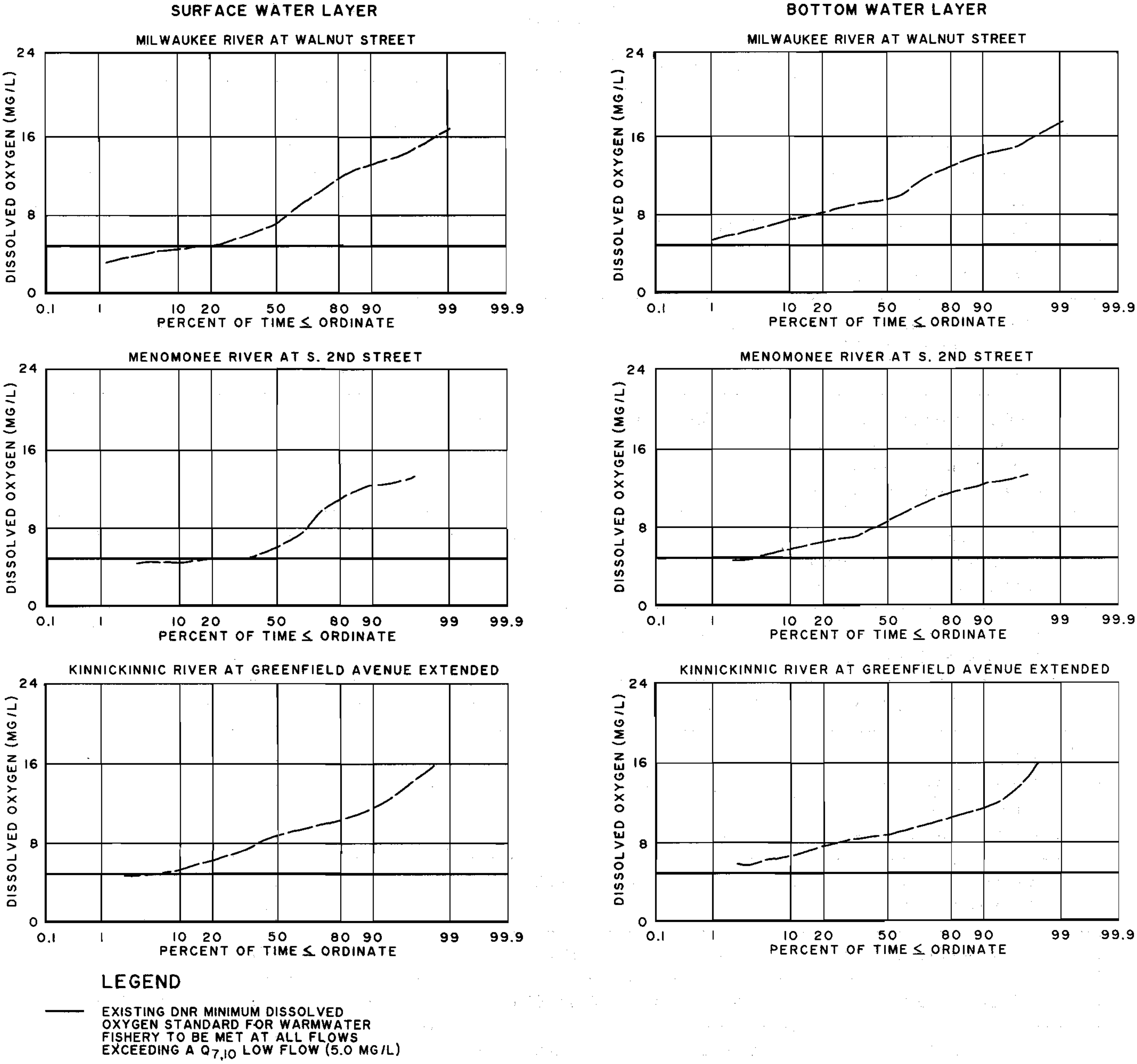
The water quality analyses for the recommended plan presented above indicated that violations of the fecal coliform standards supporting limited recreational use may be expected to occur within the Menomonee River estuary. However, a substantial reduction in fecal coliform levels would nevertheless be provided. The existing mean fecal coliform levels, which exceed 20,000 MPN/100 ml, may be expected to be reduced by more than 90 percent, to levels less than 2,000 MPN/100 ml. The limited recreational use standard allows a fecal coliform level of 2,000 MPN/100 ml to be exceeded 10 percent of the time. The estimated fecal coliform level in the Menomonee River estuary would exceed 2,000 MPN/100 ml from 10 to 50 percent of the time, depending on the location. The estimated fecal coliform level exceeded 10 percent of the time ranges from 2,000 to 10,000 MPN/100 ml, depending on the location. Depending on the location, the estimated fecal coliform levels range from meeting the fecal coliform standard to being about five times higher than the standard.

In order to provide the Wisconsin Department of Natural Resources with additional information on the dissolved oxygen levels compared to the present minimum standard of 5.0 mg/l supporting a warmwater fishery under the worst case, plots of the daily minimum dissolved oxygen levels versus percent of time the standards are achieved were prepared, as shown in Figure 90. The plots, which were prepared for a representative station on each of the three river portions of the estuary, show that the daily minimum dissolved oxygen level would be below 5.0 mg/l about 15, 20, and 8 percent of the time in the surface water layers of the Milwaukee, Menomonee, and Kinnickinnic River portions of the estuary, respectively. Within the bottom water layers, the daily minimum dissolved oxygen levels would be below 5.0 mg/l about 8 percent of the time in the Menomonee River estuary. Daily minimum dissolved oxygen levels in the bottom water layers of the Milwaukee and Kinnickinnic River estuaries would essentially always exceed 5.0 mg/l.

A variation of the recommended plan described above would provide for operation of the flushing tunnels and the Menomonee River aeration systems at all times when the dissolved oxygen levels declined to less than 5 mg/l. The tunnels would be operated even when the daily average dissolved oxygen level was above 5 mg/l if the minimum oxygen level would otherwise be below 5 mg/l. This analysis indicated that, as noted above, the tunnels would have to be operated about 15, 20, and 8 percent of the time for the Milwaukee, Menomonee, and Kinnickinnic River portions of the estuary, respectively. However, it is expected that the tunnels and aeration system together

Figure 90

DAILY MINIMUM DISSOLVED OXYGEN PROBABILITY PLOTS FOR THE RECOMMENDED PLAN



Source: HydroQual, Inc., and SEWRPC.

would be operated only during a portion of this time. This combined operation of the tunnels and the Menomonee River aeration system would result in an increase in the operation and maintenance costs of about $30,000 per year.

Cost

The costs of the recommended water quality management plan element are summarized in Table 48. Implementation of the plan would entail a capital cost of about $368.8 million, and an annual operation and maintenance cost of about $2.5 million. The 50-year present worth of the plan would approximate $340 million, and the equivalent annual cost would be about $21.6 million. The primary plan components would account for about 99 percent of the capital cost, and about 95 percent of the operation and maintenance cost. The auxiliary plan components would account for the remaining 1 percent of the capital cost and 5 percent of the operation and maintenance cost. Of the total plan cost, 99 percent of the capital cost and

Table 48

ESTIMATED COST OF THE RECOMMENDED WATER QUALITY MANAGEMENT PLAN ELEMENT FOR THE MILWAUKEE HARBOR ESTUARY

Plan Component	Capital: 1986-2000		Average Annual Operation and Maintenance		50-Year Present Worth[a]		Equivalent Annual	
	Cost (millions)	Percent of Total	Cost	Percent of Total	Cost (millions)	Percent of Total	Cost	Percent of Total
Primary Plan								
1. Abatement of Combined Sewer Overflows at a 0.7-Year Level of Protection[b]	$204.0	55.3	$ 617,000	24.8	$180.0	52.9	$ 11,420,000	52.9
2. Elimination of Separate Sanitary Sewer Flow Relief Devices[b]	134.4	36.4	923,000	37.2	123.4	36.3	7,830,000	36.3
3. Implementation of Nonpoint Source Abatement Measures Under the Milwaukee River Priority Watersheds Program[b]	25.8	7.0	750,000	30.2	29.69	8.7	1,880,000	8.7
4. Operation of Existing Flushing Tunnels in Milwaukee and Kinnickinnic River Estuaries	0.3	0.1	70,000	2.8	1.85	0.5	120,000	0.5
5. Instream Aeration of the Menomonee River Estuary	0.3	0.1	10,000	0.4	0.12	0.1	8,000	0.1
Primary Plan Subtotal	$364.8	98.9	$2,370,000	95.4	$335.06	98.5	$21,258,000	98.5
Auxiliary Plan								
1. Salt, Scrap Metal, and Other Material Storage	$ 0.6	0.2	$ --	--	$ 0.53	0.2	$ 30,000	0.2
2. Toxic Substance Study	3.2	0.8	--	--	2.85	0.8	180,000	0.8
3. Water Quality and Biological Monitoring Program	0.2	0.1	114,000	4.6	1.76	0.5	110,000	0.5
Auxiliary Plan Subtotal	$ 4.0	1.1	$ 114,000	4.6	$ 5.14	1.5	$ 320,000	1.5
Total Plan Cost	$368.8	100.0	$2,484,000	100.0	$340.20	100.0	$21,578,000	100.0
Cost of Previously Committed Measures	$364.2	98.8	$2,290,000	92.2	$333.09	97.9	$21,130,000	97.9
Net Additional Cost of Recommended Plan Over and Above Committed Measures	$ 4.6	1.2	$ 194,000	7.8	$ 7.11	2.1	$ 448,000	2.1

NOTE: All costs are in 1986 dollars.

[a] *The present worth was calculated at an interest rate of 6 percent.*

[b] *Previously committed measures, and measures expected to be implemented in order to improve water quality conditions upstream of the estuary.*

Source: SEWRPC.

92 percent of the operation and maintenance cost is for already committed improvements set forth in the Milwaukee Metropolitan Sewerage District pollution abatement program and the Wisconsin Department of Natural Resources nonpoint source priority watershed plans covering the upstream watersheds.

EVALUATION OF POTENTIAL MODIFICATIONS TO THE RECOMMENDED PLAN

In the selection of a recommended plan, it became apparent that certain modifications to the plan deserved explicit consideration. These modifications were evaluated to determine whether or not they could provide substantial additional water quality benefits. The potential modifications to the plan considered included:

1. The implementation of urban nonpoint source abatement measures within the drainage area tributary to the estuary;

2. The construction and operation of a new flushing tunnel, which would discharge to the Menomonee River at S. 25th Street, instead of instream aeration; and

3. The operation of the existing Milwaukee River and Kinnickinnic River flushing tunnels and a new Menomonee River flushing tunnel at all times, rather than just when the dissolved oxygen levels would otherwise be less than 5 mg/l.

Under the first modification to the recommended plan, additional urban nonpoint source abatement measures would be implemented. The urban nonpoint source abatement measures assumed would be those that may be expected to be recommended under the Milwaukee and Menomonee River priority watershed programs, as described in the abatement of nonpoint sources of pollution alternative section. The implementation of urban nonpoint source pollution abatement measures may be expected to increase the nonpoint source reductions of organic matter, nutrients, and fecal coliform organism loadings by about 50 percent over the reductions achieved under the recommended plan; and to double the reductions in lead loadings. The abatement of urban nonpoint sources of pollution, however, would entail an additional capital cost of about $170 million, and an annual operation and maintenance cost of about $3 million.

Under the second modification, a new flushing tunnel discharging to the Menomonee River at S. 25th Street would be installed instead of the recommended instream aeration system. This tunnel would be operated whenever the dissolved oxygen levels in the Menomonee River would otherwise decline to less than 5 mg/l. Construction of the new flushing tunnel would entail an additional capital cost of about $24 million, and an annual operation and maintenance cost of about $25,000.

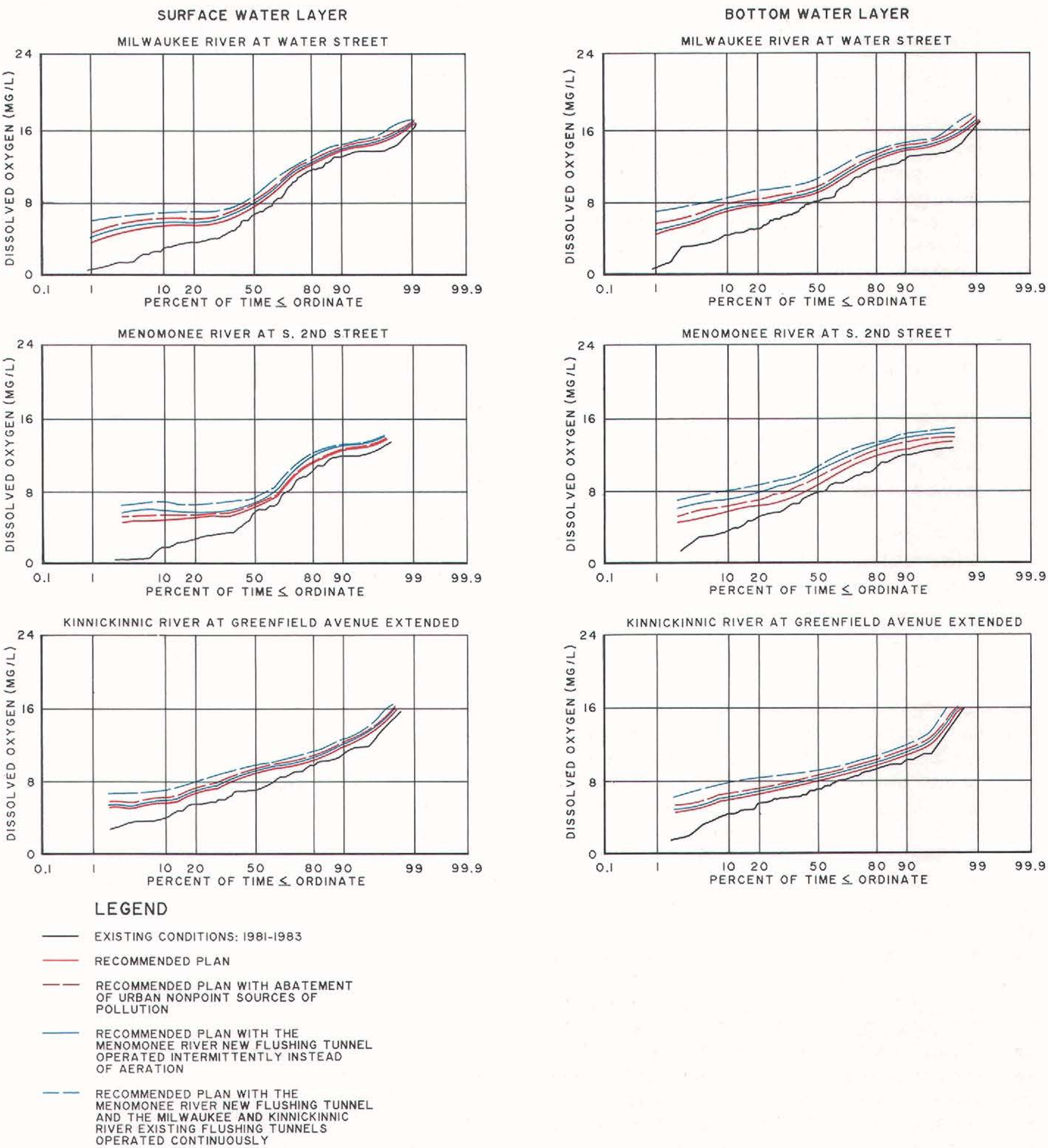
Under the third modification, the existing Milwaukee and Kinnickinnic River flushing tunnels, as well as a new Menomonee River flushing tunnel, would be operated continuously, rather than only when the dissolved oxygen levels declined to less than 5 mg/l. The continuous operation of the existing flushing tunnels would entail an additional annual operation and maintenance cost of about $760,000. The construction and continuous operation of a new Menomonee River flushing tunnel would entail an additional capital cost of about $24 million, and an annual operation and maintenance cost of about $200,000.

The impact of these modifications on dissolved oxygen levels at three representative stations within the inner harbor are illustrated in Figures 91, 92, and 93. Figure 91 shows the probability distribution of dissolved oxygen levels under each potential modification to the recommended plan. The figure indicates that operating the flushing tunnels continuously would provide the greatest benefit, increasing the dissolved oxygen levels by 1 to 2 mg/l above those expected under the recommended plan.

The plan modifications, however, would have a minimal impact on the dissolved oxygen levels during critical low-flow periods, and on the achievement of the dissolved oxygen standards supporting a warmwater fishery. Under the recommended plan, the flushing tunnels and aerators would be operated only during low-flow conditions. Figure 92 shows the dissolved oxygen levels expected under low-flow ($Q^{7,10}$) conditions, as simulated by the steady-state model. The modifications may be expected to increase the dissolved oxygen levels anticipated under the recommended plan by less than 1 mg/l. Figure 93 illustrates the anticipated achievement of the 1-day mean dissolved oxygen standard supporting a warmwater fishery, which would apply from March 15 to July 31. As shown in the figure, under the recommended plan, as well as any of the considered modifications to that plan, that standard would be fully achieved.

Figure 91

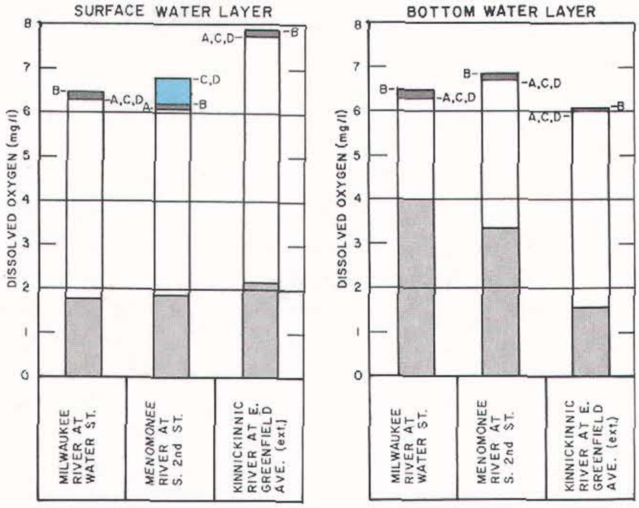
DISSOLVED OXYGEN PROBABILITY PLOTS FOR EXISTING CONDITIONS, THE RECOMMENDED PLAN, AND POTENTIAL MODIFICATIONS TO THE RECOMMENDED PLAN



Source: HydroQual, Inc., and SEWRPC.

Figure 92

IMPACT OF POTENTIAL MODIFICATIONS TO THE RECOMMENDED PLAN ON DISSOLVED OXYGEN LEVELS UNDER LOW-FLOW, STEADY-STATE CONDITIONS



LEGEND

EXISTING CONDITIONS: 1981-1983

A RECOMMENDED PLAN

B RECOMMENDED PLAN WITH ABATEMENT OF URBAN NONPOINT SOURCES OF POLLUTION

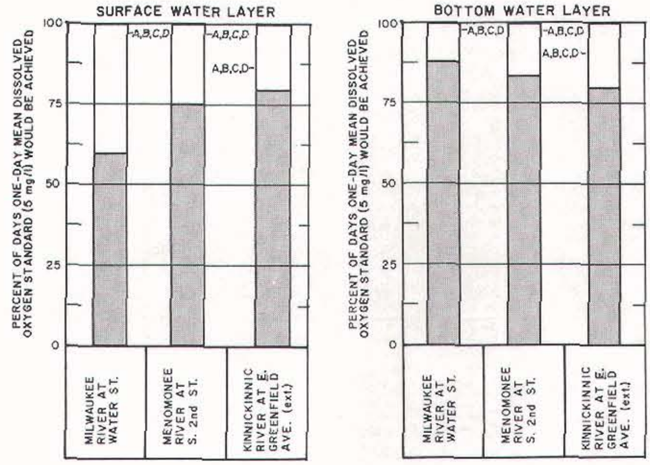
C RECOMMENDED PLAN WITH THE MENOMONEE RIVER NEW FLUSHING TUNNEL OPERATED INTERMITTENTLY INSTEAD OF AERATION

D RECOMMENDED PLAN WITH THE MENOMONEE RIVER NEW FLUSHING TUNNEL AND THE MILWAUKEE AND KINNICKINNIC RIVER EXISTING FLUSHING TUNNELS OPERATED CONTINUOUSLY

Source: HydroQual, Inc., and SEWRPC.

Figure 93

IMPACT OF POTENTIAL MODIFICATIONS TO THE RECOMMENDED PLAN ON THE ACHIEVEMENT OF THE ONE-DAY MEAN DISSOLVED OXYGEN STANDARD FOR MARCH 15-JULY 31



LEGEND

EXISTING CONDITIONS: 1981-1983

A RECOMMENDED PLAN

B RECOMMENDED PLAN WITH ABATEMENT OF URBAN NONPOINT SOURCES OF POLLUTION

C RECOMMENDED PLAN WITH THE MENOMONEE RIVER NEW FLUSHING TUNNEL OPERATED INTERMITTENTLY INSTEAD OF AERATION

D RECOMMENDED PLAN WITH THE MENOMONEE RIVER NEW FLUSHING TUNNEL AND THE MILWAUKEE AND KINNICKINNIC RIVER EXISTING FLUSHING TUNNELS OPERATED CONTINUOUSLY

Source: HydroQual, Inc., and SEWRPC.

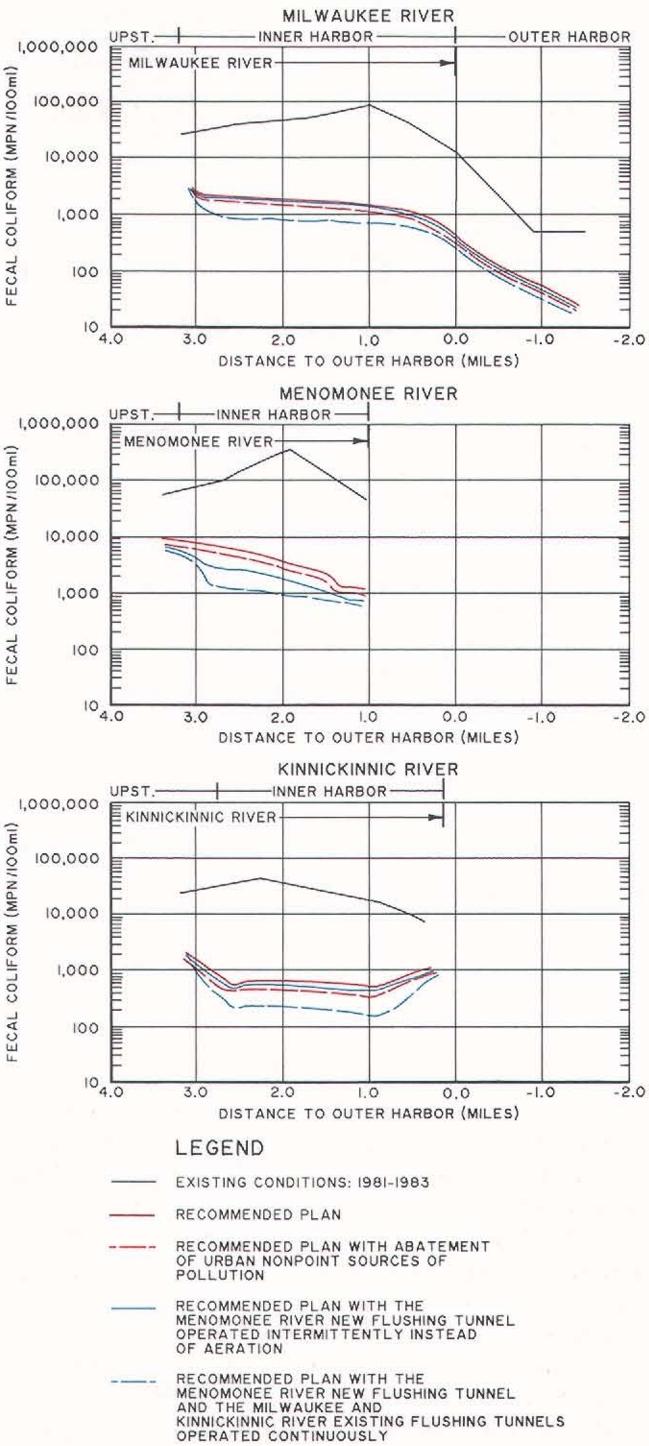
The effect of modifying the recommended plan on fecal coliform levels expected to be exceeded about 10 percent of the time is shown in Figure 94. The figure indicates that the abatement of urban nonpoint sources of pollution would be expected to result in only a minor reduction in fecal coliform levels. The construction and operation of a new flushing tunnel to discharge to the Menomonee River would provide an additional 40 to 50 percent reduction in fecal coliform levels within the Menomonee River estuary. Operating the flushing tunnels continuously would provide the greatest benefits, resulting in an additional 50 to 75 percent reduction in fecal coliform levels in comparison to the recommended plan.

Figure 95 shows the impact of these reduced fecal coliform levels on the achievement of the fecal coliform standards supporting limited recreational use. Continuous operation of the existing Milwaukee and Kinnickinnic River flushing tunnels and of a new Menomonee River flushing tunnel is the only modification considered that would meet the recommended fecal coliform standards. Without continuous operation of the tunnels, the monthly geometric mean standard of 1,000 MPN/100 ml may be expected to be the most difficult standard to achieve.

The effect of modifying the recommended plan on lead levels is shown in Figure 96. The abatement

Figure 94

IMPACT OF POTENTIAL MODIFICATIONS TO THE RECOMMENDED PLAN ON THE FECAL COLIFORM LEVELS EXCEEDED 10 PERCENT OF THE TIME



Source: HydroQual, Inc., and SEWRPC.

of urban nonpoint sources of pollution may be expected to result in a reduction of approximately 20 to 30 percent from the levels expected under the recommended plan. The greatest benefits would again result from the continuous operation of the flushing tunnels. Total lead levels expected under the recommended plan, however, would be well below the chronic and acute toxicity standards for acid-soluble lead.

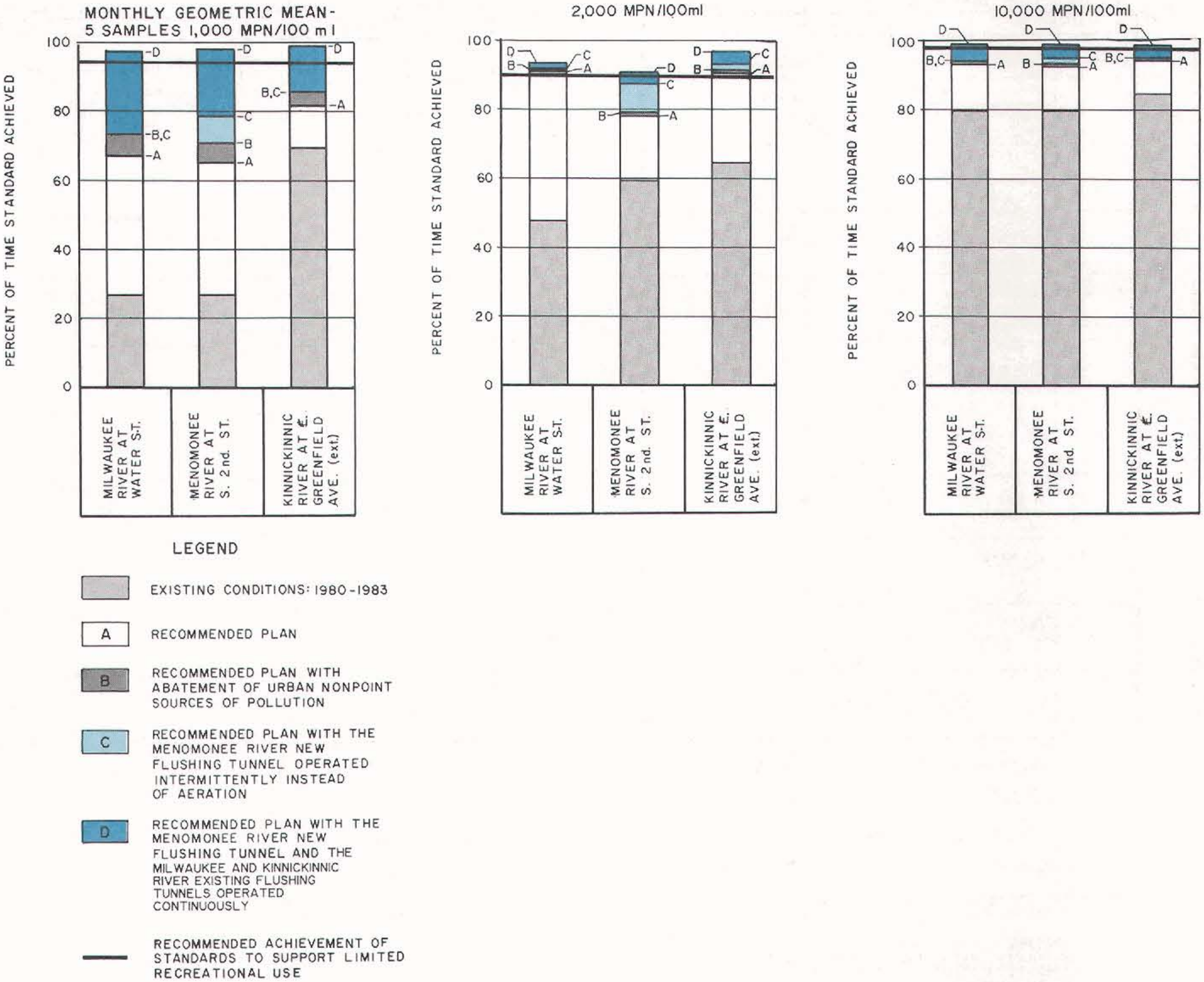
In summary, the evaluation of potential modifications to the recommended plan suggests that only the continuous operation of three flushing tunnels would provide significant water quality benefits beyond those provided by the plan. The additional abatement of urban nonpoint sources of pollution is not justified because of the high cost and the marginal water quality benefits that would be provided within the estuary. The control of nonpoint sources of pollution in some urban areas may be warranted, however, to protect certain water bodies located upstream of the estuary. Although the construction and operation of a new flushing tunnel that would discharge to the Menomonee River would provide significant water quality benefits, especially with regard to fecal coliform organisms, the construction of that tunnel is not recommended because of its high cost and because it does not appear that the added water quality benefits would substantially change the water uses. It is unlikely that the Menomonee River estuary would be used to any significant extent for partial body contact recreational uses because of the character of the urban development directly adjacent to that estuary, and the character of the channel itself. The continuous operation of the existing Milwaukee River and Kinnickinnic River flushing tunnels is also not recommended because the expected reductions in fecal coliform levels would not significantly reduce the risks of contracting waterborne diseases.

SUMMARY

This chapter documents the design, test, and evaluation of alternative water quality management plans for the Milwaukee Harbor estuary. A total of 10 alternative plans were developed and evaluated. The alternative plans considered included measures to reduce loadings of pollutants from areas tributary to, or upstream of, the estuary, and instream measures to mitigate the adverse impacts of pollutants within the estuary itself.

Figure 95

IMPACT OF POTENTIAL MODIFICATIONS TO THE RECOMMENDED PLAN ON THE ACHIEVEMENT OF THE FECAL COLIFORM STANDARDS SUPPORTING LIMITED RECREATIONAL USE



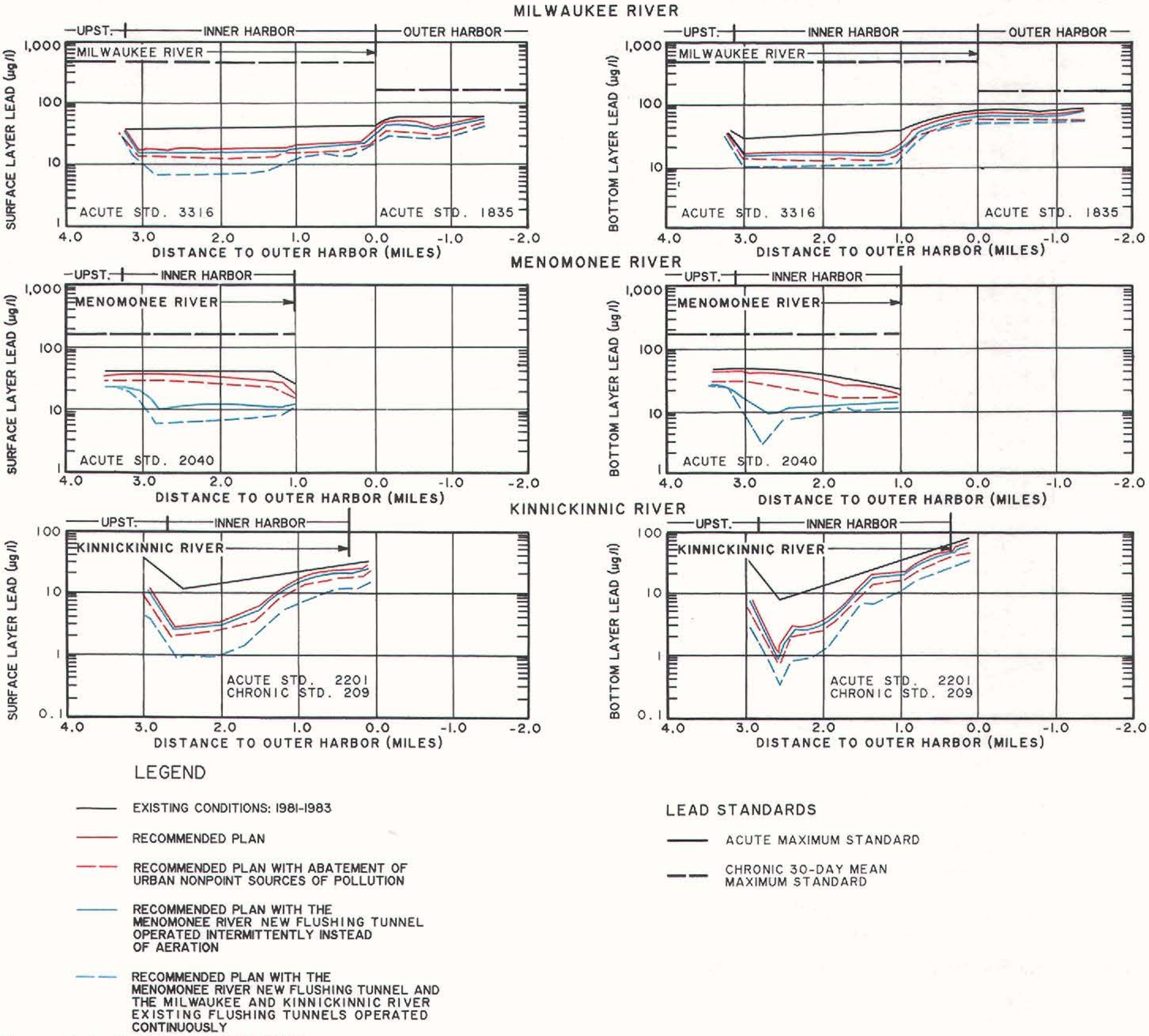
Source: Milwaukee Metropolitan Sewerage District; HydroQual, Inc., and SEWRPC.

Utilizing the water quality simulation models developed under the study, an evaluation was conducted of the ability of the various alternative plans to achieve the water quality standards supporting limited recreational use and the maintenance of a warmwater fishery or a limited fishery within the inner harbor, and full recreational use and the maintenance of a warmwater fishery within the outer harbor. Analyses indicated that the fecal coliform standards supporting full recreational use could not practicably be achieved within the inner harbor under any alternative plan.

The comparison of the alternative plans focused on the associated costs and on the impacts of the plans on concentrations of dissolved oxygen, fecal coliform, ammonia nitrogen, lead, cadmium, copper, and zinc. Dissolved oxygen problems were evaluated under critical steady-state, low-streamflow conditions. The components of the dissolved oxygen deficit, the diurnal fluctuations in dissolved oxygen levels, and the achievement of the dissolved oxygen standards under various streamflow and temperature conditions were also analyzed. Total and un-ionized ammonia nitrogen levels were

Figure 96

IMPACT OF POTENTIAL MODIFICATIONS TO THE RECOMMENDED PLAN ON MEDIAN LEAD LEVELS



Source: HydroQual, Inc., and SEWRPC.

estimated under critical steady-state, low-streamflow conditions for each alternative plan. A statistical water quality model was utilized to calculate fecal coliform and total lead levels within the water column. Pollution source and loading data and sediment quality characteristics were used to estimate the impact of the alternative plans on the metal concentrations in the bottom sediments of the inner harbor.

The committed action alternative calls for the implementation of previously committed water quality management measures, including: the abatement of combined sewer overflows at a 0.7-year level of protection; the elimination of separate sanitary sewer flow relief devices; and continued dredging of the estuary for maintenance of navigation. Pollutant loadings from combined sewer overflows would be reduced by about 97 percent. Water quality conditions within the estuary would not be suitable for limited recreational use or for the maintenance of either a warmwater or a limited fishery. The costs of this alternative are considered to be committed. This alternative has an equivalent annual cost of $19.2 million. These measures were therefore all included in the other alternative plans. The costs of these measures would also be added to all other alternatives considered.

The elimination of combined sewer overflows alternative calls for the provision of additional storage to virtually eliminate discharges from combined sewer overflows. Under this alternative, the water quality conditions within the inner harbor would be little better than under the committed action alternative. Other than the committed action alternative, this alternative has the highest cost, the equivalent annual cost being about $16.3 million.

The existing flushing tunnels subalternative calls for the continued operation of the flushing tunnels that discharge to the Milwaukee and Kinnickinnic River estuaries. Under this alternative, water quality standards for limited recreational use and for the maintenance of a warmwater fishery would be achieved in the Milwaukee and Kinnickinnic River estuaries, but violated in the Menomonee River estuary. The standards for limited recreational use and for the maintenance of a limited fishery would also be violated in the Menomonee River estuary. This alternative has a relatively low cost, the equivalent annual cost being about $110,000.

The Menomonee River new flushing tunnel subalternative calls for the continued operation of the existing flushing tunnels that discharge to the Milwaukee and Kinnickinnic River estuaries, and the construction of a new flushing tunnel which would discharge to the Menomonee River estuary near N. 25th Street. Under this alternative, all water quality standards supporting limited recreational use and the maintenance of a warmwater fishery would be met throughout the inner harbor. This alternative has a moderate cost, the equivalent annual cost being about $290,000.

The Menomonee River instream aeration alternative calls for the continued operation of the existing flushing tunnels, and the installation of four mechanical aerators to increase the dissolved oxygen levels in the Menomonee River estuary. Under this alternative, water quality standards for limited recreational use and for a warmwater fishery would be met in the Milwaukee and Kinnickinnic River estuaries. However, the fecal coliform standards for limited recreational use may be expected to be violated within the Menomonee River estuary. This alternative has a low cost, the equivalent annual cost being about $120,000.

The abatement of nonpoint sources of pollution alternative calls for the implementation of nonpoint source control measures to achieve the maximum level of control practicable. Under this alternative, the water quality conditions would be suitable for limited recreational use, but the standards for maintenance of both a warmwater fishery and a limited fishery may be expected to be violated throughout the inner harbor. This alternative has a high cost, the equivalent annual cost being about $11.7 million.

The reduction in point source phosphorus loadings alternative would reduce phosphorus loadings discharged from public sewage treatment plants to surface waters in the Milwaukee River watershed by about 90 percent. This reduction may be expected to have only a minimal impact on the chlorophyll-a and dissolved oxygen levels within the Milwaukee Harbor estuary. The water quality standards for limited recreational use and for maintenance of a warmwater or limited fishery would be violated throughout the inner harbor. This alternative has a high cost, the equivalent annual cost being about $2.9 million.

The modification/relocation of the WEPCo valley power plant outfalls alternative consists of three separate subalternatives—cooling tower, outfall diversion, and deep tunnel discharge. These subalternatives would eliminate the discharge of heated condenser cooling water from the power plant to the South Menomonee Canal. The existing flushing tunnels would also continue to discharge to the Milwaukee and Kinnickinnic River estuaries. The three subalternatives would provide similar water quality benefits. Water quality standards for limited recreational use and for the maintenance of a warmwater fishery would be met in the Milwaukee and Kinnickinnic River estuaries. The temperature of the Menomonee River estuary would be substantially reduced, and dissolved oxygen levels would improve enough to meet the water quality standards for the maintenance of a limited fishery. However, the fecal coliform standards for limited recreational use may be expected to be violated in the Menomonee River estuary. These subalternatives all have a moderate cost, with the equivalent annual costs ranging from $530,000 to $1,030,000.

The Menomonee River new flushing tunnel subalternative provides the best water quality conditions, and it is the only plan that would be expected to fully meet all of the water quality standards supporting limited recreational use and the maintenance of either a warmwater fishery or a limited fishery throughout the inner harbor. The existing flushing tunnels subalternative, the Menomonee River instream aeration alternative, and the modification/relocation of the WEPCo valley power plant outfalls alternative would also provide substantial water quality benefits, although in all cases, certain water quality standards supporting limited recreational use and/or the maintenance of either a warmwater or limited fishery would continue to be violated in the Menomonee River estuary. The committed action, elimination of combined sewer overflows, abatement of nonpoint sources of pollution, and reduction in point source phosphorus loadings alternatives would also result in improved water quality conditions, but the water quality standards supporting limited recreational use and the maintenance of either a warmwater or limited fishery would be significantly violated throughout the inner harbor.

Following careful consideration of the findings of the alternative plan evaluations, a recommended plan was selected by the Technical Advisory Committee created to guide the conduct of the study. That plan is the Menomonee River instream aeration alternative, along with the implementation of nonpoint source pollution abatement measures at a level of about 50 percent of the maximum achievable level of control, and the addition of three auxiliary plan elements. The recommended plan consists of the following primary plan components:

1. Abatement of combined sewer overflows at a 0.7-year level of protection by the provision of approximately 1,140 acre-feet of storage volume in deep tunnels for combined sewer overflows and excessive flows from the separately sewered area.

2. Elimination of all separate sanitary sewer flow relief devices by the expansion and upgrading of the Milwaukee Metropolitan Sewerage District's Jones Island and South Shore sewage treatment plants, new sewer construction, and the construction of the deep tunnel inline storage system.

3. Implementation of nonpoint source pollution abatement measures in order to improve water quality conditions upstream of the estuary, as well as within the estuary.

4. Continued operation of the existing flushing tunnels that discharge to the Milwaukee River just downstream of the North Avenue dam at a capacity of about 600 cubic feet per second (cfs), and to the Kinnickinnic River just downstream of S. Chase Avenue at a capacity of about 350 cfs, about 20 percent of the time, or about 740 hours per year.

5. Instream aeration of the Menomonee River estuary using four 25-horsepower mechanical aerators mounted on the N. 25th Street, N. 16th Street, and Soo Line bridge piers, or a pure oxygen diffuser system, which would be operated about 1,200 hours per year.

The recommended plan would also include the implementation of the following auxiliary plan components:

1. Control of stormwater runoff from the salt, scrap metal, and other material storage sites that lie within the direct drainage area to the estuary either by eliminating these sites, by moving the material to covered storage facilities, or by providing pollutant removal facilities such as retention storage ponds.

2. A study of toxic substances in the bottom sediments of the Milwaukee Harbor estuary, beginning in 1988, which would address the adoption of in-place sediment quality standards, the risk of the release of toxic substances from the sediments to the water column and biota, and the sources of the toxic substances in the bottom sediments.

3. A continuing water quality and sediment quality monitoring program, plus more intensive water quality, sediment quality, and biological conditions monitoring studies conducted at five-year intervals.

The recommended plan would entail a capital cost over the period 1986 through 2000 of about $368.8 million, an average annual operation and maintenance cost of about $2.5 million, a 50-year present worth of about $340.2 million, and an equivalent annual cost of approximately $21.6 million. Of the total annual cost, about $21.3

million, or 98.5 percent, would be for the primary plan components, while the remaining $0.3 million, or 1.5 percent, would be for the auxiliary plan components. About 97.9 percent of the total annual plan cost would be required for the implementation of those plan components which were either previously committed or expected to be implemented to control water pollution upstream of, as well as within, the estuary—that is, the abatement of combined sewer overflows, the elimination of separate sanitary sewer flow relief devices, and the implementation of nonpoint source abatement measures under the Milwaukee River Priority Watersheds Program.

Upon implementation of the recommended water quality management plan, the outer harbor should be suitable for full recreational use and the maintenance of a warmwater fishery, and the inner harbor should be suitable for limited recreational use and the maintenance of a warmwater fishery, with one exception—the coliform standard for limited recreational use. Violations of the fecal coliform standards supporting limited recreational use may be expected to continue to occur within the Menomonee River estuary. Fecal coliform levels in the Menomonee River estuary, while not fully meeting the standards, would be reduced by at least 90 percent.

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Chapter V

ALTERNATIVE DREDGING AND SPOILS DISPOSAL MEASURES

INTRODUCTION

One of the objectives of the Milwaukee Harbor estuary planning program is to prepare a plan that will facilitate harbor maintenance dredging and the environmentally safe disposal of the resulting spoil. Historically, adequate water depths were maintained in the Milwaukee Harbor by dredging, loading the dredged materials into scows, and transporting the scows to a deep-water portion of Lake Michigan, where the dredged materials were released and allowed to sink. In the mid-1960's, however, with an increasing awareness of and concern over water quality problems in the Great Lakes, the disposal of dredged materials in the open waters of Lake Michigan came under question. In November 1969, the U. S. Environmental Protection Agency (EPA) took core and bottom sediment samples in the northern outer harbor area. The results of this sampling effort indicated that the overlying silt layer was heavily polluted and that the underlying clay layer was moderately polluted. Although the samples taken by the EPA may not have been representative of the bottom materials of the entire Milwaukee Harbor estuary, the EPA recommended that all polluted dredged materials be placed in a confined disposal facility and not dumped into the open waters of Lake Michigan. In 1970, the Wisconsin Department of Natural Resources adopted regulations prohibiting the dumping of dredge spoils—whether polluted or nonpolluted—in state waters, citing the need for further evaluation of the environmental impacts of dredging and the disposal of dredge spoils on navigation, fish and other aquatic life, water quality, and the general public interest.

In response to the prohibition of the disposal of dredge spoils in the open waters of Lake Michigan, the U. S. Army Corps of Engineers constructed a confined disposal facility along the shoreline in the southern portion of the outer harbor in 1975. This facility was intended to provide a short-term solution to the problem of the disposal of polluted dredged materials until a long-term solution was found. The confined disposal facility covers an area of approximately 52.6 acres and has an estimated capacity of 1.6 million cubic yards of dredge spoils—sufficient to contain the amount of material anticipated to be dredged from the Milwaukee Harbor over a 15- to 20-year period. At the end of this period, in the mid-1990's, when its capacity is reached, the area is intended to be regraded, landscaped, and converted to public recreational use.

Dye studies conducted by the U. S. Army Corps of Engineers indicated that the containment dikes of the confined disposal facility were not operating as designed in that some portions of the dike filtered and discharged water much faster than other portions. To alleviate this problem, the Corps has plans to install a clay liner along the dike walls to improve the filtering effectiveness of the dike. This project is scheduled for 1987.

Since the confined disposal facility represents only a temporary solution to the disposition of polluted dredge spoils, the development of a plan for the disposal of spoils was made a part of the Milwaukee Harbor estuary planning program. The purpose of this chapter is to describe the dredging activities needed to maintain the Milwaukee Harbor; estimate the quantities and describe the characteristics of existing and probable future dredged materials requiring disposal; and present the technical, economic, and environmental aspects of alternative dredge spoils disposal measures from among which a recommended disposal plan can be selected.

This chapter is organized as follows: A review of the legislation, rules, and regulations pertaining to dredging activities is presented, followed by a brief review of existing bottom conditions in the Milwaukee Harbor as related to the dredging regulations, which is followed by a summary description of existing dredging activities. Alternative dredging, dredge spoils transport, and spoils disposal measures are presented, along with a discussion of the need to maintain navigation and improve water quality and aquatic habitat.

REVIEW OF THE LEGISLATION, RULES, AND REGULATIONS PERTAINING TO DREDGING ACTIVITIES

There are a number of federal, state, and local laws and regulations governing dredging activities. Governmental agencies which may participate in the review and permitting processes necessary for dredging activities include the U. S. Army Corps of Engineers, the U. S. Environmental Protection Agency, the U. S. Fish and Wildlife Service, the Wisconsin Departments of Natural Resources and Administration, and county and municipal planning agencies. These agencies all have authority for controlling, monitoring, and permitting one or more phases of dredging and dredge spoil disposal activities.

Federal Regulations

River and Harbor Act of 1899: The earliest federal regulations significantly affecting dredging projects in the United States were embodied in the River and Harbor Act of 1899. This Act consolidated and codified numerous pieces of legislation concerning the use of navigable waters as enacted by Congress during the preceding 100 years. Stemming from the authority granted in this Act, the U. S. Army Corps of Engineers established a permit system in order to monitor filling, dredging, and construction projects in the navigable waters of the United States over which the Corps had jurisdiction. For more than half a century, the emphasis of the permit process was focused on the impact of proposed projects on navigation, with little or no attention given to the impact of such projects on the environment; and prior to 1970, dredging activities were not subject to a detailed environmental impact analysis by the Corps of Engineers.

Fish and Wildlife Coordination Act: In 1958, the Fish and Wildlife Coordination Act was adopted by Congress as a result of the growing concern about habitat destruction caused by the dredging and filling of nursery and feeding areas available for marine life. This Act stipulated that whenever any body of water is to be modified in any way, such as by dredging, the responsible department or agency must first consult with the U. S. Department of the Interior, Fish and Wildlife Service, as well as with the applicable state agency. This Act thus represents the first major federal legislation relating water resource development to the conservation of wildlife resources.

National Environmental Policy Act: Under the National Environmental Policy Act (NEPA), as adopted by Congress in 1969, the environmental effects of an action must be considered prior to the issuance of any federal permit. This may require the preparation of an environmental assessment and attendant environmental impact statement. Under provisions of this Act, the preparation of such assessments is to be coordinated with federal and state agencies and concerned public and private interest groups in order to provide an opportunity for comment by all interests concerned. Where significant adverse environmental, economic, or social impacts are expected, a full environmental impact statement is required. As a result of this Act, each permit application for a dredging project must be accompanied by sufficient information to allow the Corps of Engineers to assess the primary and secondary environmental impacts of the project.

Federal Water Pollution Control Act: In 1970 Congress adopted the Federal Water Pollution Control Act, and in 1972 adopted major amendments to the Act. The principal objective of the Act was to eliminate the discharge of pollutants into the navigable waters of the United States by 1985. The provisions of the amendments of 1972 included establishment of a permit system to be administered by the U. S. Environmental Protection Agency for the purpose of regulating the discharge of pollutants into surface waters of the United States. In order to attain this objective, the Act prohibited the discharge of any pollutant from a point source unless a permit was obtained. The Act granted the EPA the authority to issue such permits, under Section 402, provided that certain criteria and conditions were met. The EPA permit program is administered under the National Pollutant Discharge Elimination System (NPDES). The goal of this system is to eliminate pollution at its source through the development, implementation, and enforcement of water quality standards and effluent limitations.

The Federal Water Pollution Control Act amendments of 1972 also provided for the establishment of a permit system, under Section 404, to be administered by the U. S. Army Corps of Engineers working in cooperation with the EPA, in order to regulate the disposal of dredged or fill materials into surface waters of the United States, including navigable waters and adjacent wetlands. Thus, the Corps of Engineers and the EPA share responsibilities concerning the disposal of dredged materials, the Corps being the sole agency authorized to grant dredging or filling permits, and the EPA having an overriding authority with regard to the environmental effects of the disposal of dredged materials, acting on the advice of the U. S. Fish and Wildlife Service and the Wisconsin Department of Natural Resources.

The disposal of dredged materials in open waters is also regulated under Section 404 of that Act. Since dredgings are specifically included under the definition of a pollutant, the effluents from land-based dredged materials disposal sites may be subject to regulation as a point source under the National Pollutant Discharge Elimination System. Although the Corps of Engineers remains the sole regulating body responsible for administering permits for dredging projects, the authority granted the EPA through the administration of the Federal Water Pollution Control Act places environmental criteria on an equal basis with navigational criteria in the evaluation of applications for dredging permits.

Guidelines for the evaluation of Great Lakes harbor sediments have been established by the U. S. Environmental Protection Agency. The guidelines, which are presented in Chapter VI of Volume One of this report, are used to classify sediments as heavily polluted, moderately polluted, or nonpolluted. The overall classification of a sample is based on the most predominant classification of individual parameters. Additional factors such as elutriate test results, source of contamination, particle size distribution, benthic macroinvertebrate populations, color, and odor are also considered. Because of known bio-accumulations of mercury and polychlorinated biphenyls (PCB's), sediments which exceed these guideline values are classified as heavily polluted and unacceptable for open lake disposal no matter what the other data indicate. The pollution classifications of sediments with total PCB concentrations between 1.0 milligram per kilogram (mg/kg) and 10.0 mg/kg dry weight are to be determined on a case-by-case basis. Sediment classification guidelines for determining the suitability of dredge spoils for open water disposal were also presented in an October 1985 report by the Wisconsin Department of Natural Resources, entitled Report of the Technical Subcommittee on Determination of Dredge Material Suitability for In-Water Disposal.

Resource Conservation and Recovery Act: On October 21, 1976, the President signed Public Law 94-580, also known as the Resource Conservation and Recovery Act (RCRA). The overall objectives of the Act were to provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials and for the safe disposal of discarded materials, and to regulate the management of hazardous wastes.

Section 301 of that Act requires the EPA to define criteria and methods for identifying and listing hazardous wastes. In order to make this assessment, the EPA has developed a toxicant extraction procedure. Maximum concentrations of toxic substances for the classification of hazardous wastes are presented in Chapter VI of Volume One of this report. Dredge spoils that are classified as hazardous under the regulations must be disposed of in a special facility or landfill approved to accept hazardous wastes. No landfills in Wisconsin are currently approved to accept hazardous wastes.

Recent Federal Legislative Activities: Recently under review and revision by Congress were two bills which could impact harbor dredging activities and disposal alternatives: the Deep-Draft Navigation Act, and the Outer Continental Shelf Revenue Sharing Bill. The Deep-Draft Navigation Act would establish a user-fee and matching federal revenue system of funding the maintenance and improvement of harbors. The major implication of the bill for the Milwaukee Harbor is that the Milwaukee Board of Harbor Commissioners would be primarily responsible for administering the construction, operation, and maintenance activities of disposal facilities, with the U. S. Army Corps of Engineers providing technical assistance only. The bill would not, however, provide a legislative recommendation as to a particular disposal method for polluted dredge spoils. The Outer Continental Shelf Revenue Sharing Bill could impact Milwaukee Harbor dredge disposal plans by providing grant funds to the State for pilot projects, such as open-water disposal.

State Regulations

Wisconsin Administrative Code Chapter NR 347: Chapter NR 347 of the Wisconsin Administrative Code sets forth regulations for dredging projects on the beds of waterways. The chapter provides legal descriptions of dredging-related terms, lists required project and environmental information, and specifies how the Wisconsin Statutes, under the provisions of the Wisconsin Environmental Policy Act, the Wisconsin Chapter 30 permit program, solid and hazardous waste management programs, and the Wisconsin Pollutant Discharge Elimination System, apply to dredging projects. In 1987, the Wisconsin Department of Natural Resources was reviewing the regulations in Wisconsin Administrative Code NR 347 for possible revision. The Department was also considering the development of new solid waste management codes to address procedures and requirements for dredging activities and dredged material disposal.

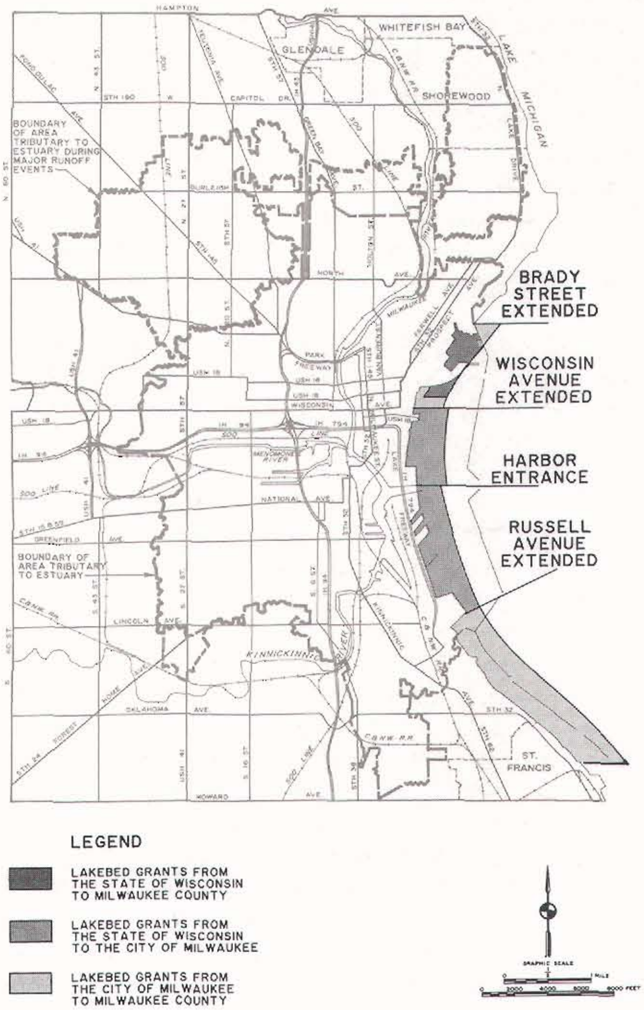
Wisconsin Environmental Policy Act: Three years after the National Environmental Policy Act was adopted by Congress, the State of Wisconsin, in April 1972, enacted the Wisconsin Environmental Policy Act (WEPA), Section 1.11 of the Wisconsin Statutes. As with the parallel federal legislation, State legislation requires an environmental impact assessment for any major state action affecting the quality of the environment, with an environmental impact statement required for proposed actions which may be accompanied by significant environmental impacts. Dredging in the navigable waters of the State of Wisconsin and attendant disposal procedures are defined as actions which must meet the requirements of the Wisconsin Environmental Policy Act.

Wisconsin Statutes Chapter 30: The Wisconsin Statutes, under Section 30.20, require that, prior to the initiation of any dredging project in the navigable waters of the State of Wisconsin, a permit for such activity be obtained from the Wisconsin Department of Natural Resources. Permit applications are reviewed for water regulation, water management, and solid waste implications. Environmental impacts are evaluated prior to issuance of a permit by the Department.

Although the Wisconsin Department of Natural Resources regulates dredging and shore protection activities throughout most of the Lake Michigan shoreline of the State, much of the immediate shoreline in Milwaukee County, including the shoreline within the Milwaukee outer harbor, is regulated under lakebed grants made to the City of Milwaukee, or to Milwaukee County, between 1909 and 1973. The lakebed grants made to the City of Milwaukee or to Milwaukee County govern submerged lands extending into Lake Michigan. Under the terms of the grant, these submerged lands are to be held and used by the City or County for navigation or harbor facilities, or for public park or highway purposes. The shoreline areas included within the lakebed grants issued to the City of Milwaukee or to Milwaukee County within the Milwaukee outer harbor are shown on Map 15. To protect the public interest within the county lakebed grant areas, the County administers a permit program for shore protection measures and dredge and fill activities. The program requires the submittal of a plan and requires that any condi-

Map 15

SUBMERGED LAKEBED GRANTS WITHIN THE MILWAUKEE OUTER HARBOR



The ownership and regulation of submerged land along the immediate shoreline of the outer harbor is governed by lakebed grants made from the State of Wisconsin to the City of Milwaukee or to Milwaukee County between 1909 and 1973. The lakebed grants require that the submerged land be held and used by the City or County for navigation, harbor facility, public park, or highway purposes.

Source: Wisconsin Department of Natural Resources, Milwaukee County, and SEWRPC.

tions established by the County be met. The City of Milwaukee, under Chapter 8 of the Code of Ordinances, requires that a city permit be obtained for the construction of dock improvements within the city lakebed grant areas. Along the entire shoreline of Lake Michigan within the State of Wisconsin, including within the lakebed grant areas, the Wisconsin Department of Natural Resources has the authority under Section 401 of the Federal

Water Pollution Control Act to review and grant water quality certification of federal actions that require a permit under Section 404 of the Act. This review, administered under Chapter NR 299 of the Wisconsin Administrative Code, is conducted to determine if the proposed activity will result in a discharge of wastes to surface waters, result in violations of applicable water quality standards, or interfere with public rights and the public interest.

Wisconsin Solid and Hazardous Waste Requirements: Sections 144.43 through 144.784 of the Wisconsin Statutes define dredged materials as solid waste and make applications for licensing the construction and operation of solid and hazardous waste disposal facilities subject to the review of the Wisconsin Department of Natural Resources in accordance with Chapters NR 180 and NR 181 of the Wisconsin Administrative Code. These regulations apply to any new upland or coastal solid waste facility.

Confined Disposal Facilities: Confined disposal facilities were developed under a Congressional directive prohibiting open water disposal of sediment classified as moderately or heavily polluted. Since Wisconsin prohibits open water disposal of any material, the Corps of Engineers must also use confined disposal facilities for the disposal of nonpolluted sediments or seek upland disposal sites. Disposal within confined disposal facilities is limited to nonhazardous sediment. Sediment analyses and the elutriate results are submitted with each maintenance dredge submittal to indicate whether the sediment is hazardous or nonhazardous.

Disposal within a confined disposal facility is usually limited to sediments dredged from areas in proximity to the facility in order to ensure that the sediment being placed in the facility possesses physical and chemical characteristics indigenous to that area. Such sediment would have already migrated throughout the area as a result of being dispersed by wave action and shipping traffic, thereby minimizing the potential for new environmental impact.

Land Disposal Sites and Facilities: Chapter NR 180, "Solid Waste Management," of the Wisconsin Administrative Code sets forth requirements for the disposal of dredge spoils in landfill sites. Section NR 180.13(4) requires that a permit be obtained from the Wisconsin Department of Natural Resources prior to the disposal of more than 3,000 cubic yards of dredge spoils in landfill sites. An exemption to this requirement, however, may be granted by the Department if, as a result of an evaluation of the landfill site, it can be demonstrated that the dredged materials will not contribute to environmental pollution—particularly in terms of contamination of surface waters or groundwaters. If, however, the dredged materials contain hazardous waste products, they must be disposed of pursuant to the regulations of Chapter NR 181 of the Wisconsin Administrative Code governing hazardous waste management. The owner of an existing solid waste facility that wanted to accept dredged solids would have to apply for a permit modification. There are presently no solid waste landfills in Wisconsin that can accept hazardous substances.

Land Spreading Sites and Facilities: Chapter NR 180 of the Wisconsin Administrative Code allows the application of nonhazardous dredge spoils on agricultural or silvicultural sites if the material can be demonstrated to have soil conditioning or fertilizer value, and provided the dredged materials are applied as a soil conditioner or fertilizer in accordance with accepted agricultural practices. Although a specific land spreading plan need not be prepared and approved for dredge spoils with soil conditioner or fertilizer value, approval for such practices must be obtained from the Wisconsin Department of Natural Resources. The transport of dredge spoils from the source to the disposal site is exempt from the collection and transportation service licensing requirements of Chapter NR 180.

Wisconsin Pollutant Discharge Elimination System Permit: The Wisconsin Department of Natural Resources is responsible for issuing Wisconsin Pollutant Discharge Elimination System (WPDES) permits consistent with the goals of Section 147.02 of the Wisconsin Statutes and the requirements of the Federal Water Pollution Control Act amendments of 1972. A permit is required for any upland or coastal dredge spoils disposal facility that discharges pollutants into the waters of the State. Periodic effluent monitoring must be conducted during spoils disposal activities to ensure that performance standards are met. The performance standards for each confined disposal facility are established on a case-by-case basis. The Milwaukee contained disposal facility does not currently have a Wisconsin Pollutant Discharge Elimination System permit.

Wisconsin Air Pollution Control Permit: The Wisconsin air pollution permit program is administered by the Wisconsin Department of Natural Resources. Section 144.39 of the Wisconsin Statutes directs the Department to organize a comprehensive program to enhance the quality, management, and protection of the State's air resources. Chapter NR 154 of the Wisconsin Administrative Code specifies that, for on-land storage of dredged spoils material, a permit should be obtained for fugitive dust emissions.

Local Regulations
The Wisconsin Statutes grant to local units of government the authority to regulate by ordinance any conditions bearing upon the health, safety, and welfare of the community. Therefore, local units of government may also exercise regulatory authority over the disposal of dredge spoils within their boundaries. Planning for the disposal of dredged materials at upland sites must therefore consider the need to conform to local zoning and other ordinances of cities, villages, towns, and counties, as well as state and federal regulations.

EXISTING DREDGING ACTIVITIES

Bottom Sediment Conditions
As bottom sediments in the Milwaukee Harbor estuary are known to contain toxic substances, there is a need to evaluate the characteristics of those sediments in order to recommend an environmentally safe method of disposal of dredged sediments. As part of the Milwaukee Harbor estuary study, sediment samples were taken at six stations located within the portion of the inner harbor subject to dredging in order to maintain commercial navigation. Approximately 600 sediment samples were taken at these six stations from 1982 through 1983. A summary of the results of the sampling, along with the results of previous field observations of sediment characteristics, and a summary of organic toxic substances found in the bottom sediments are presented in Chapter VI of Volume One of this report. Sedimentation rates for the Milwaukee inner harbor were computed for the dredge-free periods of 1971 through 1974 and 1981 through 1983 using Corps of Engineers annual examination soundings. Chapter VI of Volume One of this report describes channel characteristics as determined at intervals of approximately 100 feet within the existing dredged portion of the Milwaukee Harbor during these survey periods, and sets forth sedimentation rates and deposition volumes for each reach.

Dredging Activities
Maintenance dredging in the Milwaukee Harbor is carried out by the federal government, the City of Milwaukee, and private riparian property owners. Map 16 shows the jurisdictional areas of responsibility for maintaining adequate depths in the harbor. The federal government, through the U. S. Army Corps of Engineers, maintains the federal channels at project depths ranging between 21 and 30 feet below established low water datum, as shown on Map 17.[1] The City of Milwaukee, through the Board of Harbor Commissioners, conducts maintenance dredging between the federal project water limits and terminal facilities and in berthing areas within the Port of Milwaukee. Maintenance activities conducted from the shoreline to the federal project limits are the responsibility of private facility operators and the City of Milwaukee.

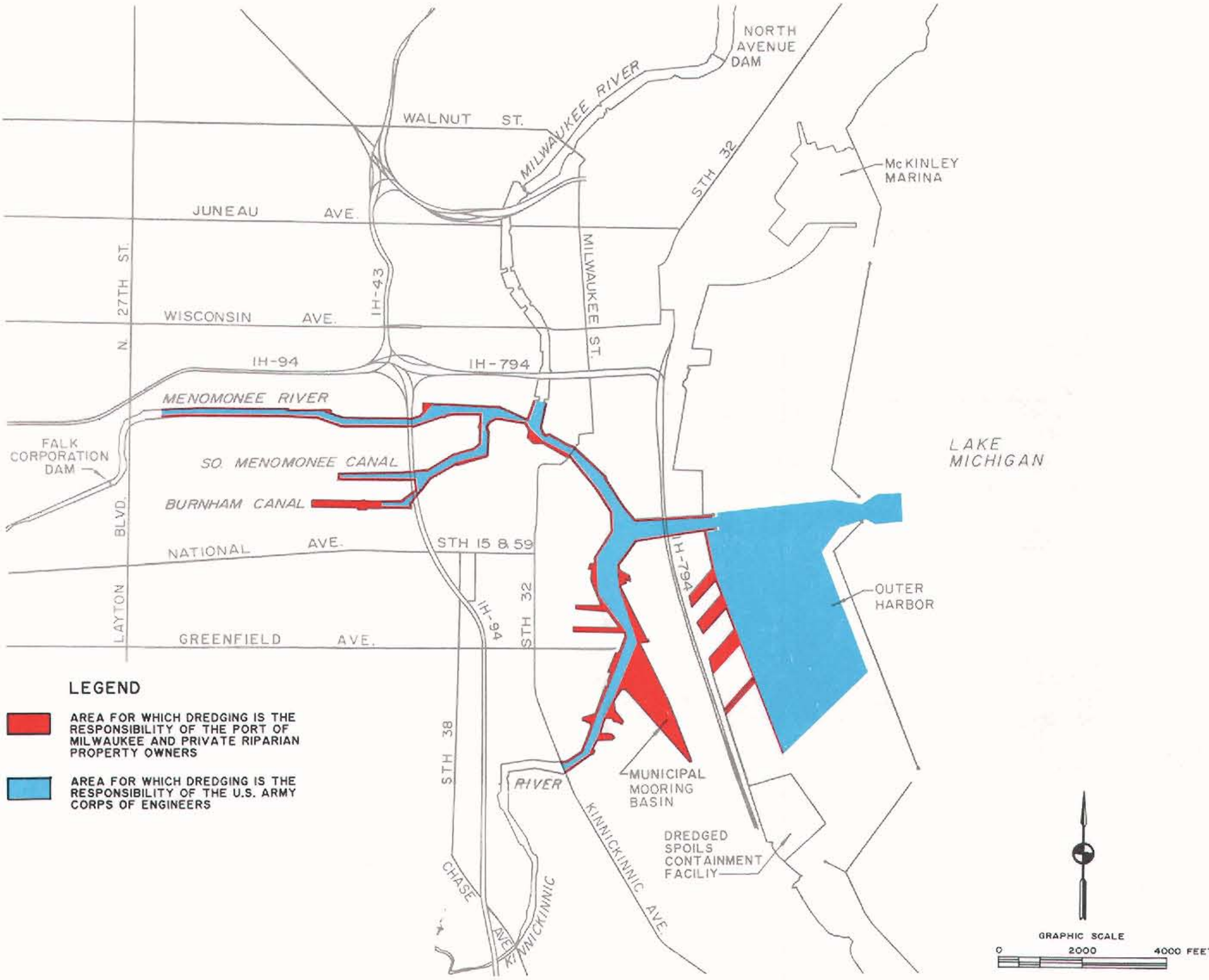
Available Milwaukee Harbor dredging records for the period 1961 through 1970 indicate that dredge spoils were disposed of in the open waters of Lake Michigan. From 1971 through 1974, no significant dredging activity took place in the Milwaukee Harbor estuary because of the imposed ban on open water disposal of dredged material. The most recent federal dredging projects in the Milwaukee Harbor were conducted by the Corps of Engineers from 1975 to 1978, and in 1981. The City of Milwaukee conducted dredging projects from 1978 through 1984. The dredged materials were deposited in the confined disposal facility located at the southern end of the outer harbor.

Existing Dredge Methods
and Material Disposal Processes
The methods used to dredge bottom sediments in the federally maintained channels of the Milwaukee Harbor are selected by the U. S. Army Corps of Engineers, primarily on the basis of the location of the proposed dredging project. Maintenance dredging within the outer harbor and the main channel was last performed with a hydraulic

[1]*Prior to 1962, the federal channel extended up the Milwaukee River to N. Humboldt Avenue. Subsequent to the construction of fixed bridges across the river, the federal channel was officially truncated at E. Buffalo Street on October 23, 1962. The Milwaukee River upstream of E. Buffalo Street was last dredged in the late 1940's, and no commercial navigation has occurred since 1959.*

Map 16

JURISDICTIONAL RESPONSIBILITY FOR HARBOR DREDGING MAINTENANCE IN THE MILWAUKEE HARBOR AREA: 1986



The federal government, through the U. S. Army Corps of Engineers, conducts maintenance dredging in the major navigation waterways within the inner harbor and outer harbor. Navigation is maintained on the Milwaukee River downstream of E. Buffalo Street; on the Menomonee River downstream of S. 25th Street; and on the Kinnickinnic River downstream of Kinnickinnic Avenue. The City of Milwaukee conducts maintenance dredging near the Port of Milwaukee terminal facilities and the berthing areas. Private facility operators are responsible for maintenance dredging within 75 feet of the shoreline.

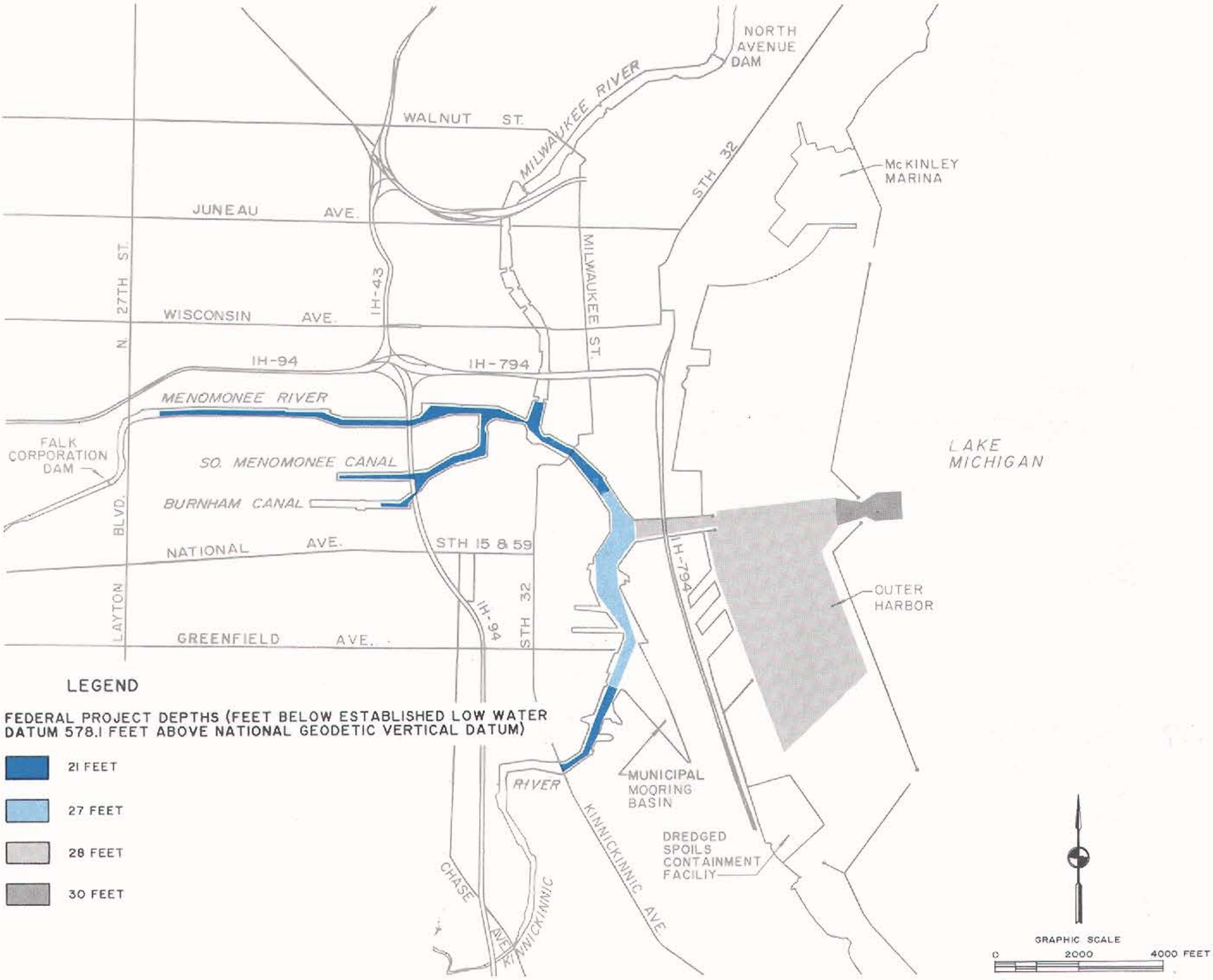
Source: SEWRPC.

hopper dredge, which sucks up the spoils and temporarily deposits them in the hold of the dredge. The spoils are later pumped out of the dredge into the confined disposal facility. Maintenance dredging within the inner harbor is performed with mechanical dipper and clamshell dredges, which remove the spoils using a dipper shovel or clamshell bucket, and place them on a barge for transport to the confined disposal facility. With the use of a crane, the spoils are removed from the barge and placed within the confined disposal facility in a mound, which is later leveled with a bulldozer.

Dredging activities within the Milwaukee Harbor but outside the federally maintained channels have also utilized the mechanical dipper and clamshell dredges because of the locations of the dredged areas near boat slips and bulkhead walls. These

Map 17

FEDERAL CHANNEL PROJECT DEPTHS: 1986



Within the federal project limits shown on Map 16, the channels are maintained at depths ranging from 21 to 30 feet below established low water datum—or elevation 578.10 National Geodetic Vertical Datum. Maintenance dredging within the outer harbor is normally performed with a hydraulic dredge, while mechanical dipper and clamshell dredges are usually used within the inner harbor. The dredge spoils are disposed of within the confined disposal facility located within the outer harbor.

Source: U. S. Army Corps of Engineers.

dredge spoils are transported and disposed of in the same manner as described above for the federally maintained channels.

Estimated Quantity of Dredged Materials

From 1961 through 1970, approximately 4.7 million cubic yards of material were dredged from the existing federal project areas within the estuary, consisting of the 0.7 mile of the Milwaukee River downstream of E. Buffalo Street; the 1.7 miles of the Menomonee River downstream of N. 25th Street; the 1.4 miles of the Kinnickinnic River downstream of S. Kinnickinnic Avenue; the 1.4 miles of the Burnham and South Menomonee Canals; and the outer harbor. These spoils were disposed of in the open waters of Lake Michigan. The estimated volume of dredged materials was based on bottom depth sounding records. Of the

Table 49

SUMMARY OF QUANTITIES OF MATERIALS DREDGED FROM THE MILWAUKEE HARBOR UNDER FEDERAL PROJECTS: 1975-1984

Year	Entrance Channel and Outer Harbor		Milwaukee River		Menomonee River		Kinnickinnic River		Burnham Canal		South Milwaukee Canal		Total	
	Volume (cubic yards)	Percent of Total	Volume (cubic yards)	Percent of Total	Volume (cubic yards)	Percent of Total	Volume (cubic yards)	Percent of Total	Volume (cubic yards)	Percent of Total	Volume (cubic yards)	Percent of Total	Volume (cubic yards)	Percent of Total
1975	93,100	10.1	--	--	--	--	65,900	7.2	--	--	--	--	159,000	17.3
1976	--	--	--	--	173,100	18.8	100,500	11.0	25,100	2.7	8,100	0.9	306,800	33.4
1977	56,700	6.1	--	--	--	--	--	--	--	--	--	--	56,700	6.1
1978	44,200	4.8	85,200	9.3	43,000	4.7	22,300	2.4	13,700	1.5	--	--	208,400	22.7
1979	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1980	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1981	12,900	1.4	64,700	7.0	80,900	8.8	21,800	2.4	6,800	0.8	1,300	0.1	188,400	20.5
1982-1984	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	206,900	22.4	149,900	16.3	297,000	32.3	210,500	23.0	45,600	5.0	9,400	1.0	919,300	100.0

NOTE: Quantities estimated based upon bottom depth sounding records.

Source: Port of Milwaukee.

total volume, approximately 0.8 million cubic yards, or 17 percent, were dredged for harbor maintenance, and approximately 3.9 million cubic yards, or 83 percent, were dredged for harbor expansion or improvement. No new work dredging has been conducted since 1967. Of the total maintenance dredging quantity, about 418,000 cubic yards of material, or about 55 percent, was dredged by the Corps of Engineers, and about 348,000 cubic yards, or about 45 percent, was dredged by private riparian owners and the Port of Milwaukee.

The most recent federal dredging projects were conducted by the Corps of Engineers in the Milwaukee Harbor from 1975 through 1981. Table 49 lists the quantities of materials dredged by water body during each of these years. No dredging activities occurred during 1979 or 1980. Based on bottom depth sounding records, the total amount of material dredged during this period was about 919,300 cubic yards. Of this total, approximately 206,900 cubic yards, or 23 percent, were taken from the entrance channel and the outer harbor; 149,900 cubic yards, or 16 percent, were taken from the 0.7 mile of the Milwaukee River downstream of E. Buffalo Street; 297,000 cubic yards, or 32 percent, were taken from the 1.7 miles of the Menomonee River downstream of N. 25th Street; 210,500 cubic yards, or 23 percent, were taken from the 0.6 mile of the Kinnickinnic River downstream of S. Kinnickinnic Avenue; and 55,000 cubic yards, or 6 percent, were taken from the 1.4 miles of the Burnham and South Menomonee Canals. During this period, the Corps, dredging only in federal project waters, deposited the bottom materials in the confined disposal facility at the southern end of the outer harbor. An annual average of 131,300 cubic yards of bottom materials were removed from within those project limits in the harbor and placed in the confined disposal facility from 1975 to 1981, compared to an annual average of 77,000 cubic yards of material dredged for maintenance from 1961 through 1970. The amount of sediment removed annually for maintenance purposes was probably lower from 1961 to 1970 because newly dredged areas require little initial maintenance.

Dredging activities done under City of Milwaukee contracts during the years 1980 through 1984 are shown in Table 50. All of these dredging activities were conducted in the Kinnickinnic River, the municipal mooring basin, and the outer slips of piers. Based on bottom depth sounding records, approximately 231,600 cubic yards of bottom sediments were removed during this time period. The dredged materials were placed in the Corps of Engineers confined disposal facility. Some dredging has also been conducted under contract to private firms, particularly near bulkhead walls and in the slips. Only a very small amount of bottom sediment, however, has been removed under private contract since 1970.[2]

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[2]*Lawrence E. Sullivan, Design Engineer, Port of Milwaukee, Personal Communication, May 18, 1986.*

Table 50

SUMMARY OF QUANTITIES OF MATERIAL DREDGED FROM THE MILWAUKEE HARBOR UNDER CITY OF MILWAUKEE CONTRACT: 1975-1984

Date	Location	Volume (cubic yards)	Percent of Total
1975-1977	- -	- -	- -
October 1978	Municipal Mooring Basin.	9,600	4.1
December 1979	Kinnickinnic River downstream from Becher Street—Right Bank.	5,000	2.2
May 1982	Municipal Mooring Basin and Outer Slips of Piers.	115,000	49.6
June 1982	Municipal Mooring Basin and Liquid Cargo Pier	49,500	21.4
December 1983	Kinnickinnic River downstream from Becher Street—Left Bank	12,200	5.3
December 1983	Kinnickinnic River at 401 E. Greenfield Dock	3,000	1.3
December 1984	Kinnickinnic River at 401 E. Greenfield Dock	37,300	16.1
- -	Total	231,600	100.0

NOTE: Quantities estimated based upon bottom depth sounding records.

Source: Port of Milwaukee.

In summary, from 1975 through 1984, a period for which relatively accurate records of dredging quantities are available, significant dredging operations were carried out in the estuary by both the U. S. Army Corps of Engineers and the City of Milwaukee. During that time, a total of 1,150,900 cubic yards of material, or an average of 115,000 cubic yards per year, was dredged from within the estuary for maintenance purposes. Of this total, 919,300 cubic yards, or an annual average of 92,000 cubic yards, was dredged by the Corps of Engineers, and 231,600 cubic yards, or about 23,000 cubic yards per year, were dredged by the City of Milwaukee. In addition, an indeterminate, but minor, amount of dredging was done under private contract. No records are available of the means by which the spoils from the private dredging operations were disposed of.

ALTERNATIVE DREDGING AND SPOILS DISPOSAL METHODS

Since 1980, alternative methods of dredging and disposing of the dredge spoils from the Milwaukee Harbor estuary have been addressed in two studies. In December 1981, the Regional Planning Commission published SEWRPC Community Assistance Planning Report No. 68, Upland Disposal Area Siting Study for Dredged Materials from the Port of Milwaukee. This report described the existing conditions and the dredging activities and practices in the Milwaukee Harbor, and evaluated alternative methods of disposing of dredge spoils at upland disposal sites. The report addressed the general feasibility of alternative upland disposal methods and sites, and concluded that while upland disposal was feasible, it was considerably more costly than other methods of dredge spoil disposal. The report accordingly recommended that more detailed studies of the technical, economic, environmental, and regulatory aspects of non-upland spoils disposal alternatives be conducted prior to the selection and implementation of a recommended plan.

The second study of dredging and dredge spoils disposal alternatives was prepared by Camp Dresser & McKee, Inc., for the Port of Milwaukee. The findings and recommendations of this study were reported in a document entitled, Dredge Material Disposal Planning Study, published in August 1983. The study evaluated several dredge spoil disposal alternatives, some of which were identified in an initial screening process as either not viable or not legally feasible. The alternatives were evaluated with respect to cost, equipment availability, technical suitability, environmental acceptability, and regulatory limitations. The study recommended that the capacity of the existing confined disposal facility be increased, and the construction of a new confined disposal facility be considered.

This section discusses the need for continued dredging within the Milwaukee Harbor estuary, addresses alternative methods of dredging, considers various methods to transport and process the dredge spoils prior to disposal, and evaluates alternative dredge spoil disposal methods and sites. Cost estimates, expressed in 1986 dollars, are also presented for each of the alternatives. All unit costs provided are expressed as the cost per cubic yard of bottom sediments removed, measured in situ. As appropriate, the results of the Regional Planning Commission and Camp Dresser & McKee studies are incorporated.

Need for Dredging

Commercial Navigation Maintenance: Sedimentation in the inner harbor and outer harbor is a hindrance to commercial navigation and related activities in the Port of Milwaukee. Commercial vessels cannot operate at full capacity—or, in extreme cases, at all—in shallower waters that are the result of sediment accumulation in the channels, mooring basin, and outer harbor. In order to accommodate the draft of large lake- and sea-going commercial ships, the channels of the St. Lawrence Seaway are intended to be uniformly constructed and maintained at 27 feet below established low water International Great Lakes Datum (IGLD). Accordingly, harbors and ports serving such vessels should be maintained at similar depths.

The frequency and magnitude of dredging for maintenance of navigation is influenced by the rate of sedimentation and by lake water elevations. If sedimentation is relatively low, or if the elevation of the lake water is relatively high, maintenance dredging can be performed on a less frequent basis than if the sedimentation rates are high or the lake levels low.

Sedimentation rates in the Milwaukee Harbor estuary are presented in Chapter VI of Volume One of this report. That segment of the Milwaukee River upstream of the Menomonee River to the North Avenue dam, which currently is not dredged for maintenance of navigation, exhibited the lowest sedimentation rate within the inner harbor. Those estuarine reaches that are currently dredged exhibited higher sedimentation rates. In both the Menomonee and Kinnickinnic River estuaries, the sedimentation rates were highest at the upper ends. In the Milwaukee River estuary, the highest sedimentation rates were found downstream of the confluence with the Menomonee River.

The fluctuation of Lake Michigan water levels affects the need for dredging to maintain an adequate water depth for navigation. High lake levels—such as the record high levels of 1986—reduce the need for dredging to provide adequate water depths, whereas low lake levels—such as the record low levels experienced in 1964—increase the need for dredging.

Bottom depth soundings are made annually by the Corps of Engineers to establish the elevation of the top of the sediments and the depths of the channels in the Milwaukee Harbor. These soundings indicate the elevation of the top of the sediments at river cross-sections located at intervals of approximately 100 feet. Based on these sounding data, lake level information, navigation-related data, and the availability of funds, the Corps of Engineers establishes priorities for dredging projects and identifies which areas should be dredged to the established project depths during which years.

Future Sedimentation Rates: The relative contribution of combined sewer overflow solids to the bottom sediments of the inner harbor was estimated in order to determine the effect that the abatement of combined sewer overflows would have on the sedimentation rate and on the need for future dredging to maintain navigation. Estimated sediment loadings to the inner harbor from the upstream tributary rivers and from combined sewer overflows, together with data on the density of the bottom sediments, as measured in the sediment core analyses, were used to calculate the sedimentation rate contributed by both upstream and combined sewer sources, assuming that all of the sediments settle out in the inner harbor. Since the proportion of the total sediment loads from the rivers and from combined sewer overflows which actually settles out in the harbor is unknown, the relative importance of the influence of the rivers and the combined sewer overflows on the sedimentation rates can only be approximated.

The analyses indicated that, if all sediments settled out in the inner harbor, combined sewers would account for about 20 percent of the total sedimentation rate in the Milwaukee River estuary, and about 40 percent of the total sedimentation rate in the Menomonee and Kinnickinnic River estuaries. Since it may be assumed that, overall, sediments from combined sewer overflows are more likely to settle than are sediments being transported to the harbor by the tributary rivers, the relative contribution by combined sewers is probably somewhat higher than estimated. It may therefore be concluded that, for the inner harbor in general, the abatement of combined sewer overflows will likely reduce the existing sedimentation rates by 40 to 50 percent. Over the period 1975 through 1984, an average of 115,000 cubic yards of dredge spoils per year were removed from the Milwaukee Harbor and placed in the confined disposal facility. Following the abatement of the combined sewer overflows, the volume of spoils generated by dredging for maintenance of navigation should be reduced to approximately 65,000 cubic yards per year.

This estimate of the quantity of material to be dredged for maintenance assumes that the Lake Michigan levels for the years 1975 through 1984—the period for which dredged material quantities were analyzed—would be representative of future conditions. The average annual lake level during those years was 579.4 feet National Geodetic Vertical Datum (NGVD), about the same as the long-term—1915 through 1985—average level of 579.5 feet NGVD. The 10-year—1975 through 1984—level was substantially lower, however, than the 1985 and 1986 average lake levels of 580.7 and 582.6 feet NGVD, respectively. Should the lake remain at higher levels during the plan period than were experienced from 1975 through 1984, there may be less need for dredging, and the quantity of dredged material may be lower than the above estimate. This could result in an increase in the life of the facility recommended for disposal of dredged materials.

Water Quality Considerations: Chapter VI of Volume One of this report described the effects of the existing bottom sediments on water quality conditions in the estuary. Sediment oxygen demand was identified as the primary cause of the dissolved oxygen depletions that occur in the inner harbor under low-flow, dry-weather conditions; and approximately 70 percent of the sediment oxygen demand in the inner harbor was attributed to organic loadings from combined sewer overflows. Immediate oxygen demand caused by sediment scour at combined sewer outfalls was found to be insufficient to account for the rapid dissolved oxygen depletions that were observed to occur in the inner harbor during wet-weather periods. Wet-weather depletions in dissolved oxygen levels were attributed instead to the inhibition of photosynthetic oxygen production by algae. Once the combined sewer overflows are abated, the bottom sediments are expected to decompose and stabilize relatively quickly—within about a two-year period. Thus, dredging the bottom sediments in the inner harbor would not significantly increase the dissolved oxygen levels in the inner harbor following abatement of the combined sewer overflows. Low dissolved oxygen levels have seldom occurred in the outer harbor.

Based on the comparison of sediment quality characteristics to U. S. Environmental Protection Agency sediment quality guidelines set forth in Chapter VI of Volume One, the bottom sediments of the inner and outer harbors were classified as heavily polluted. These classifications were based on levels of conventional pollutants—such as chemical oxygen demand, total phosphorus, and ammonia nitrogen—and of toxic and hazardous substances—several metals, cyanide, and polychlorinated biphenyls—measured in the bottom sediments. The toxic substances pose the greatest threat to aquatic life when they are released from the sediment to the interstitial water, where biological uptake can occur.

A preliminary analysis of the release of toxic organic substances to the interstitial water under worst case conditions was conducted to determine whether concentrations of toxic substances in the interstitial water of the inner and outer harbors exceed the acute or chronic criteria protecting warmwater fish and aquatic life. The following equation was used to calculate the concentrations of organic substances in the interstitial water using the measured concentrations of those substances in the bottom sediments:[3]

$$C = \frac{r}{p}$$

where:

- C = organic substance concentration in the interstitial water expressed in micrograms per liter,
- r = organic substance concentration in the bottom sediments expressed in micrograms per kilogram, and
- p = partition coefficient in liters per kilogram—which is determined by:
  p = Kow x foc.

  where:
  - Kow = octanol-water partition coefficient,[4] and
  - foc = fraction of organic carbon in the bottom sediments.

The preliminary analysis of worst case conditions involved the screening of all available toxic organic substance measures in the bottom sediments and the calculation of the likely maximum organic substance concentrations in the interstitial water. Those substances which might violate acute or chronic criteria within the interstitial water could then be determined. Table 83 of Volume One of this report was used to identify maximum concentrations of organic substances measured in the bottom sediments of the inner and outer harbors over the period 1975 through 1985. Octanol-water partition coefficients for organic substances were compiled from several references.[5]

In those cases where more than one partition coefficient was found for a particular substance, the lowest number was used in the calculation in order to estimate the maximum concentration of the substance in the interstitial water. Sediment

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[3]*Dominic M. DiToro, "A Particle Interaction Model of Reversible Organic Chemical Sorption," Chemosphere, Vol. 14, No. 10, 1985, pp. 1,503-1,538.*

[4]*The adsorption partition coefficient characterizes the properties of an organic substance which affect sorption onto sediment particles, and bio-concentration in aquatic organisms. The adsorption partition coefficient determines the fraction of the total substance concentration that is in the particulate and dissolved phases under specific environmental conditions. The octanol-water partition coefficient is one property which was found to be a good predictor of the adsorption partition coefficient. The octanol-water partition coefficient, together with the organic carbon content of the sediments, can be used to estimate the adsorption partition coefficient. The octanol-water partition coefficient is a physical-chemical property developed in the laboratory using an organic solvent to characterize the lipophilicity—or affinity for lipids or fats—and hydrophobicity—or lack of affinity for water—of an organic substance. Of particular concern with respect to aquatic toxicity are those toxic organic substances that have a low solubility in water, but a high octanol-water partition coefficient—that is, a high affinity for lipids. Such substances tend to concentrate in the organic matter of sediments, and in lipid deposits of biota.*

[5]*References used to identify octanol-water partition coefficients:*

Michele M. Miller and Stanley P. Wasek, "Relationships Between Octanol-Water Partition Coefficient and Aqueous Solubility," Environ Science Technology, Vol. 19, No. 6, 1985, p. 522529.

E. E. Kenaga and C. A. I. Goring, "Relationship Between Water Solubility, Soil Sorption, Octanol-Water Partitioning, and Concentration of Chemicals in Biota," Proceedings of the Third Annual Symposium on Aquatic Toxicology, October 1978, p. 78101.

D. Mackay, A. Dobra, and W. Y. Shiu, "Relationships Between Aqueous Solubility and Octanol-Water Partition Coefficients," Chemosphere, Vol. 9, 1980, p. 701711.

Michael R. Overcash and James M. Davidson, Environmental Impact of Nonpoint Source Pollution, Ann Arbor Science Publishers, Inc., 1980.

Dominic M. DiToro, "A Particle Interaction Model of Reversible Organic Chemical Sorption," Chemosphere, Vol. 14, No. 10, 1985, p. 1,503-1,538.

Kent B. Woodburn, William J. Doucette, and Anders W. Andren, "Generator Column Determination of Octanol/Water Partition Coefficients for Selected Polychlorinated Biphenyl Congenics," Environ Science Technology, Vol. 18, No. 6, 1984, p. 457459.

Table 51

ORGANIC SUBSTANCES EVALUATED IN THE PRELIMINARY ANALYSIS OF INTERSTITIAL WATER CONCENTRATIONS

Alpha-BHC	Endosulfan Sulfate
Acenapthene	Endrin
Beta-BHC	Fluoroanthene
Bis (2-chloroethyl) Ether[a]	Gamma-BHC
Bis (2-chloroethoxyl) Methane	Heptachlor
Bis (2-chloroisopropyl) Ether	Hexachlorobenzene[a]
Bis (2-ethylhexyl) Phthalate[a]	Hexachlorobutadiene
4-Bromophenol Phenyl Ether[a]	Hexachloroethane[a]
Butyl Benzyl Phthalate[a]	Hexachlorocyclopentadiene
Chlordane	Isophorone[a]
2-Chloronaphthalene[a]	Naphthalene
2-Chlorophenol	Nitrobenzene[a]
4-Chlorophenyl Phenyl Ether[a]	2-Nitrophenol
Delta-BHC[a]	4-Nitrophenol[a]
1,3-Dichlorobenzene[a]	n-Nitrosodimethylamine
1,4-Dichlorobenzene[a]	n-Nitrosodi-n-propylamine
1,2-Dichlorobenzene	N-nitrosodiphenylamine[a]
Dichloro diphenyl dichloro ethane	Pentachlorophenol[a]
Dichloro diphenyl dichloro ethylene	Phenols
Dichloro diphenyl trichloro ethane	Polychlorinated Biphenyls (PCB's)
Dichloromethane	Aroclor 1016[a]
2,4-Dichlorophenol	Aroclor 1221
Dieldrin	Aroclor 1242
Diethyl Phthalate[a]	Aroclor 1248
4,6-Dinitro-o-cresol	Aroclor 1254
2,4-Dimethylphenol	Aroclor 1260
2,4 Dinitrotoluene	Toluene
Di-n-butyl Phthalate[a]	Toxaphene
Di-n-octyl Phthalate[a]	1,2,3-Trichlorobenzene[a]
1,2-Diphenylhydrazine	2,4,6-Trichlorophenol[a]
Endosulfan I	Trichloroethene[a]
Endosulfan II	

[a]*Organic substances that were always below detection level.*

Source: SEWRPC.

concentrations and partition coefficients were compiled for 83 toxic organic substances. Water quality criteria were available for 62 of these substances. The lowest concentration of organic carbon measured within the inner harbor over the period 1982 through 1983—620 mg/kg—was used in the analysis. For a given concentration of a toxic organic substance in the bottom sediments, the lower the organic carbon content of the bottom sediments, the higher the concentration of the toxic organic substance in the interstitial water. Acute and chronic criteria obtained from the Wisconsin Department of Natural Resources on March 4, 1986, were used where available. Additional U. S. Environmental Protection Agency criteria from the November 1980 edition of the Federal Register were used for those substances for which no Department of Natural Resources criteria existed.

Table 51 lists the 62 organic substances evaluated in the preliminary analysis of interstitial water concentrations. Sediment concentrations of 23 of the 62 substances were found to be always below the minimum laboratory detection levels, and these substances were therefore not evaluated further. The preliminary analysis of worst case conditions indicated that the calculated interstitial water concentrations of 18 of the 39 substances may violate the acute and chronic criteria for warmwater fish and aquatic life. These 18 substances were further evaluated.

For the final analysis, the interstitial water concentrations of the 18 toxic organic substances were recalculated using the average concentration of organic carbon measured in the bottom sediments of each water body over the period 1982 through 1983. In comparison to the worst case conditions evaluated in the preliminary analysis, the final analysis presents a more realistic estimate of those substances which actually violate the criteria within the interstitial water.

The organic substances evaluated in the final analysis are listed in Table 52. While the preliminary analysis indicated that 18 organic substances may violate the criteria assuming the minimum organic carbon content, the final analysis indicated that only 11 of the substances would violate the criteria assuming the mean organic carbon content. The organic substances that were estimated to violate the acute or chronic criteria in the final analysis are listed in Table 53. The criteria were estimated to be violated within the interstitial water for six organic substances within the Milwaukee River estuary, two organic substances within the Menomonee River estuary, six organic substances within the Kinnickinnic River estuary, and eight organic substances within the outer harbor.

Once the combined sewer overflows are abated, the loading of toxic organic substances should be substantially reduced, and the bottom sediments covered by cleaner sediments. However, as the organic carbon content of the bottom sediments declines as the sediments decompose and stabilize, a greater portion of the sediment-attached toxic organic substances will be released to the interstitial water.

Because of these complex interactions, and because the above analyses were based on a limited data base, it cannot be determined at this time whether it will be necessary to dredge or otherwise modify the bottom sediments to abate toxic effects on benthic organisms which reside in the sediments, or on their predators.

In addition to dredging, other measures may be considered to reduce the toxic effects of bottom sediments. These measures involve dilution of toxic sediments, or the prevention of contact of the sediments with water or biota. In general, these measures have limited application and their effectiveness is not well known. As discussed below, the toxic effects of bottom sediments can be abated through the use of impervious screening, accelerated deposition, and ploughing. These measures could be considered following the abatement of combined sewer overflows and following further studies into the causes and effects of these toxic materials. No benefits to navigation would be provided.

Impervious screening involves the placement of an impervious layer—usually a plastic sheet or layer of clay—over the bottom sediments. Relatively nonpolluted sediments would accumulate above the impervious layer. This method would prevent contact of the biota with the polluted sediments, reduce resuspension of the sediments, and reduce the release of toxic substances from the sediments to the overlying water column. A major disadvantage of this method is that methane, ammonia nitrogen, hydrogen sulfide, and other gases produced and released from the existing organic sediments could accumulate beneath the impervious layer, which could lead to disruption of the layer. The placement of a pervious layer—such as sand and gravel—would not effectively prevent interaction of the sediments with the biota or the bottom water layer.

A second method of reducing the impacts of polluted sediments involves accelerated deposition. Since the concentration of a toxic substance in the bottom sediments is a function of the loading of the substance and the total sediment loading over time, the accelerated deposition of nonpolluted sediments will reduce the concentration of toxic substances in the sediments. Furthermore, total abatement of toxic conditions may be expected to occur once the polluted sediment layers are buried to a depth exceeding the depth of mixing by physical resuspension and bioturbation. The disadvantages of this method are that excessive turbidity may occur during artificial deposition; continued disturbance and resuspension of flocculent, organic sediments could make burial difficult; desired spawning and habitat areas—though sparse—may be destroyed; and water depths would be reduced, which could intensify navigation problems, particularly during periods of low water levels.

Table 52

ORGANIC SUBSTANCES EVALUATED IN THE FINAL ANALYSIS OF INTERSTITIAL WATER CONCENTRATIONS

Inner Harbor			
Milwaukee River	Menomonee River	Kinnickinnic River	Outer Harbor
Acenapthene[b]	Acenapthene[a]	Dichloro diphenyl dichloro ethane[b]	Chlordane[b]
Dichloro diphenyl dichloro ethane[b]	Dichloro diphenyl dichloro ethane[b]	Heptachlor[b]	Dieldrin[a]
Dichloro diphenyl trichloro ethane[b]	Dichloro diphenyl trichloro ethane[b]	Naphthalene[a]	Endrin[b]
Dichloromethane[b]	Endrin[b]	Polychlorinated Biphenyls	Gamma-BHC[b]
Endrin[b]	Naphthalene[a]	Aroclor 1221[b]	Heptachlor[b]
Fluoroanthene[b]	Phenols[b]	Aroclor 1242[b]	Phenols[a]
Gamma-BHC[b]	Polychlorinated Biphenyls	Aroclor 1248[a]	Polychlorinated Biphenyls
Heptachlor[b]	Aroclor 1242[b]	Aroclor 1254[b]	Aroclor 1242[b]
Phenols[b]	Aroclor 1254[b]		Aroclor 1248[a]
Polychlorinated Biphenyls			Aroclor 1254[b]
Aroclor 1242[b]			
Aroclor 1248[b]			
Aroclor 1254[b]			
Aroclor 1260[b]			
Toluene[b]			

NOTE: Those substances that were below the detection level were not evaluated in the final analysis.

[a]*Based on the preliminary analysis, the concentration of these substances in the interstitial water may violate the chronic criterion.*

[b]*Based on the preliminary analysis, the concentration of these substances in the interstitial water may violate both the chronic and acute criteria.*

Source: SEWRPC.

Ploughing the bottom sediments is a third method of reducing the impacts of polluted sediments. Ploughing involves the physical overturning of the top 15 to 20 inches of the sediment. Where toxic substances are confined to a surface layer, ploughing may expose unpolluted subsurface sediments and partially bury polluted surface sediments. In soft flocculent sediments, however, the actual overturning of the sediments would be difficult, although the polluted and nonpolluted sediments would be well mixed.

Although the measures described above to abate the toxic effects of polluted bottom sediments could be applied to resolve some site-specific problems, these measures would not likely be

Table 53

ORGANIC SUBSTANCES WHICH MAY VIOLATE THE ACUTE OR CHRONIC CRITERIA IN THE INTERSTITIAL WATER OF THE BOTTOM SEDIMENTS: FINAL ANALYSIS

Organic Substance	Octanol Water Partition Coefficient (Kow, in l/Kg)	Warmwater Fish and Aquatic Life Criteria (μg/l)		Inner Harbor						Outer Harbor	
				Milwaukee River		Menomonee River		Kinnickinnic River			
		Acute	Chronic	Maximum Substance Concentration in Sediment (mg/kg dry weight)	Calculated Substance Concentration in the Interstitial Water (μg/l)	Maximum Substance Concentration in Sediment (mg/kg dry weight)	Calculated Substance Concentration in the Interstitial Water (μg/l)	Maximum Substance Concentration in Sediment (mg/kg dry weight)	Calculated Substance Concentration in the Interstitial Water (μg/l)	Maximum Substance Concentration in Sediment (mg/kg dry weight)	Calculated Substance Concentration in the Interstitial Water (μg/l)
Chlordane	2,108	6.9	0.2	--	--	--	--	--	--	0.44	8.70[b]
Dichloromethane	17.8	118,000	20,000	30.0	63,500[a]	--	--	--	--	--	--
Endrin	1,619-4,050	0.33	0.15	0.02	0.47[b]	--	--	--	--	0.03	0.77[a]
Gamma-BHC	643	10.5	3.3	--	--	--	--	--	--	0.06	3.89[a]
Heptachlor	7,366	1.8	1.26	0.25	1.28[b]	--	--	0.25	1.57[a]	1.10	6.22[b]
Naphthalene	1,300-2,239	6,600	620	--	--	--	--	24.30	865[a]	--	--
Polychlorinated Biphenyls (PCB's)											
Aroclor 1221	630-12,300	2.02	2.02	--	--	--	--	1.00	73.50[b]	--	--
Aroclor 1242	380,200	2.64	0.35	31.7	3.14[b]	17.0	1.79[a]	40.60	4.94[b]	68.20	7.47[b]
Aroclor 1248	1,288,000	29	0.2	32.0	0.94[a]	--	--	11.09	0.39[a]	33.00	1.07[a]
Aroclor 1254	1,071,500-2,017,000	1.18	0.27	--	--	--	--	11.03	0.48[a]	15.30	0.59[a]
Phenols	28.8	17,500	1,370	1.56	2,044[a]	3.51	4,793[a]	--	--	2.63	3,805[a]

NOTE: Those substances that were below the detection level were not evaluated in the final analysis. The mean organic carbon contents measured in each water body were used to calculate the substance concentrations within the interstitial water.

[a] *Violates chronic criterion only.*

[b] *Violates acute and chronic criteria.*

Source: SEWRPC.

effective within the Milwaukee Harbor estuary in general. Impervious screens would likely be disturbed by the accumulation of gases produced by the sediments, and would interfere with dredging activities required for navigation purposes. Accelerated deposition would also not be suitable for those areas dredged, and could interfere with navigation. The effectiveness of ploughing the bottom sediments of the estuary would be limited because 25-inch vertical sediment profiles collected in 1983 indicated no consistent trends in sediment chemistry with depth. The vertical profiles described in Chapter VI of Volume One of this report demonstrate that the sediments are relatively uniform and vertically well mixed.

The transport and fate of toxic metals in the estuary is largely controlled by sorption processes in the sediments. Since it is currently not possible to quantify the release of metals from the bottom sediments to the interstitial water, a comparison to acute and chronic toxicity criteria could not be made. Only when adequate analytical techniques become available, and accepted laboratory procedures are established by the U. S. Environmental Protection Agency, will the toxic metal problem in the estuary be able to be properly identified and addressed.

It is important to note in this respect that the biological uptake and the bio-accumulation of toxic substances in the estuary are poorly understood. Bio-accumulation rates, which are defined as the ratio of the concentration of the substance in tissue to that in the water, range up to 10^6 for some organic substances.[6] Many metals also bio-accumulate. However, the role of the bottom sediments as a supplier of toxic substances to the biota is unknown. For example, it is unclear what portion of the polychlorinated biphenyls that were found in the tissue of fish caught in the estuary was released from the bottom sediments. Therefore, additional study on the sources, fate, and transport of toxic substances, including metals and organics, will be required to determine whether dredging of the bottom sediments is needed to abate problems of pollution by toxic substances.

Habitat Improvement: The soft, organic, fine-grained, heavily polluted sediments found throughout most of the inner harbor provide a poor habitat for desirable forms of warmwater aquatic organisms. There are localized areas within the inner harbor, however, that provide suitable feeding, cover, and spawning habitats for warmwater fish and aquatic life. For example, in the reach of the Milwaukee River from the North Avenue dam to Humboldt Avenue, there are numerous scoured areas with a substrate of rocks, sand, and hard clay. Many warmwater species, including walleye, smallmouth and largemouth bass, northern pike, bullhead, catfish, suckers, carp, and sunfish, currently spawn in this reach. Similarly, there are localized shallow areas in the upper ends of the Menomonee and Kinnickinnic River estuaries, as well as in the upper ends of the Burnham and South Menomonee Canals, that support rooted aquatic vegetation that is used for spawning by northern pike, yellow perch, carp, and sunfish. Many of the fish that spawn in the inner harbor migrate in from Lake Michigan during spring and summer. These localized areas may be expected to provide improved habitat for the maintenance of a limited, yet diverse, population of warmwater fish after combined sewer overflows are abated.

Furthermore, as the organic matter in the sediments decomposes after combined sewer overflows are abated, the organic content of the sediments may be expected to decrease substantially. The existing sediments will also in time be covered by cleaner sediments with less organic matter. Thus, within the inner harbor, a habitat suitable for pollution-tolerant organisms should develop. Dredging beyond that required to maintain navigation to further improve the physical characteristics of the habitat would not be desirable and could, indeed, be detrimental since dredging could eliminate some of the shallow water areas that currently support reproduction of desired species. Further site-specific analyses may indicate that it would be desirable to dredge or otherwise modify selected small areas within the estuary in order to improve habitat for aquatic life. Such limited dredging should be considered only if further site-specific evaluation or findings support such a need.

Within the outer harbor, the existing bottom sediments, although classified as heavily polluted, are known to be conducive to the successful propagation of diverse populations of warmwater fish and other aquatic life. Widespread dredging of the outer harbor bottom sediments would therefore not be desirable for the purpose of improving habitat.

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[6] *Versar, Inc.,* *Water-Related Environmental Fate of 129 Priority Pollutants, prepared for the U. S. Environmental Protection Agency, December 1979.*

The potential adverse impact of dredging during and immediately following dredging must also be considered. The adverse impacts of dredging operations may include increases in turbidity, resuspension of contaminated sediments, and decreases in the dissolved oxygen content of the water column. The type of dredging system used as well as the type of sediment being dredged affect the severity of these impacts. Although the majority of the metals, nutrients, and chlorinated hydrocarbons present in sediments are associated with the fine-grained and organic components of the sediments, only a limited release of these chemical constituents to the water column occurs during and immediately after dredging. Levels of certain metals, ammonia nitrogen, and phosphate in the water column may increase somewhat over background conditions for short periods; however, normally no persistent, well-defined plumes of dissolved metals or nutrients at levels significantly greater than background concentrations occur.[7] The potential environmental impact of contaminants associated with sediments must be evaluated in light of chemical and biological data describing the potential for these contaminants to be transferred to biological organisms. Information must then be compiled on the effects of specific substances on organism survival and function. Many contaminants are not readily released from sediment attachment and are thus less toxic than contaminants in the free, or soluble, state on which most toxicity data are based.

Dredging operations may also have immediate localized effects on the bottom life. The recovery of the affected sites may require weeks, months, or years, depending on the type of environment and the specific animals and plants affected. The more naturally variable the physical environment, especially in relation to shifting substrate due to waves or currents, the less effect dredging and disposal will have. Animals and plants common to areas of unstable sediments are adapted to physically stressful conditions and have life cycles which allow them to withstand the stresses imposed by dredging and disposal.

These and other factors should be evaluated in selecting a dredge disposal method and season in order to minimize habitat disruption. The required evaluations must be made on a site-specific, case-by-case basis.

Dredge Alternatives

Dredge methods can generally be divided into mechanical and hydraulic methods. Some of the important factors to be considered when selecting the type of dredge equipment include access to the shoreline and shore characteristics, location of the disposal sites, location of the area to be dredged, water depth and depth of dredging, volume and type of bottom sediments to be removed, and equipment availability.

Mechanical Dredges: Mechanical dredges are similar to land excavation equipment and include dragline, dipper, and clamshell dredges. The mechanical dredges, which can be operated either from dry land or from a barge, scoop the sediments from the bottom and deposit them onto an accompanying barge, trucks, or nearby disposal site. Since mechanical dredging equipment is generally highly maneuverable, previous dredging activities in the Milwaukee Harbor estuary have usually utilized clamshell or dipper dredges to dredge areas near boat slips and bulkhead walls. Barge-mounted dredges are towed to the project area and, within limited areas, are moved and positioned using spuds and anchors. Mechanical dredging normally creates a high level of turbidity as the sediments are resuspended.

Dragline: The most commonly used dredging equipment operated from dry land is the track-mounted dragline. The dragline includes a long boom from which a bucket is suspended, as shown in Figure 97. The bucket is lowered into the bottom sediments and dragged toward the shoreline. The excavated material is then deposited onto a truck or barge. Large draglines can dredge out to a distance of about 125 feet from the shoreline.[8] The dragline requires a stable, level shore, and is inefficient in handling soft, fine-grained, flocculent sediments.

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[7] *U. S. Army Corps of Engineers, "Dredging and Dredged Material Disposal," Engineer Manual, EM 1110-2-5025, March 5, 1983.*

[8] *N. D. Pierce, "Inland Lake Dredging Evaluation," Wisconsin Department of Natural Resources Technical Bulletin No. 46, 1970.*

Dipper: The barge-operated dipper dredge, shown in Figure 97, utilizes a shovel to remove sediments and, with excellent leverage, is particularly useful for hard clay and certain rock substrates. Although it is difficult to retain soft, fine-grained sediments in the shovel, it is also used for soft sediments because it is highly maneuverable. The dredged material is deposited onto a barge and transported to the disposal site.

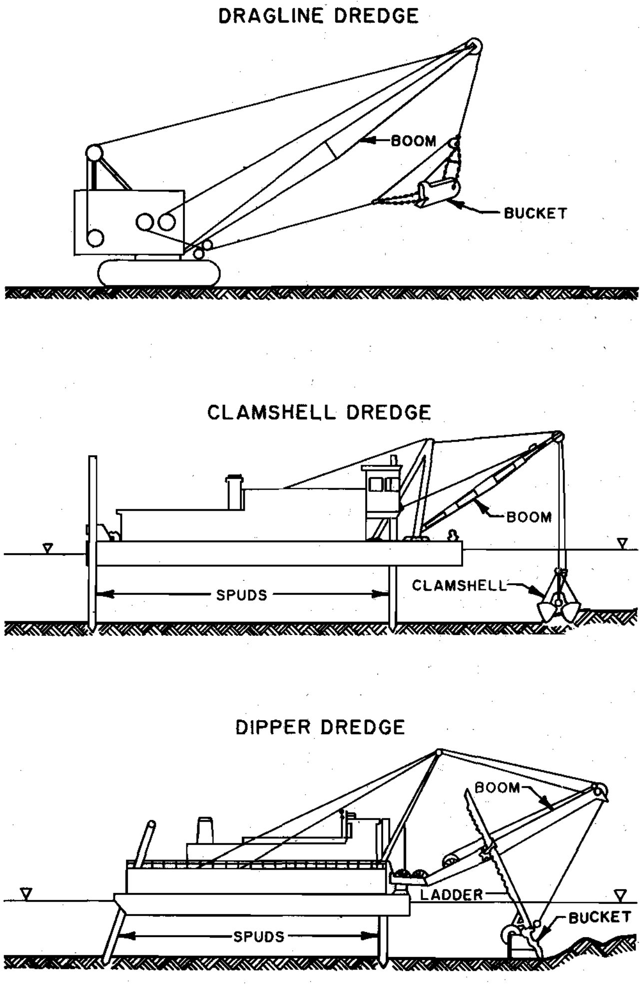
Clamshell: The clamshell dredge, also operated from a barge, consists of a boom, hoisting mechanism, and a clamshell bucket, as shown in Figure 97. The clamshell is particularly effective in removing soft sediments and stumps and boulders. Watertight clamshell buckets with covered tops have been developed which seal when the bucket is closed. Use of a sealed clamshell dredge can reduce turbidity by 30 to 70 percent from that resulting from use of a dipper dredge or regular clamshell dredge.[9] The dredged material is deposited onto a barge and transported to the disposal site.

Hydraulic Dredges: Hydraulic dredges use pumps to suck up highly diluted dredge spoils and to discharge the spoils to a storage or disposal facility. Types of hydraulic dredges include the cutterhead, hopper, plain suction, dustpan, and sidecasting dredges. Only the cutterhead and hopper dredges are discussed herein since they are the most feasible for use in the Milwaukee Harbor. Hydraulic dredges are generally able to remove sediment at a higher rate than can mechanical dredges, but the energy requirement per unit volume of sediment removed is higher for hydraulic dredges because of the large amount of dilution water which must also be pumped.[10] Hydraulic dredges are not as maneuverable as mechanical dredges, and hence are less useful near bulkhead walls and in boat slips.

Cutterhead: The most common hydraulic dredging machine utilized in the United States is the cutterhead dredge. It excavates and transports the material, and places it at the disposal site. Figure 98 shows the operation of a typical hydraulic cutter-

Figure 97

MECHANICAL DREDGES



Source: U. S. Army Corps of Engineers.

head dredge. The cutterhead itself rotates and swings from side to side, using negative pressure from a large centrifugal pump to suck up the material—which is diluted to a slurry of 10 to 20 percent solids—and discharge the spoils, along with the dilution water, through a pipeline at a velocity of 15 to 20 feet per second to a disposal area. Disposal areas are normally located within three miles of the project dredging area. The sediments settle out at the disposal site and the water is returned to the waterway via drainage channels or pumps. The dredge is generally controlled on stern-mounted spuds. The cutterhead dredge can operate on a continuous dredge cycle, resulting in maximum efficiency and economy.

Hopper: The hopper dredge, shown in Figure 98, is a self-propelled vessel, equipped with hopper bins to contain and carry hydraulically dredged material

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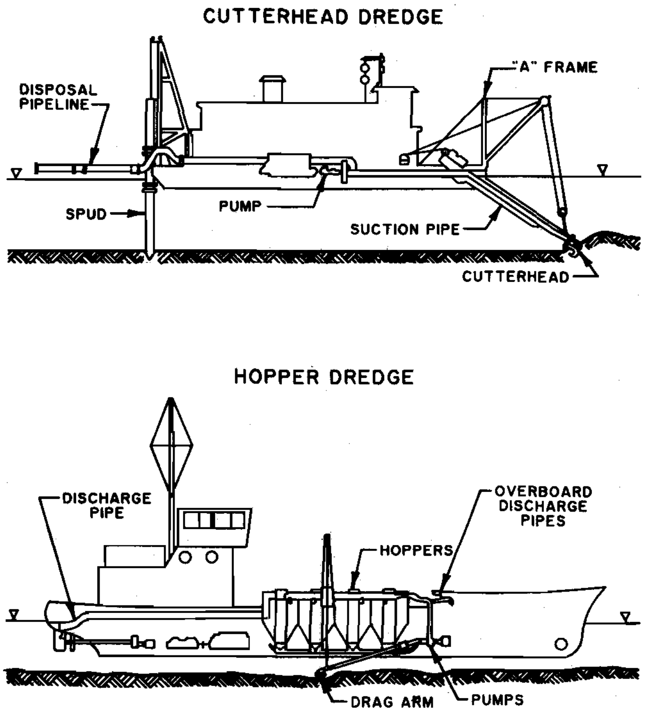
[9] *U. S. Army Corps of Engineers, "Dredging and Dredged Material Disposal," Engineer Manual EM 1110-2-5025, March 5, 1983.*

[10] *G. G. Gren, "Hydraulic Dredges, Including Boosters," Proceedings of the Specialty Conference on Dredging and Its Environmental Effects, ed. P. A. Krenkel, J. Harrison, and J. C. Burdick III, Mobile, Alabama, January 26-28, 1976.*

Figure 98

HYDRAULIC DREDGES



Source: U. S. Army Corps of Engineers.

to a disposal facility. Dredging is carried out using a centrifugal pump attached to drag arms which extend down from the vessel. Dredge spoils are pumped into the hopper. Since a hopper dredge can excavate material while mobile, without anchors or moorings, it is highly maneuverable and provides minimum interference with nearby navigation. When the hopper is filled with spoils, the dredge moves to the disposal facility, where the spoils are pumped out. Hopper dredges can operate under high wave conditions and do not interfere significantly with navigation. A hopper dredge has been used by the Corps of Engineers to dredge the Milwaukee outer harbor and the main channel, but the dredge is no longer in operation.

Dredge Spoils Processing
and Transport Alternatives

Dredge spoils processing alternatives, which are intended to increase the solids content of the spoil, were evaluated for the Port of Milwaukee by Camp Dresser & McKee, Inc.[11] Methods which involve chemical or mechanical processes such as pressure or vacuum filtration, centrifugation, and the addition of polymers and inorganic coagulants may be used prior to the placement of the dredge spoils in a disposal facility. These methods were considered to be too costly by Camp Dresser & McKee.

Other methods, such as evaporation, gravity drainage, sand drains, surface trenching, mounding, vacuum well points, and electro-osmosis, may be used to de-water the sediments after placement in a disposal facility. Because of the high water table in the existing confined disposal facility, Camp Dresser & McKee recommended that spoils mounding be used to maximize the life of the existing facility located within the outer harbor. Mounding increases the density of the spoils as the water drains out, and allows the implementation of additional de-watering methods, such as gravity surface draining and chemical treatment, which are effective only on solids layers above the water table. Solids mounding at the existing confined disposal facility could be expected to increase the sediment content of dredge spoils to approximately 50 percent total solids.

Five alternative methods of transporting the dredge spoils to a spoils disposal facility were considered in the Camp Dresser & McKee study: pipeline, railway, barge, truck, and belt conveyor. A study by the Corps of Engineers[12] found that transportation of dredge spoils by belt conveyor and truck was more costly than by pipeline, railway, or barge regardless of the annual volume of spoils transported. Transportation by railway was found to be economical only at a haul distance greater than 60 miles and with annual volumes of spoils exceeding 500,000 cubic yards. Because of the smaller volumes of spoils entailed—more than 500,000 cubic yards has been removed from the Milwaukee Harbor in only two years since 1957—and anticipated shorter haul distances, transportation by railway was not considered further. Pipeline and belt conveyor transport of dredge spoils was considered feasible only for short distances because of interferences with navigation and adjacent land uses, and could therefore be used only if the disposal facility was located near the dredging operation. However, pipeline and belt conveyor

[11] *Camp Dresser & McKee, Inc., Dredge Material Disposal Planning Study, prepared for the Port of Milwaukee, August 1983.*

[12] *P. Souder, Jr. et. al., "Dredged Material Transport Systems for Inland Disposal and/or Productive Use Concepts," Technical Report D-78-28, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi, 1978.*

transport could be used in combination with other methods to pump out barges or to load trucks. Truck and barge transportation of dredge spoils were recommended by the Camp Dresser & McKee study because of their economic benefits, flexibility, and reliability. Accordingly, each of the spoils disposal alternatives herein evaluated calls for either trucks or barges as the means of transporting the dredge spoils to the disposal facility.

Dredge Spoils Disposal Alternatives

As of 1986, the existing confined disposal facility had a remaining capacity for approximately 800,000 cubic yards of dredge spoils. Assuming an average annual dredge spoil quantity of 115,000 cubic yards, the existing facility should be filled in about 1992. Therefore, it is assumed that no additional dredge spoils disposal facilities will be required prior to 1993. Filling in the existing confined disposal facility would have an estimated capital cost of $2.9 million and an average annual operation and maintenance cost of $740,000. Alternative methods were considered for the disposal of dredge spoils generated from 1993 through the year 2000, the end of the planning period, during which about 650,000 cubic yards of spoils would need to be disposed of. To estimate the capital cost of new confined or upland disposal facilities, it was assumed that these facilities would have a 20-year design life—from 1993 through the year 2013—and would therefore provide a capacity of about 1,430,000 cubic yards.

In evaluating the volume of sediment removed from the harbor, transported by truck, or confined within a disposal facility, a total solids content of approximately 50 percent was assumed. Within the inner harbor, the mean solids content of the bottom sediments, measured in situ in 1982 and 1983, ranged from 33 to 55 percent, wet weighted. Once combined sewer overflows are abated, it is expected that the solids content will increase as the organic content of the sediments decreases. During dredging, spoils are frequently diluted to solids contents ranging from 10 to 20 percent.[13] However, once de-watered within a confined disposal facility, the solids content of the spoils increases to a level approximating 50 percent. Dredge spoils with a solids content of about 50 percent would also be suitable for transport by truck for placement in an upland disposal site.

A variety of dredge spoils disposal alternatives were developed and evaluated in the Camp Dresser & McKee study.[14] Upland disposal methods were developed and evaluated in the Regional Planning Commission study.[15] One additional disposal alternative—disposal of dredge spoils in the Burnham Canal upstream of S. 11th Street—was evaluated and considered under the Milwaukee Harbor estuary study. A summary of the findings of the evaluation of 11 alternatives is set forth in Table 54. In a preliminary screening, six of the 11 alternatives were eliminated from further consideration because they were found to be technically or economically impractical, or because of legal constraints. Evaluations of five of the remaining alternatives are presented in the Camp Dresser & McKee and Regional Planning Commission reports. The findings of these evaluations are summarized below, along with a summary of the findings of an evaluation of the additional disposal alternative considered. A cost estimate, including the cost of dredging, is provided for each alternative disposal method for 1993 through the year 2000. Dredging, using mechanical dredging equipment, would cost approximately $460,000 on an average annual basis, and this cost is assumed under all disposal alternatives.

1. Open Water Disposal: This alternative would involve transporting the dredge spoils by barge several miles into Lake Michigan, and then injecting the spoils into deep water for disposal. As already noted, open water disposal was used for Milwaukee Harbor sediments until the late 1960's. This alternative would require site identification surveys, special environmental impact studies, and specialized equipment for near-bottom injection of spoils. It is likely that the spoils would be transported by barge or hopper dredge up to 10 miles from shore and deposited by subsurface injection at water depths exceeding 200 feet either on a level area of lake bottom or in a pit excavated

[13] *R. J. Krizek, J. A. Fitzpatrick, and D. K. Atmatzidis, "Dredged Material Confinement Facilities Solid-Liquid Separation Systems," Dredging and Its Environmental Effects, ed. P. A. Krenkel, J. Harrison, and J. C. Burdick III, 1976.*

[14] *Camp Dresser & McKee, op. cit.*

[15] *SEWRPC Community Assistance Planning Report No. 68, Upland Disposal Area Siting Study for Dredged Materials from the Port of Milwaukee, 1981.*

Table 54

COMPARISON OF MILWAUKEE HARBOR DREDGE DISPOSAL ALTERNATIVES

Dredge Disposal Alternative	Cost	Equipment Availability	Technical Suitability	Environmental Acceptability	Legal Limitations	Total Impact
Open Water Disposal	Major advantage. Relatively economical because of low construction and transportation costs	Advantage. Is an existing practice in the Great Lakes	Advantage. Demonstrated to be technically feasible in the Great Lakes	Disadvantage. Open water disposal of polluted dredge spoils may have detrimental effects on fish and aquatic life	Major disadvantage. Presently prohibited by the State of Wisconsin	Disadvantage. Presently prohibited by the State of Wisconsin, but considered a feasible and economical alternative for nonpolluted dredge spoils
Increase Capacity of the Existing Confined Disposal Facility	Advantage. Relatively economical	Advantage	No significant advantage or or disadvantage. Disposal of nonhazardous solids in a confined disposal facility is technically feasible	Advantage. Demonstrated to be environmentally safe	Disadvantage. Requires the approval of several federal and state agencies	Advantage. Considered to be a feasible and relatively economical alternative
New Harbor Confined Disposal Facility	Disadvantage	Advantage	Advantage. Disposal of nonhazardous solids in a confined disposal facility is technically feasible	No significant advantage or disadvantage. Net effect on the surrounding area would have to be evaluated on a case-by-case basis	Disadvantage	Advantage. Considered to be a feasible alternative
New Confined Disposal Facility in Burnham Canal Upstream of S. 11th Street	Advantage	Advantage	Advantage. Disposal of nonhazardous solids in a confined disposal facility is technically feasible	No significant advantage or disadvantage. Net effect on the surrounding area would have to be evaluated on a case-by-case basis	Disadvantage	No significant advantage or disadvantage. Would provide for the disposal of a relatively small amount of dredge spoils but considered to be a feasible alternative
Upland Disposal	Major disadvantage. Costs are relatively high because of high transportation costs	Advantage	Advantage. Technically acceptable with proper engineering	Major disadvantage. Major concern of potential metal leachate and groundwater problems associated with toxic metals and organic substances	Disadvantage. Strong public/legal resistance	No significant advantage or disadvantage
Incineration[a]	Major disadvantage. Costs are relatively high because of construction of new incineration facility or alterations to existing one	Major disadvantage. Requires a new facility, or utilization and possible modification of the South Shore incinerator	Disadvantage. Considered detrimental owing to the high water/low British thermal unit content, lack of an available and suitable facility, and the intermittent need of dredge projects	Major disadvantage. Major concern of air emissions problems and the concentration/oxidation of metals in the ash which may be classified as hazardous	Major disadvantage. Strong local resistance; facility funding, siting, air regulation, and ash leachate problems	Major disadvantage. Considered to be an unfeasible alternative owing to high cost and low efficiency
Subaqueous Borrow Pits[a]	Major disadvantage	Advantage. Requires conventional equipment	Major disadvantage	Major disadvantage	Major disadvantage. Could not be used for polluted dredge spoils	Major disadvantage. Considered to be an unfeasible alternative
Offshore Dispersion[a]	Major advantage	Advantage. Requires conventional equipment	Advantage	Major disadvantage	Major disadvantage. Could not be used for polluted dredge spoils	Major disadvantage. Considered to be an unfeasible alternative
Beach Enrichment[a]	Disadvantage	Advantage. Requires conventional equipment	Advantage	Major disadvantage	Major disadvantage. May use clean dredged materials only. Must be placed above the ordinary high water mark, or behind an approved bulkhead line	Major disadvantage. Considered to be an unfeasible alternative
Quarry Disposal[a]	Major disadvantage	Advantage. Requires conventional equipment	Major disadvantage	Major disadvantage	Major disadvantage. Could not be used for polluted dredge spoils	Major disadvantage. Considered to be an unfeasible alternative
Wetlands Disposal[a]	Disadvantage	Advantage. Requires conventional equipment	Advantage	Major disadvantage	Major disadvantage. Could not be used for polluted dredge spoils	Major disadvantage. Considered to be an unfeasible alternative

[a] *Eliminated in preliminary analyses of alternative dredge spoils disposal methods.*

Source: Camp Dresser & McKee, Inc., and SEWRPC.

into the lake bottom, with a minimum diameter of about 1,500 feet and a depth of about 16 feet. Because of water quality concerns, the State prohibits open water disposal of any dredge spoils. The U. S. Army Corps of Engineers has, however, concluded that properly conducted open water disposal of nonpolluted dredge spoils is technically sound, and environmentally safe.

Open water disposal, including dredging and transport of dredge spoils by barge, would have an estimated capital cost of $200,000 and an annual operation and maintenance cost of $510,000. Although legally prohibited by the State at the present time, open water disposal would be a feasible alternative if Section 30.12 of the Wisconsin Statutes was amended.

2. Increase Capacity of the Existing Confined Disposal Facility: This alternative would involve modifying the dike of the existing confined disposal facility in order to increase its capacity to dispose of the approximately 650,000 cubic yards of dredge spoils expected to be generated through the year 2000. The dredge spoils would continue to be transported to the confined disposal facility by barge. De-watering of the dredge spoils would be implemented by mounding and gravity drainage. Some leakage of spoil leachate through the dike could occur during construction.

   Continued dredging of the harbor and modification of the existing dike to dispose of dredge spoils generated through the year 2000 would have an estimated capital cost of $3,250,000 and an annual operation and maintenance cost of about $530,000. Increasing the capacity of the existing confined disposal facility was considered to be a feasible alternative.

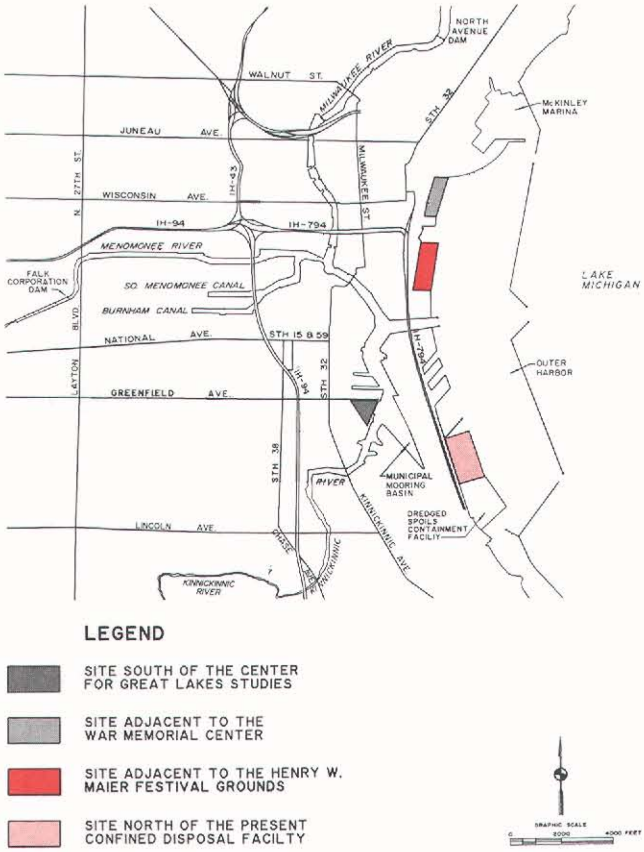
3. New Harbor Area Confined Disposal Facility: This alternative would involve the construction of a new confined disposal facility, similar to the existing facility, within the outer harbor or adjacent land area. The containment dikes would be designed and constructed--with clay liners if necessary--to effectively and safely filter contaminants and thereby prevent contaminated leachate from being discharged to the outer harbor. For the purposes of the evaluation, it was assumed that the effluent, or drainage water, from the new confined facility would not need to be conveyed to and treated at the Jones Island wastewater treatment plant. The dredge spoil transport and de-watering processes would be similar to those proposed above for the existing facility. Mounding and gravity drainage could be used to de-water the dredge spoils. The de-watered dredge spoils that are nonhazardous could be transported by truck to landfills, which would extend the life of the disposal facility. A new disposal facility could pose land use, navigation, and recreation conflicts in the outer harbor, and require the loss of navigable harbor area for development.

   Four new confined disposal facility sites within the harbor area were considered in the Camp Dresser & McKee study. These sites were located just north of the present confined disposal facility; adjacent to the Henry W. Maier festival grounds property; adjacent to the War Memorial Center; and just south of the Center for Great Lakes Studies, as shown on Map 18. The first three sites are located within the outer harbor, while the last site is located on land adjacent to the Kinnickinnic River estuary. The most feasible new disposal site is located immediately north of the existing disposal facility. The festival grounds and War Memorial Center sites would probably be feasible only for development of disposal facilities that could be implemented as part of other lakefront development projects.

   Continued dredging of the harbor and construction of a new confined disposal facility would have an estimated capital cost of $9 million and an annual operation and maintenance cost of $550,000. Because of the proven methodology entailed, a new confined disposal facility was considered to be a feasible alternative. The cost estimate for the new confined disposal facility is about $1.5 million higher than estimates developed based upon the costs of construction of the existing facility adjusted for inflation. This higher cost provides for the construction of a clay, or synthetic material, liner within the facility in order to minimize the potential for leakage from the facility. Such leakage occurred at the existing facility and had to be corrected.

Map 18

POTENTIAL NEW CONFINED DISPOSAL FACILITY SITES WITHIN THE MILWAUKEE HARBOR AREA



The existing dredge spoils confined disposal facility, with a 1986 remaining capacity of about 800,000 cubic yards of dredge spoils, is expected to be filled by about 1993. Four new confined disposal facility sites—shown on this map—were identified and evaluated. The most feasible new disposal site is located immediately north of the existing disposal facility.

Source: Camp Dresser & McKee, Inc.

4. New Confined Disposal Facility in Burnham Canal Upstream of S. 11th Street: This alternative would consist of filling in the Burnham Canal upstream of S. 11th Street with dredge spoils, with the filled land made available for additional development in this area. This portion of the Burnham Canal is not currently dredged for maintenance of navigation. The City of Milwaukee is planning to construct a two-span fixed bridge over the Burnham Canal at S. 11th Street, which will preclude commercial navigation upstream of this bridge. The portion of the canal that would be filled with dredge spoils has a surface area of about 3.5 acres, and, at an assumed spoil storage depth of about 10 feet, would have a capacity of about 60,000 cubic yards of dredge spoils—or for less than one year of dredge spoils. Dredge spoils could be conveyed to the canal by barge. Filling in a portion of the Burnham Canal would eliminate the need for a bridge at S. 11th Street. It would, however, require extension of the storm sewer outfalls that discharge into the Canal, require de-watering of the dredge spoils, and require covering with a suitable fill material to facilitate development.

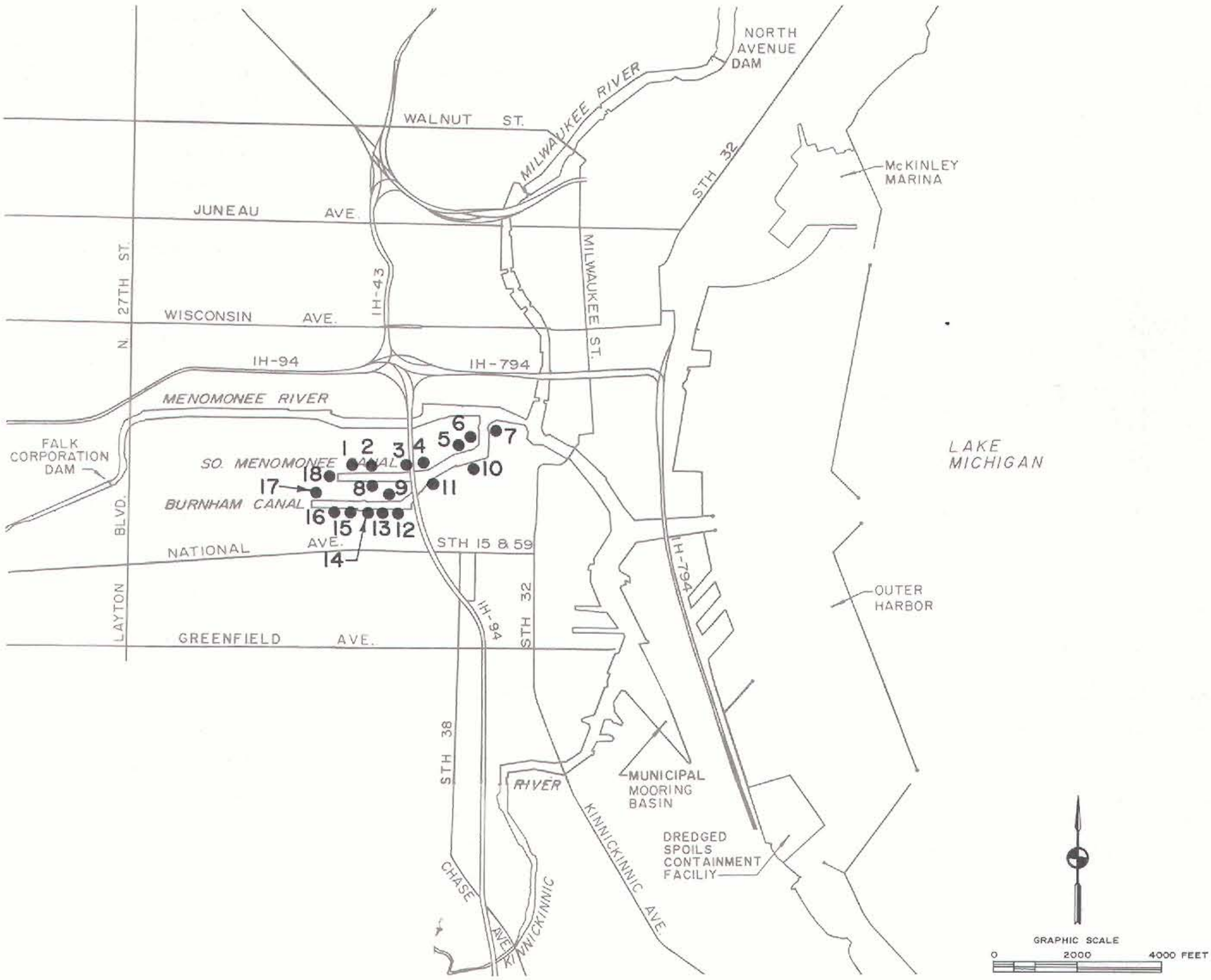
Filling a portion of the Burnham Canal with dredge spoils would have an estimated capital cost of $400,000 and an operation and maintenance cost of about $390,000 for the one-year project. In addition, the combined storm sewers that currently discharge to the upper canal would need to be extended to new outfall locations—and such sewers would probably have to be constructed on piling—at an estimated capital cost of $400,000. The total capital cost, therefore, would be about $800,000. Although this alternative would provide for the disposal of a relatively small amount of dredge spoils, it was considered to be feasible.

Filling in the entire Burnham and South Menomonee Canals with dredge spoils was also considered. However, the South Menomonee Canal and the Burnham Canal downstream of S. 11th Street are still used for waterborne commerce by Schneider Fuel Company, Balco Metal Company, the Wisconsin Electric Power Company, Lone Star Industries (Marquette Cement), Morton Salt, Construction Aggregate, Inc., the Milwaukee Metropolitan Sewerage District, Cargill, Inc., and Huron Cement.[16] The locations of these canal users are shown on Map 19. The other property owners adjoining the canals may be considered to be potential users of the Canal. The costs for vacating and filling the canals would be very high, and acquisition of the operating industrial sites that use the canals could be

[16] *William Ryan Drew, Commissioner of the Department of City Development, City of Milwaukee, Letter to Kurt W. Bauer, Executive Director, Southeastern Wisconsin Regional Planning Commission, March 25, 1986.*

Map 19

USERS OF AND ADJOINING PROPERTY OWNERS ALONG THE SOUTH MENOMONEE AND BURNHAM CANALS: 1986



LEGEND

1	SCHNEIDER FUEL COMPANY	7	MILWAUKEE METROPOLITAN SEWERAGE DISTRICT	13	BREMER SALVAGE
2	BALCO METAL COMPANY	8	CARGILL, INC.	14	DEBELAK
3	WISCONSIN ELECTRIC POWER COMPANY	9	HURON CEMENT	15	GEBHARDT-VOGEL TANNING COMPANY
4	LONE STAR INDUSTRIES (MARQUETTE CEMENT)	10	SOO LINE	16	DUNDEE CEMENT COMPANY
5	MORTON SALT	11	P & V ATLAS INDUSTRIAL CENTER, INC.	17	MILLER COMPRESSING COMPANY
6	CONSTRUCTION AGGREGATES, CORP.	12	BLACKHAWK TANNING	18	PECK PACKING COMPANY

Filling in the South Menomonee and Burnham Canals was considered an alternative means of disposal for dredge spoils, creating new land for additional development. However, the South Menomonee and Burnham Canals were still in 1986 used for waterborne shipping by the Schneider Fuel Company, Balco Metal Company, Wisconsin Electric Power Company, Lone Star Industries (Marquette Cement), Morton Salt, Construction Aggregate, Inc., Cargill, Inc., and Huron Cement. Under this alternative, industrial sites that use the canal may need to be purchased, and the canal users relocated.

Source: Department of City Development, City of Milwaukee.

required, along with relocation of those industries and public improvement costs.[17] When the City of Milwaukee closed the Holton Canal in 1980, the estimated cost was $600,000 exclusive of property acquisition costs. Accordingly, filling in the canals was not considered feasible.

5. Upland Disposal: Upland disposal would involve the placement of dredge spoils in various types of upland disposal sites. The Regional Planning Commission study[18] found that it was technically feasible to dispose of dredge spoils in a new upland landfill specifically designed and used for dredge spoils, and in an existing or new general refuse sanitary landfill. Also found to be feasible was use of the spoils as a soil conditioner for agricultural land, or as fill material for industrial, commercial, or recreational development. Each of these alternative upland disposal methods would require a spoils storage and de-watering system, a transportation system most likely utilizing trucks, and a filling or application system at the upland sites. A combination of upland disposal methods could also be utilized. Detailed site location and feasibility analyses would need to be conducted.

   The capital costs of upland disposal would be about $3 million for disposal as fill; about $8 million for disposal in an existing landfill; about $11 million for disposal in a new landfill or lagoon; and about $2 million for application of dredge spoils to agricultural land as a soil conditioner. The annual operation and maintenance costs of upland disposal would be about $690,000 for disposal as fill; about $760,000 for disposal in an existing landfill; about $760,000 for disposal in a new landfill or lagoon; and about $1.2 million for application to agricultural land. These cost estimates are based on the assumption that the dredge spoils are not classified as hazardous wastes. If future sediment analyses indicate that the spoils are in fact hazardous, the spoils would have to be disposed of in a landfill designed, constructed, and licensed to receive hazardous wastes. Disposal at a licensed hazardous waste disposal facility would have an annual cost of approximately $12 million. Transportation costs are the primary reason that most of the upland disposal costs are higher than the cost of using open water disposal or a confined disposal facility. In addition, upland disposal methods may result in strong public resistance, groundwater contamination problems, local zoning and land use problems, and long transportation distances. Although somewhat more costly than other disposal alternatives, the upland disposal alternative was considered further.

Summary of Costs and Economic Analysis

Table 55 summarizes the costs of removing and disposing of the material dredged annually for continued maintenance of navigation. From 1986 through 1992, the existing confined disposal facility would be filled at a capital cost of about $2,900,000 and an average annual operation and maintenance cost of about $740,000. The total annual cost would range from about $1,150,000, or $10.06 per cubic yard of dredge spoils, if no interest was paid on the capital expenditures, to about $1,300,000, or $11.38 per cubic yard, if the capital expenditures were financed at an interest rate of 8 percent.

From 1993 through 2000, the capital cost of dredging and nonhazardous spoils disposal would range from $200,000 for open water disposal to $11 million for the construction of a new landfill or lagoon. The average annual operation and maintenance costs would range from $510,000 for open water disposal to $1.2 million for use of the spoils as an agricultural soil conditioner. If no interest was paid on the capital expenditures, the total annual costs would range from $520,000, or $7.26 per cubic yard of dredge spoils, for open water disposal, to $1,310,000, or $18.32 per cubic yard, for construction of a new landfill or lagoon. If the capital expenditures were financed at an interest rate of 8 percent, the total annual costs would range from $530,000, or $7.41 per cubic yard of dredge spoils, for open water disposal, to $1,880,000, or $26.29 per cubic yard, for construction of a new landfill or lagoon.

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[17] *William Ryan Drew, Commissioner of the Department of City Development, City of Milwaukee, Letter to Kurt W. Bauer, Executive Director, Southeastern Wisconsin Regional Planning Commission, March 17, 1986.*

[18] *SEWRPC Community Assistance Planning Report No. 68, Upland Disposal Area Siting Study for Dredged Materials from the Port of Milwaukee, 1981.*

Table 55

SUMMARY OF COSTS AND FISCAL ANALYSIS OF ALTERNATIVE DREDGING AND SPOILS DISPOSAL MEASURES: 1986-2000

Time Period	Alternative[a]	Cost (1986-2000) Capital	Cost (1986-2000) Annual Operation and Maintenance	Cost Analysis[b] Total Annual	Cost Analysis[b] Cost per Cubic Yard of Dredge Spoils[g]	Fiscal Analysis[c] Total Annual	Fiscal Analysis[c] Cost per Cubic Yard of Dredge Spoils[g]
1986-1992	Fill Existing Confined Disposal Facility.	$ 2,900,000	$ 740,000	$ 1,150,000	$ 10.06	$ 1,300,000	$ 11.38
1993-2000	Open Water Disposal[d]	200,00	510,000	520,000	7.26	530,000	7.41
	Increase Capacity of Existing Confined Disposal Facility.	3,250,000	530,000	940,000	11.57	1,100,000	13.54
	New Harbor Area Confined Disposal Facility.	9,000,000	550,000	1,000,000	13.99	1,430,000	20.00
	New Confined Disposal Facility in Burnham Canal[e].	800,000	390,000	1,190,000	19.83	1,190,000	19.83
	Upland Disposal						
	Fill.	3,000,000	690,000	840,000	11.75	1,000,000	13.99
	Existing Landfill	8,000,000	760,000	1,160,000	16.22	1,570,000	21.96
	New Landfill or Lagoon. . . .	11,000,000	760,000	1,310,000	18.32	1,880,000	26.29
	Agricultural Soil Conditioner	2,000,000	1,200,000	1,300,000	18.18	1,400,000	19.58
	Hazardous Waste Disposal in a Specially Designed and Licensed Disposal Facility[f]	- -	12,000,000	12,000,000	168.00	12,000,000	168.00

[a] *All alternatives include dredging with mechanical dredging equipment.*

[b] *The cost analysis assumes that all capital expenditures will be paid off over the life of the facilities with no interest.*

[c] *The fiscal analysis assumes that all capital expenditures will be paid off over the life of the facilities at an interest rate of 8 percent.*

[d] *Open water disposal of dredge spoils is currently prohibited by Section 30.12 of the Wisconsin Statutes.*

[e] *The Burnham Canal upstream of S. 11th Street would have capacity for only 60,000 cubic yards of dredge spoils. It was assumed that the canal will provide capacity for one year of dredge spoils removal after combined sewer overflows are abated.*

[f] *Disposal costs if future sediment analyses indicate spoils are hazardous under Resource Conservation and Recovery Act requirements. All other alternatives assume that the spoils will not be classified as hazardous waste. Since no capital cost would be required, the cost analysis is the same as the fiscal analysis.*

[g] *The unit costs are provided per cubic yard of dredge spoils at an assumed solids content of 50 percent total solids.*

Source: SEWRPC.

Disposal of dredge spoils in the Burnham Canal upstream of S. 11th Street, which would provide capacity for only about 60,000 cubic yards of spoils, would have a capital cost of about $700,000 and an operation and maintenance cost of about $390,000, and an annual cost ranging from $1,090,000 to $1,130,000. If future sediment analyses indicate that the dredge spoils are hazardous under the Resource Conservation and Recovery Act requirements, the total annual cost of dredging and disposal could be expected to increase to about $12 million, or $168 per cubic yard of dredge spoils.

RECOMMENDED DREDGING ACTIVITIES AND SPOILS DISPOSAL MEASURES

Dredging

To accommodate waterborne commerce within the Port of Milwaukee, it is essential that dredging continue to be conducted to maintain a navigable waterway. Maintenance dredging should continue within the project areas, and to the project depths, established by the U. S. Army Corps of Engineers. No new work dredging for navigation is envisioned at this time. No additional dredging is recommended for water quality or habitat improvement purposes. The hydraulic hopper dredge and the mechanical dipper and clamshell dredges which have been used in the Milwaukee Harbor estuary are suitable, acceptable methods of dredging. It is expected that, once combined sewer overflows are abated—in the mid-1990's under current projections—sedimentation rates, and the attendant required frequency of dredging, will be reduced by about 40 to 50 percent, requiring the removal of about 65,000 cubic yards of dredge spoils per year. Prior to the completion of combined sewer overflow abatement measures, however, the sedimentation rate is expected to continue at its existing level, requiring the removal of about 115,000 cubic yards of dredge spoils per year.

Dredge Spoils Disposal

The Camp Dresser & McKee study concluded that increasing the capacity of the existing confined disposal facility, construction of a new harbor confined disposal facility, and open water disposal were all feasible alternatives which should be considered for the disposal of dredge spoils generated through the year 2000. Detailed evaluations of each of these alternatives were presented in the Camp Dresser & McKee study. In addition, the use of the Burnham Canal upstream of S. 11th Street as a disposal facility, and the use of upland disposal sites, are also considered to be feasible alternatives.

It is recommended that, for the disposal of dredge spoils following the filling of the existing facility in about 1992, a new confined disposal facility be constructed in the outer harbor just north of the existing facility. This alternative is technically sound, basically being a continuation of existing disposal techniques, and may minimize any environmental problems by including a high level of environmental protection measures, and by being separated from the existing facility. It should be noted that regulations presently being revised by the Wisconsin Department of Natural Resources could affect the detailed design and costs of the disposal facility. Such impacts may also apply to the other alternatives considered.

The cost analysis set forth in Table 55 indicates that the recommended alternative is about 20 percent more costly than the alternative of increasing the capacity of the existing confined disposal facility by modifying the height of the dike walls. It was concluded that increasing the capacity of the existing facility would create additional environmental problems, and aesthetically, increasing the height of the dike walls substantially would not be desirable. Thus, constructing a new facility was preferred over expanding the capacity of the existing facility.

It may be economically feasible to dispose of dredge spoils in the Burnham Canal. However, a recommendation to fill a portion of the canal should be made in coordination with a land use development plan which considers factors such as land use, socioeconomics, and recreation.

Since the dredge spoils from the Milwaukee Harbor estuary are heavily polluted, and in the future are likely to remain either moderately or heavily polluted, it is not recommended that further consideration be given to open water disposal of dredge spoils. Although open water disposal would be a permanent, essentially unlimited disposal method for dredge spoils, and would be less costly than any other alternative, it is unlikely that a sufficient volume of suitable nonpolluted material would be available to develop and apply this means of disposal.

It is also unlikely that the polluted dredge spoils could be used as upland fill or as an agricultural soil conditioner. Disposal of dredge spoils in an existing landfill or a new landfill or lagoon would cost about 15 to 30 percent more than the recommended alternative.

SUMMARY

Within the Milwaukee Harbor estuary, the Milwaukee River downstream of E. Buffalo Street, the Menomonee River downstream of N. 25th Street, the Burnham and South Menomonee Canals, the Kinnickinnic River downstream of S. Kinnickinnic Avenue, and a portion of the outer harbor have been routinely dredged for navigation purposes. All the dredging required for harbor expansion or improvement was conducted prior to 1968. Since that time, only maintenance dredging has been conducted to retain the established navigation project depths.

Over the period of 1975 through 1984, approximately 1,150,900 cubic yards of material were dredged from the estuary under federal or City of Milwaukee contracts, with about 206,900 cubic yards, or 18 percent, being dredged from the entrance channel and outer harbor, and about 944,000 cubic yards, or 82 percent, being dredged from the inner harbor. Thus, an annual average of 115,000 cubic yards of bottom materials were removed from within the project limits. Of this total, about 919,300 cubic yards, or an average of 92,000 cubic yards per year, were dredged by the U. S. Army Corps of Engineers, and a total of 231,600 cubic yards, or about 23,000 cubic yards per year, were dredged under contract to the City of Milwaukee. The dredged materials were placed in the U. S. Army Corps of Engineers' confined disposal facility in the outer harbor. In addition, an indeterminate but minor amount of dredging was done under private contract.

The sediments contributed to the harbor estuary by combined sewer overflows tend to be relatively large-sized and are more likely to settle than are sediments being transported to the harbor by the tributary rivers. It was concluded that abatement of combined sewer overflows will likely reduce the sedimentation rates by 40 to 50 percent. Therefore, following abatement of the combined sewer overflows, the volume of spoils generated by dredging for maintenance of navigation should be reduced to an average of 65,000 cubic yards per year.

Studies of the water quality effects of the polluted bottom sediments indicated that dredging the bottom sediments beyond that required to maintain navigation would not effectively increase the dissolved oxygen levels in the harbor water. Furthermore, it does not appear necessary to dredge the bottom sediments to abate toxic effects of organic substances on benthic organisms that reside in the sediments, or for habitat improvement purposes. However, it is not presently possible to quantify the release of metals from the bottom sediments to the interstitial or overlying water. Therefore, additional study on the fate and transport of toxic substances, especially metals, will be required to determine whether dredging of the bottom sediments is needed to abate toxic pollution.

Several dredging methods and dredge spoils transport and disposal alternatives have been considered for the estuary. Dredge methods include use of mechanical dredges such as the dragline, dipper, and clamshell dredges, and of hydraulic dredges such as the cutterhead and hopper dredges. For the disposal of dredge spoils from 1986 through 1992, it was concluded that the existing confined disposal facility should be filled. This will involve a total volume of 800,000 cubic yards, and an annual cost of $1.15 million. For the disposal of dredge spoils generated from 1993 through 2000, a total of 11 dredge spoils disposal alternatives were evaluated in terms of cost, equipment availability, technical suitability, environmental acceptability, and legal limitations. More detailed evaluations were conducted of five of the 11 alternatives. The alternatives considered in detail were: open water disposal, increasing the capacity of the existing confined disposal facility, construction of a new harbor confined disposal facility, construction of a confined disposal facility in the Burnham Canal upstream of S. 11th Street, and upland disposal. These five alternatives have estimated annual costs ranging from $530,000, or $7.41 per cubic yard of dredge soils, for open water disposal to about $1.88 million, or $26.29 per cubic yard, for upland disposal. The annual costs could be $12 million, or $168 per cubic yard, if a hazardous waste disposal facility were required for disposal.

It is accordingly recommended that dredging continue to be conducted to maintain navigation, but that no additional dredging be conducted for water quality or habitat improvement purposes, pending further evaluation of toxicity problems. To dispose of dredge spoils generated after the filling of the existing confined disposal facility in about 1992, it is recommended that a new confined disposal facility be constructed in the outer harbor just north of the existing facility. This facility should have a capacity of approximately 1,430,000 cubic yards. The recommended plan is more environmentally acceptable than increasing the capacity of the existing facility or open water disposal, and is less costly than the upland disposal alternative. Disposing of dredge spoils in the Burnham Canal may also be economically feasible, although that alternative should be considered further only in coordination with a land use development plan for the area.

Chapter VI

ALTERNATIVE ANCHORAGE, DOCKAGE, AND FLOOD PROTECTION MEASURES

INTRODUCTION

Prior to the completion of breakwater construction in Lake Michigan at Milwaukee in 1889, safe anchorage and dockage was found only in the inner harbor, which was not fully protected from storms on Lake Michigan. The entrance to the inner harbor was at the natural mouth of the Milwaukee River at the south end of Jones Island. The location of the mouth had been fixed by the construction of jetties on both sides of the channel by the U. S. Army Corps of Engineers in 1843, as shown on Map 20. A few piers on the unprotected shoreline of the lake were utilized for loading and unloading of ships but suffered frequent storm damage.

Because the origins and destinations of much of the ship traffic were piers on the Milwaukee River in the reach between the Menomonee River and the North Avenue dam, a new channel was completed from the river to the lake in 1857, as shown on Map 20. The new channel was constructed at the present location primarily to reduce costs associated with maintenance dredging.

In 1877, the Chicago & North Western Railway Company built a breakwater about 100 feet offshore of North Point south to the inner harbor entrance channel to protect the railway line in its lakeside location. As shown on Map 21, in 1889, the Corps of Engineers completed construction of a breakwater farther offshore to provide a harbor of refuge and to impede shoaling (sedimentation) in the inner harbor entrance channel. The protected area of 540 acres was located north of the entrance channel and did not include Jones Island. The protected area was also used for temporary mooring when inner harbor traffic was heavy. By 1910, the breakwater had been extended south another 980 feet, as shown on Maps 21 and 22.

In 1912, a City Harbor Commission was formed by the City of Milwaukee. A high priority of that Commission was planning for the construction of outer harbor facilities and a longer breakwater to accommodate and protect larger ocean-going ships following completion of the proposed St. Lawrence Seaway. In 1929, the breakwater was completed by the U. S. Army Corps of Engineers in its present-day location, as shown on Map 23.

South Pier 1 in the outer harbor was completed at its present-day location in 1933. South Pier 2 was completed in 1961. The car ferry pier was completed in 1960 at the present location of the Harbor Commission North Pier, as shown on Map 24. The McKinley Park lakefill and marina were completed in 1964, as shown on Map 25. The most recent major change in the geometry of the outer harbor occurred in 1976 with construction of the confined disposal facility for polluted dredge spoils, which is located on the south end of the outer harbor next to the U. S. Coast Guard Station, as shown on Map 25.

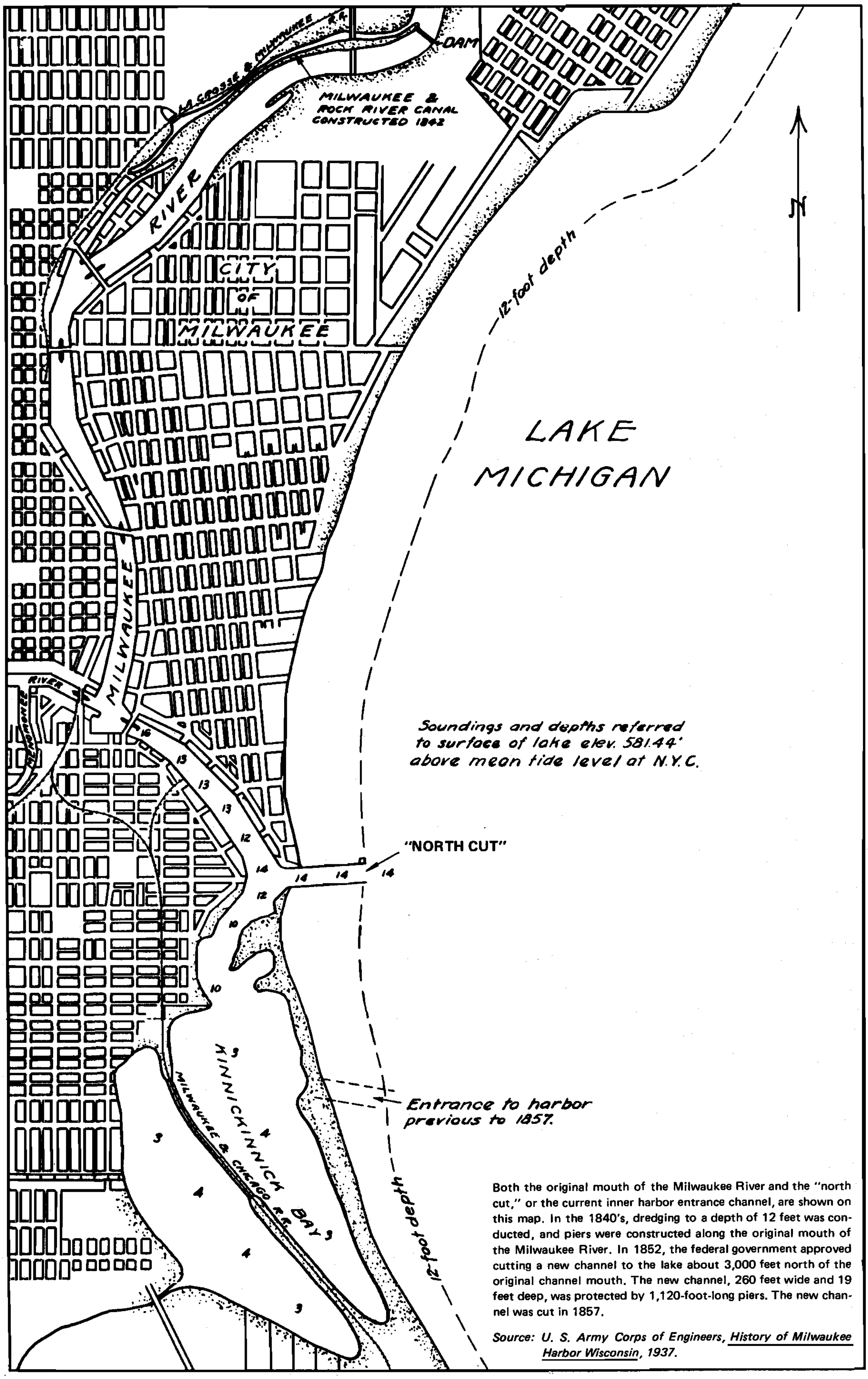
Although completion of the breakwater in 1929 provided a much safer harbor than previously existed, the breakwater did not entirely eliminate damage and danger in the outer harbor. At the present time, storm waves frequently overtop the structure and occasionally damage port facilities and shore protection structures. During storms, hazardous conditions exist for smallcraft even within the confines of the breakwater, and even in the McKinley Park smallcraft anchorage area. A storm on April 9, 1973, caused about $280,000 in damage in the outer harbor, and provided evidence that additional protective measures may be needed.

The construction of the McKinley Park peninsula, while providing some protection to smallcraft from waves generated by winds from the southeast quarter, created conditions enhancing the formation of a relatively thick winter ice cover in the protected area north of the peninsula. Damage caused by ice to the McKinley Marina and Milwaukee Yacht Club dockage can be severe, particularly during periods of relatively high lake levels.

During prolonged periods of high lake levels, the threat of shoreland flooding in the inner harbor, caused by occasional high tributary river flow, is increased by the additional backwater effect of Lake Michigan. The always present threat of an indefinitely long period of above-normal precipitation, resulting in rising lake levels, requires that previously developed regulatory flood stages and flood control measures in the inner harbor be reevaluated in light of the most recent data.

Map 20

LOCATION OF THE MOUTH OF THE INNER HARBOR: 1867

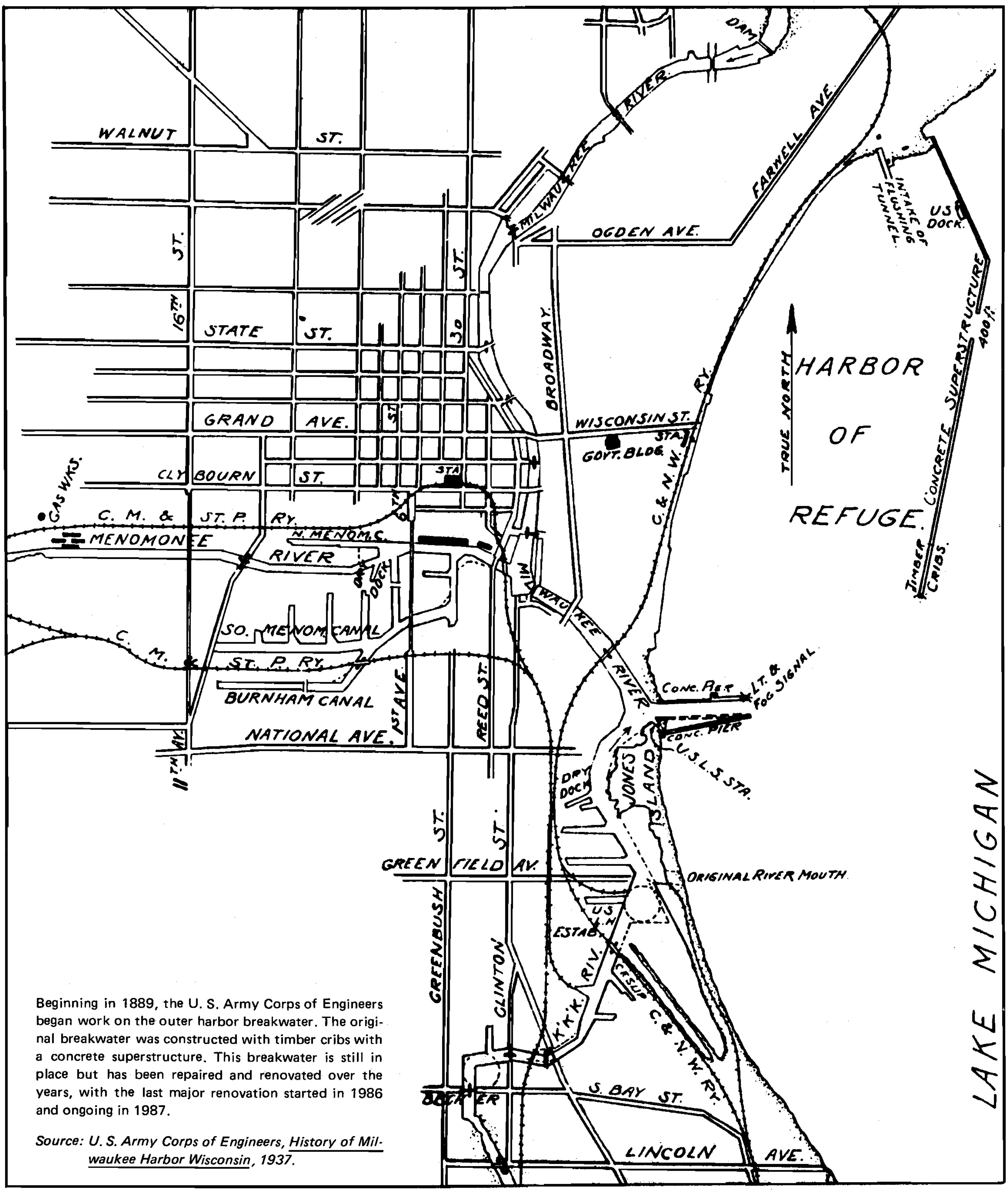


Both the original mouth of the Milwaukee River and the "north cut," or the current inner harbor entrance channel, are shown on this map. In the 1840's, dredging to a depth of 12 feet was conducted, and piers were constructed along the original mouth of the Milwaukee River. In 1852, the federal government approved cutting a new channel to the lake about 3,000 feet north of the original channel mouth. The new channel, 260 feet wide and 19 feet deep, was protected by 1,120-foot-long piers. The new channel was cut in 1857.

Source: U. S. Army Corps of Engineers, History of Milwaukee Harbor Wisconsin, 1937.

Map 21

MILWAUKEE HARBOR FACILITIES: 1911

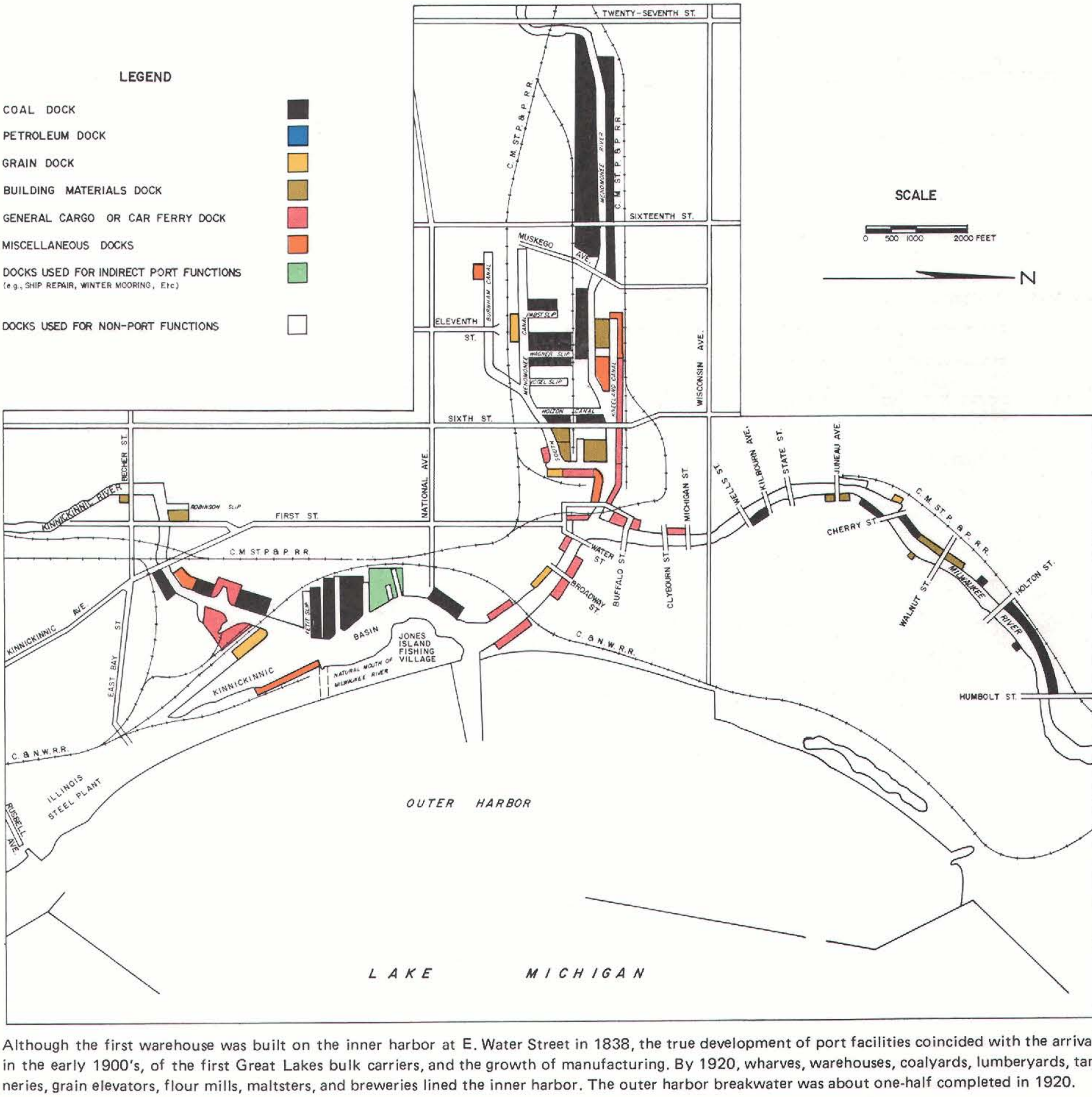


Beginning in 1889, the U. S. Army Corps of Engineers began work on the outer harbor breakwater. The original breakwater was constructed with timber cribs with a concrete superstructure. This breakwater is still in place but has been repaired and renovated over the years, with the last major renovation started in 1986 and ongoing in 1987.

Source: U. S. Army Corps of Engineers, History of Milwaukee Harbor Wisconsin, 1937.

Map 22

HARBOR LAND USE, PORT OF MILWAUKEE: 1920

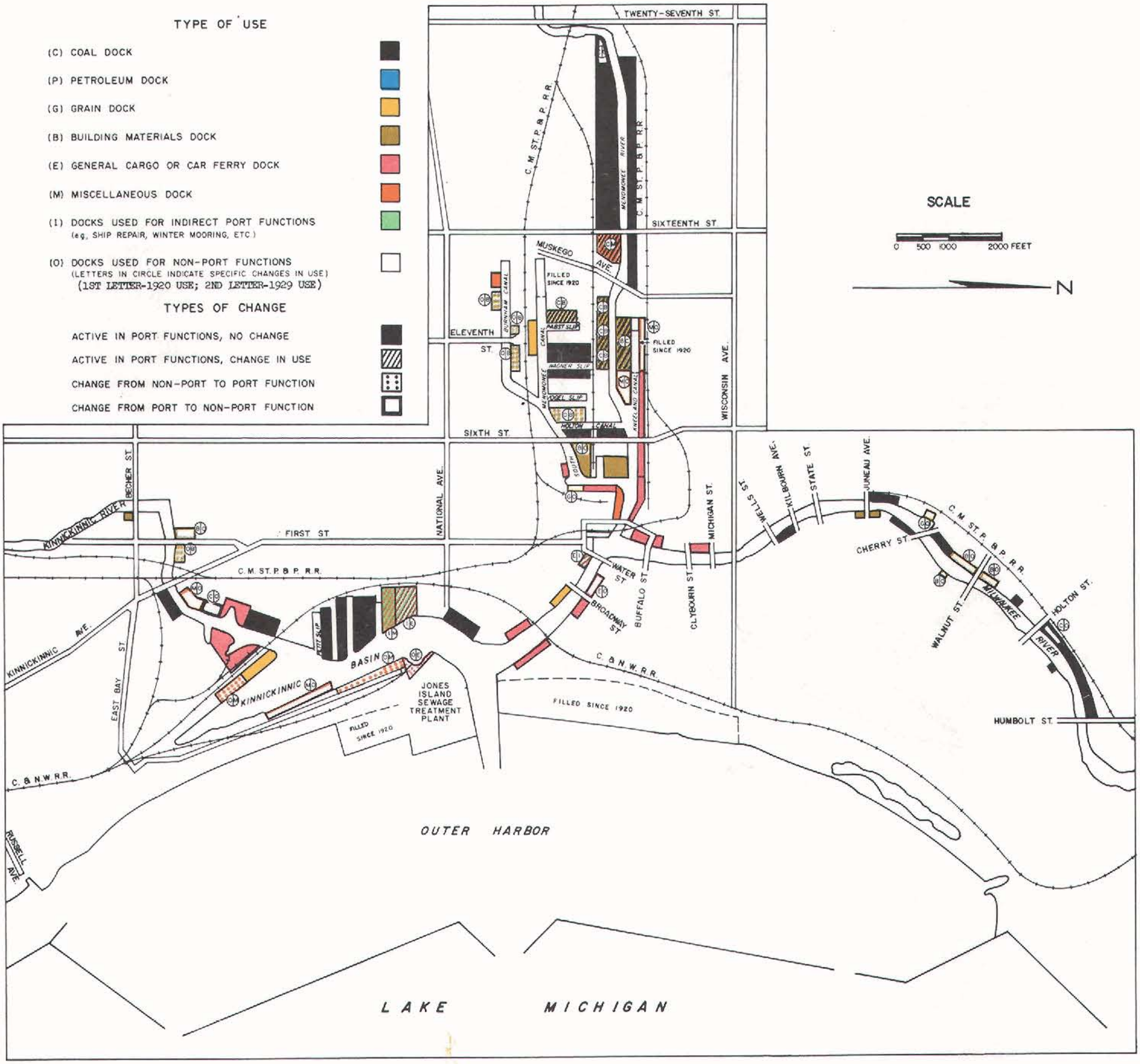


Although the first warehouse was built on the inner harbor at E. Water Street in 1838, the true development of port facilities coincided with the arrival, in the early 1900's, of the first Great Lakes bulk carriers, and the growth of manufacturing. By 1920, wharves, warehouses, coalyards, lumberyards, tanneries, grain elevators, flour mills, maltsters, and breweries lined the inner harbor. The outer harbor breakwater was about one-half completed in 1920.

Source: Donald A. Gandre, Land Use Changes in the Milwaukee Port Area 1920-1963, University of Wisconsin-Madison, PhD. Thesis, 1965.

Map 23

HARBOR LAND USE, PORT OF MILWAUKEE: CHANGES 1920-1929

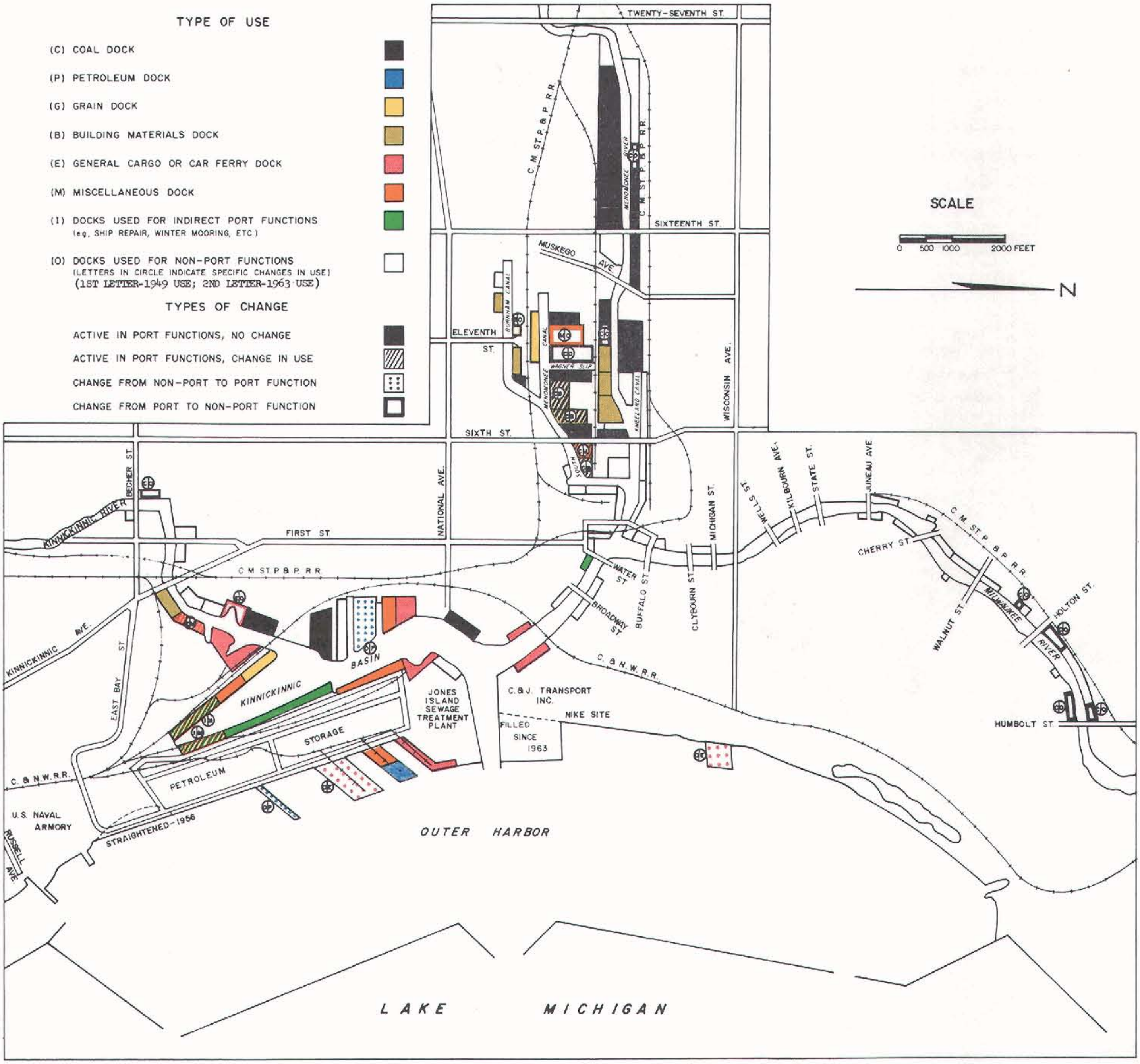


Development of the port facilities continued in the 1920's, with the completion of the outer harbor breakwater. The inner harbor area became a major manufacturing center, particularly for heavy pumping machinery, large gas engines, lubricating equipment, steam shovels, automobile parts, industrial machinery, hydroelectric units, and malt projects, including beer manufacturing. Milwaukee was one of the largest grain markets in the United States, and a major coal receiving port.

Source: Donald A. Gandre, Land Use Changes in the Milwaukee Port Area 1920-1963, University of Wisconsin-Madison, PhD. Thesis, 1965.

Map 24

HARBOR LAND USE, PORT OF MILWAUKEE: CHANGES 1949-1963

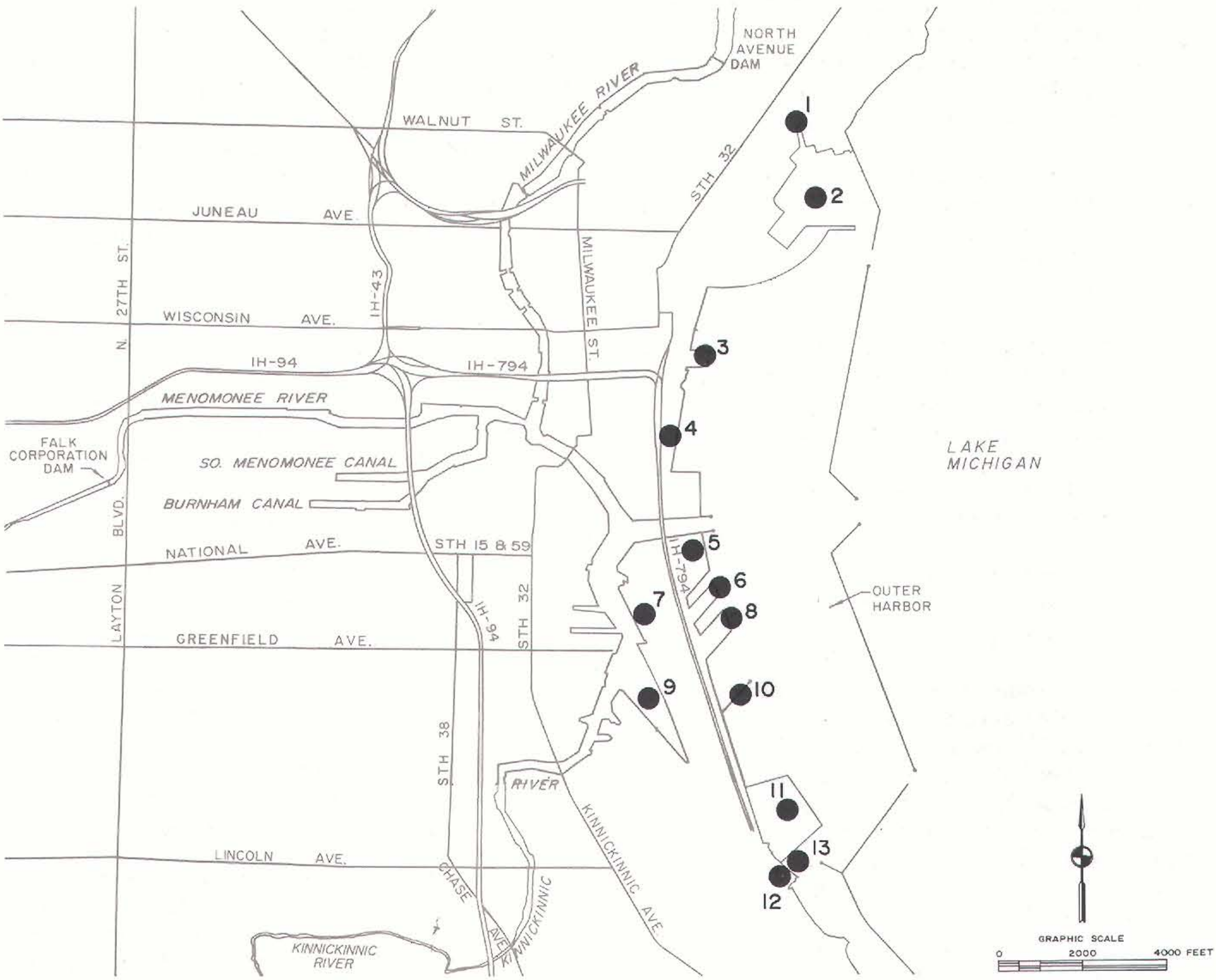


Changing lifestyles and land use patterns, along with the desire to eliminate bridge openings to accommodate automobile traffic, resulted in the end to commercial navigation on the Milwaukee River upstream of Buffalo Street in 1959. Emphasis shifted to the development of the land adjacent to the outer harbor. Fill was placed in the outer harbor to create new land and provide additional lakefront facilities.

Source: Donald A. Gandre, Land Use Changes in the Milwaukee Port Area 1920-1963, University of Wisconsin-Madison, PhD. Thesis, 1965.

Map 25

MILWAUKEE HARBOR FACILITIES: 1986



LEGEND

1	MILWAUKEE RIVER FLUSHING TUNNEL INLET	5	JONES ISLAND SEWAGE TREATMENT PLANT	9	MUNICIPAL MOORING BASIN	13	KINNICKINNIC RIVER FLUSHING TUNNEL INLET
2	McKINLEY MARINA	6	PIER NO. 1	10	LIQUID CARGO PIER		
3	HARBOR COMMISSION NORTH PIER	7	HEAVY LIFT DOCK	11	DREDGE SPOIL CONTAINMENT FACILITY		
4	HENRY W. MAIER FESTIVAL GROUNDS	8	PIER NO. 2	12	U.S. COAST GUARD STATION		

Major port development projects since the 1960's have included further development of Juneau Park and the McKinley Park anchorage area, the construction of the U. S. Army Corps of Engineers confined dredge spoils disposal area, and the ongoing eastward expansion of the Jones Island sewage treatment plant property. Port facilities designed to handle both manufactured goods and agricultural products include refrigerated terminals, building material wharves, grain elevators, petroleum terminals, bulk handling and storage facilities, and fixed and mobile derricks and cranes.

Source: SEWRPC.

DESCRIPTION OF PROBLEMS

Safe anchorage in Milwaukee Harbor is necessary for continued and increased usage of the harbor by both recreational and commercial watercraft. Anchorage in the inner harbor is relatively safe for both smallcraft and larger vessels. However, the amount of available anchorage and potential marina development area in the inner harbor is limited by the following:

1. The confining geometry of inner harbor channels which limits the size of commercial vessels that can be efficiently served and which limits the area available for marina development;

2. The relatively high shoaling rates in the Menomonee and Kinnickinnic River federal channels which occasionally hinder movement of deeper draft vessels;

3. The limited area for potential dockage of larger vessels; and

4. The aesthetic unsuitability of certain land uses along the waterways for marina development.

Anchorage in the outer harbor of Milwaukee is relatively safe during ordinary Lake Michigan storm events. The larger storms, however, can produce wave conditions in the outer harbor, including the McKinley Park anchorage area, which can damage not only moored smallcraft, but also larger commercial vessels berthed at the municipal piers. Therefore, although anchorage conditions in Milwaukee Harbor are much improved compared to conditions prior to completion of the breakwater, safe anchorage has not yet been fully achieved, limiting to some extent the attractiveness of the Milwaukee Harbor as a commercial shipping facility, a smallcraft recreation center, and a harbor of refuge.

Wind storms over Lake Michigan periodically cause damage to facilities operated by the Port of Milwaukee, to the McKinley Marina, and to the Henry W. Maier festival grounds due, primarily, to large waves incoming through the breakwater gaps, and to wave energy transmission over the breakwater. Within the McKinley anchorage area, the most severe damage generally is to piers and is caused by horizontal and vertical movement of winter ice cover, and also by ice floes occurring in various combinations with storm waves, seiche action, winds, and lake level.

Protection of the shoreline and riparian facilities behind the breakwater forming the outer harbor of Milwaukee has become increasingly important as the number of facilities has increased and as the level of Lake Michigan at Milwaukee has risen to, and above, previous records for the 20th century. Higher lake levels were recorded in 1886, but major dredging of the St. Clair River at the outlet of Lake Huron in the latter 19th century and early 20th century caused the levels of Lakes Michigan and Huron to decrease about one foot. Therefore, direct comparisons of present day lake levels with the relatively high levels recorded in the 19th century are inappropriate. Indeed, 20th century record levels would have exceeded 19th century levels if the St. Clair River had not been dredged. Geological evidence indicates that during the last 1,000 years, there have been at least two episodes in which Lake Michigan levels have exceeded by about four feet the 20th century record level recorded in 1985 of 580.7 feet International Great Lakes Datum (IGLD), or 582.0 feet National Geodetic Vertical Datum (NGVD).[1] In comparison, selected spot elevations on adjacent land surfaces are: 585.5 feet NGVD on a walkway along the Lake Michigan shoreline leading north from the War Memorial Center to the McKinley Marina; 586.1 feet NGVD on the parking lot serving the Pieces of Eight restaurant on the lakefront; and 586.1 feet NGVD on the Henry W. Maier festival grounds just south of the old main stage location.

Coastal communities along the Great Lakes must anticipate the pervasive effects that a continued long-term rise to prehistoric lake levels might have. To maintain the potential for growth in commercial and recreational navigation, and to maintain the attractiveness of the lakefront for commercial and recreational development, improved protection from Lake Michigan storm waves may be called for, in the event that the rising trend in Lake Michigan water levels continues.

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[1] *In 1986 the mean annual level of Lake Michigan at Milwaukee reached 582.5 feet NGVD, representing a record high since 1860, when levels were first recorded. A record instantaneous high level of 584.1 feet NGVD occurred at Milwaukee on October 4, 1986.*

Port of Milwaukee

As already noted, anchorage in the inner harbor of Milwaukee is safe but is limited because the area is relatively confined. Anchorage in the outer harbor is spatially adequate, but not as safe as desirable. Large storm waves overtop the breakwater with sufficient energy remaining to create hazardous conditions for smallcraft in the outer harbor south of McKinley Park. Larger commercial vessels can safely moor in the open water of the outer harbor during large storms, but berthing at the municipal piers during very severe storms can be hazardous. Storm waves moving unimpeded through the main harbor entrance into the slip adjacent to South Pier 1, shown on Map 25, reflect off the vertical dock-wall and thus cause the development of standing waves having about twice the height of the incoming waves. Waves as high as 13 feet were reported in this slip during the storm of April 9, 1973. Such standing waves generate very strong reversing horizontal currents. These currents, combined with the violent vertical motion of the water surface, severely tax mooring lines and repeatedly push moored vessels into the pier walls, causing damage to both vessels and walls. During a severe storm on December 26, 1979, the vessel E. M. Ford, owned by the Huron Cement Company, sank at berth in Slip 1 after repeated collisions with the pier. Similar but less severe problems occur in Slip 2.

The large standing waves generated by storms from the northeast and occurring at the dock walls of the municipal piers not only create hazardous berthing conditions in the slips, but also have caused flooding on Jones Island. Crests of these waves can peak higher than the top of the dock walls. Strong onshore winds cause these waves to break over the top of the walls and into adjacent buildings. The storm of April 9, 1973, which overtopped the north breakwater, caused standing waves which overtopped the dock wall and crashed into adjacent buildings, staving in doors and creating standing water and water damage.

A continuous flow of water across Jones Island to the Kinnickinnic River due to waves overtopping the dock wall has been observed during a few severe storms and has interrupted vehicular traffic to and from the Milwaukee Metropolitan Sewerage District Jones Island wastewater treatment plant. Fish have been seen swimming in this "intermittent river," and have been found stranded on Jones Island after storm conditions receded. The storm of April 9, 1973, was particularly severe in this regard in that the flow ran down the service road "like a river" and washed out portions of the railroad yard on Jones Island. Such conditions have also occurred in winter and are aggravated when ice plugs the storm drainage system at the slips and causes local flooding. Such local flooding has also impeded access to the wastewater treatment plant.

Nearly all of the storms causing significant damage to Port of Milwaukee facilities have been associated with onshore winds. An atypical situation was observed in January 1986, however, when a strong, persistent northwest wind created waves inside the outer harbor which broke over the breakwater moving in an offshore direction. Waves reflected from the breakwater moved onshore and overtopped the dock wall at the municipal piers.[2]

In 1977, the U. S. Army Corps of Engineers constructed a parapet on top of the north breakwater from the shoreline to the mouth of the McKinley Park anchorage area to protect pedestrians on the pier during flight from rising storms on the lake. The parapet also increased the effective height of the breakwater and significantly reduced the frequency and severity of wave conditions in the outer harbor.[3]

McKinley Park Anchorage Area

Three recreational boating facilities are located within the McKinley Park anchorage area—the McKinley Marina, the Milwaukee Yacht Club, and the Milwaukee Sailing Club. The McKinley Marina is operated by the Milwaukee County Department of Parks, Recreation and Culture; the Yacht Club is privately operated; and the Milwaukee Sailing Club is a private, nonprofit organization. The locations of these facilities are shown on Map 26.

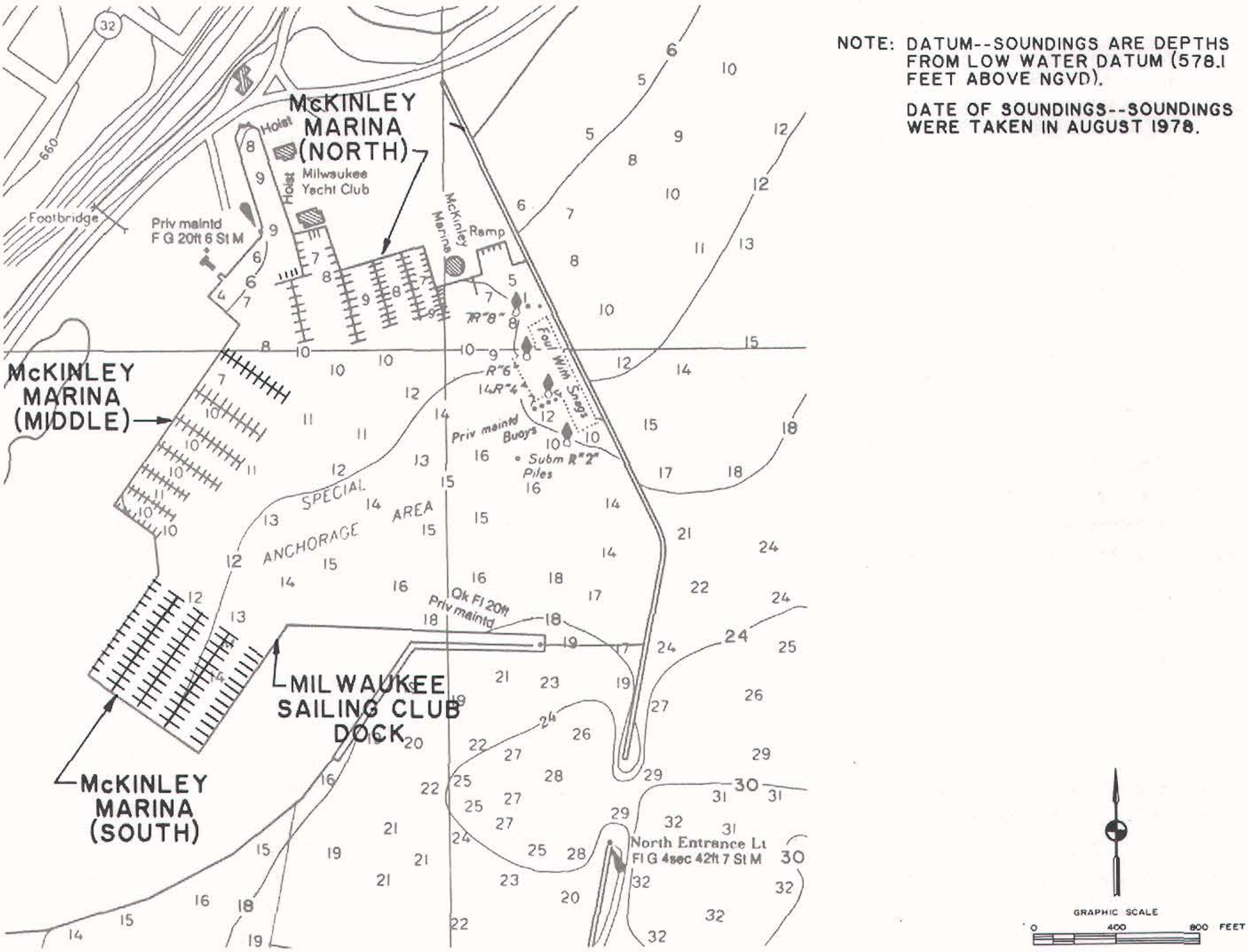
The McKinley Marina has 655 boat slips located in three separate areas referred to as the north, middle, and south marinas. The Yacht Club has one pier with 64 slips and is located next to the north marina. Both the Yacht Club and the Marina have utility lines attached to the head piers to provide electric power, potable water, and telephone service. The Milwaukee Sailing Club has a dock without slips which is located just northeast of the south marina.

[2]*Earl K. Anderson, Harbor Engineer, Port of Milwaukee, Personal Communication, March 11, 1986.*

[3]*Lawrence E. Sullivan, Civil Engineer, Port of Milwaukee, Personal Communication, February 19, 1981.*

Map 26

LOCATIONS OF RECREATIONAL BOATING FACILITIES IN THE MCKINLEY PARK ANCHORAGE AREA: 1986



The McKinley Park anchorage area, consisting of the McKinley Marina, the Milwaukee Yacht Club, and the Milwaukee Sailing Club, contains a total of 719 boat slips. Wave damage to piers and recreational craft has been minimal, although ice damage has been significant within the pier areas.

Source: U. S. Department of Commerce National Oceanic and Atmospheric Administration, National Ocean Service.

The Milwaukee Community Sailing Center removes its dock for winter storage. The Yacht Club and the middle and south marina piers are not removed because the cost of annual removal and re-installation would exceed the winter damage usually incurred. The finger piers of the north marina are removed, but the head pier is not.

In the McKinley Park anchorage area wave heights are generally smaller than at the municipal piers because the area is better protected from northeast winds, which generally produce the largest waves in the Milwaukee coastal zone. Significant overtopping of the north breakwater can occur, however. Waves transmitted past the breakwater are reflected off the vertical walls bordering nearly all of the anchorage area. Waves are reflected in many directions and create a severe chop capable of breaking smallcraft mooring lines and smashing these craft into piers and other structures.

Damage to recreational craft and harbor facilities from Lake Michigan storms has not been a major problem during the smallcraft boating season. Although some damage to improperly secured boats has occurred in slips, damage to piers has been minimal. Significant damage, and in some years major damage, does occur with the movement of ice in the pier areas. Ice damage to the Marina and Yacht Club piers is caused by two general phenomena. One is associated with the ice sheet which annually covers the entire 98-acre McKinley Park anchorage area, and the second is associated with the movement of ice floes following breakup.

Ice cover in the McKinley Park anchorage area frequently exceeds 24 inches in thickness, whereas ice in the outer harbor to the south generally does not exceed six to eight inches in thickness. The thick cover in the McKinley anchorage area remains intact for most of the winter, whereas the ice cover in the outer harbor is intermittent, generally remaining intact for only a few days after freezeup because of frequent turbulence caused by Lake Michigan. The broken outer harbor ice is blown either to shore or out into the lake. Consequently, the outer harbor is often not ice covered in the winter.

The thick ice sheet in the McKinley anchorage area also forms under the piers and around the pilings supporting the piers. Thermal expansion and contraction of the sheet with air temperature fluctuations can exert large horizontal loads on pier pilings. Gravity loads due to water level declines caused by seiching can also exert large loads, as ice hangs on the pilings unsupported from below. However, designs have taken these forces into account, and thus these phenomena generally do not cause significant damage in either the Marina or the Yacht Club. When lake levels are very high, however, the surface of the ice cover is very close to the bottoms of the piers. The seiche can lift the ice cover which in turn can lift the piers off the pilings, causing extensive damage.

The important ice phenomena in the McKinley anchorage area generally are ice collars and ice floes. Ice collars form around pier pilings above the main ice sheet as water shoots up through the annular space around the round pilings from below the ice sheet, and then freezes on the pilings and on top of the main ice sheet. When lake levels are relatively high, the collar can form up to the bottom of the pier and still remain intact with the main ice sheet. When the ice sheet moves with the ever-present seiche, the ice collar moves too, and can damage the pier above. Ice rubble, formed around pilings as ice attached to the pilings breaks on a receding cycle of the seiche, can damage piers in a similar fashion. Figure 99 presents photographs of ice conditions in the McKinley Marina.

The most serious damage in the McKinley anchorage area has been caused by ice floes. Ice floes form as the ice cover breaks up in late winter or early spring. If a large, late-winter wind storm occurs over the lake, the ice cover in the anchorage area can be broken early in the season. The resultant floating ice, sometimes more than two feet thick,[4] can be much thicker than that associated with the normal spring breakup, which is more affected by melting. The thick ice floes, driven by winds, currents, long swells, and seiche, can cause extensive damage to piers in both the Marina and the Yacht Club.

A situation such as that described above developed on March 3, 1985, when a thick ice cover, resting on a 20th century record high lake level for that month, broke up during a severe storm, producing waves that overtopped the breakwater and reflected from the vertical walls bordering the anchorage area. The effects of reflection, refraction, and diffraction reportedly produced wave heights in the slip areas of one to three feet. The resultant severe chop and long swells from the southeast, having an estimated period of 10 to 15 seconds[5] moved through the north gap in the breakwater and then through the entrance to the McKinley anchorage area, pushing the two-foot-thick ice floes into the pier area, where repeated vertical surging of the ice destroyed the Yacht Club pier and caused extensive damage to the Marina piers, particularly in the north Marina.

The Yacht Club pier cost about $150,000 to replace. The finger piers were raised to the same level as the main pier during reconstruction, having been one step closer to the water previously. Ice damage incurred during the winter of 1984 to 1985 at the McKinley Marina totaled about $146,000, with 90 percent or more of the cost being attributable to the March storm.

Although the monthly mean level of Lake Michigan in March 1986 exceeded the previous 20th century record level for March, set in 1985, by 0.4 foot, ice damage to the piers in the McKinley anchorage

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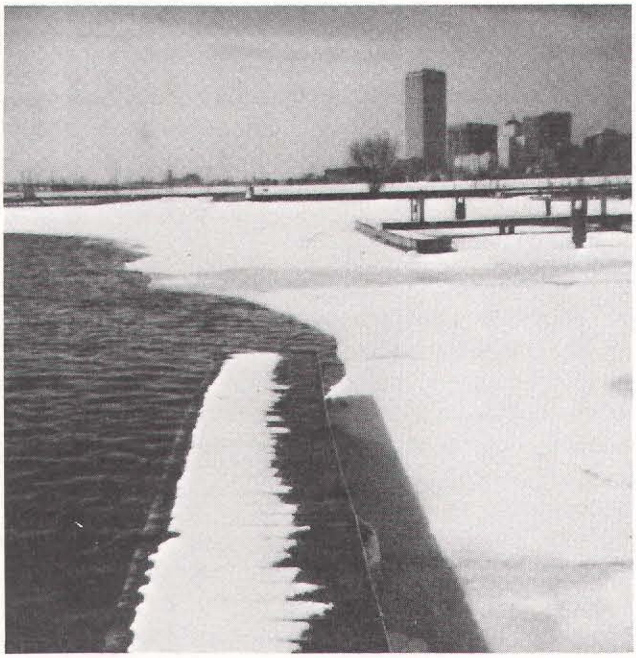
[4]*Gerald Limberg, Engineering Technician IV, Milwaukee County Department of Public Works, Professional Services Division, Personal Communication, May 9, 1986.*

[5]*Ibid.*

Figure 99

ICE CONDITIONS IN MCKINLEY MARINA ON MARCH 11, 1986



Looking South from East End of Pier G

Looking South from Pier A

Looking North at Pier E Finger Pier

Looking North at Pier F Finger Pier

Source: SEWRPC.

area was minor compared with that in 1985 because the ice cover melted before the first late winter-early spring wind storm occurred over the lake. Had the storm conditions in March 1985 recurred at a critical time in 1986, ice damage could have been as much as or more than in 1985.

To combat the ice problem in the McKinley Marina, a compressed air deicing system was installed to inhibit ice formation in the pier area. Problems with the system, however, and its ineffectiveness against ice floes resulted in the discontinuation of its operation.

Henry W. Maier Festival Grounds

The Henry W. Maier festival grounds are located just north of the mouth of the Milwaukee River and are bounded on the east by the outer harbor. A revetment protecting the festival grounds shoreline has experienced periodic damage from storm waves from Lake Michigan which move onshore through the main harbor entrance, and also from waves overtopping the breakwater. Extensive damage was caused to the revetment by the storm of April 9, 1973, when it was overtopped and partly washed out, causing about $100,000 in damage.

DESIGN LAKE LEVEL CONSIDERATIONS

Sound management of the coastal zone of Lake Michigan requires knowledge of lake levels as characterized by analyses of systematically collected historic data, and by historical and geological water level events prior to the period of systematic records. Records collected for relatively short periods of time may be inadequate as a basis for developing sound water level projections. A review of historical and geological information is therefore desirable as a check on projections of water levels based upon relatively short periods of record.

Stage-frequency analyses of Lake Michigan water level records collected at Milwaukee are herein presented, and then are considered in the perspective of geological and archeological evidence of prehistoric and historic lake levels. In the design of major facilities to be located along the lake, consideration should be given to the potential for a long-term rise to assure adequate protection.

Water level frequency data presented in Chapter V of Volume One of this report were used in the evaluation of the need for a higher breakwater to protect the outer harbor of Milwaukee; and in the revision of the flood stage profiles for the Kinnickinnic, Menomonee, and Milwaukee River estuaries developed under other Regional Planning Commission studies. In developing revised flood profiles for the three estuaries, a joint probability analysis was conducted of the occurrence of high river flows and high lake levels. Details of this analysis are contained in the section of this chapter entitled "Flood Protection." This chapter also presents the findings of an analysis made of projected water levels, should Lake Michigan indeed be in a long-term rising trend. These findings were also considered in the determination of the need for a higher breakwater, and in the preparation of flood profiles and associated inundation areas along the three river estuaries. The long-term rising trend water level analysis was conducted in order to provide additional information for use in the design of major public and private works in and near the harbor estuary. Owners considering major capital improvements can use this long-term, high-water elevation to evaluate the marginal cost of constructing a facility using a higher lake level than the revised regulatory elevation in order to protect the facility, assuming the possibility that the lake is in a long-term rising trend.

There are a number of governmental institutions concerned with Great Lakes water levels, including the International Joint Commission (IJC); the U. S. Army Corps of Engineers; the National Oceanic and Atmospheric Administration, U. S. Department of Commerce; the Great Lakes Commission; and the Council of Great Lakes Governors. The governments of the United States and Canada in August 1986 requested that the IJC undertake yet another study of methods of alleviating the adverse impacts of changing water levels, ranging from very high to very low levels, on the Great Lakes/St. Lawrence River Basin.

Projected Levels for Long-Term Rising Lake Scenario

It is the view of some practitioners that in light of the relatively short period of record available, the selection of design high-water levels for new projects along the Lake and estuary should not be based solely on consideration of water levels recorded systematically since 1860, but should also involve the review of geological and archeological evidence of prehistoric and historic lake levels. In accordance with good engineering practice, the flood stages and flood profiles developed under this study are based upon statistical analysis of water levels in the Milwaukee Harbor as systematically recorded since 1915. Geological evidence is believed by some to indicate that within the last 1,000 years, there have been at least two episodes in which Lake Michigan levels have exceeded the

1985 record annual mean level of 582.0 feet NGVD (580.7 feet IGLD)[6] by about four feet. These episodes of high water may have lasted for many decades, perhaps centuries. Interpretation and application of this evidence is, however, complicated by differential crustal movement within the Great Lakes Basin, and by man-made chages in the hydrologic and hydraulic conditions that effect the lake level. In this later respect, it should be noted that if prehistoric hydrologic conditions occurred under present-day outlet channel hydraulic capacities, then the prehistoric level of Lake Michigan would have been about one foot lower than indicated by the geologic record.

More specifically, channel improvements on the St. Clair-Detroit River System, which includes Lake St. Clair, between Lakes Michigan-Huron and Lake Erie began in 1855 when a channel was cut across sandbars in the St. Clair River, creating a nine-foot draft. Commercial dredging for gravel occurred on the St. Clair River between 1908 and 1925. Periodic dredging of the St. Clair and Detroit Rivers and Lake St. Clair for navigational purposes has continued during the 20th century. Some of the dredged materials were returned to the system in areas where they would not affect navigation in an attempt to compensate for some of the increased flow capacity that resulted from deepening the navigation channel. Dikes and sills were also constructed in the Detroit River as a compensating measure. The effects of dredging the St. Clair-Detroit River System since 1855, which have not been compensated for, are reported to have reduced the level of Lakes Michigan-Huron by about 1.2 feet. About one-half of this reduction may be attributed to dredging of the St. Clair and Detroit Rivers and Lake St. Clair between 1933 and 1962, which has not been compensated for. If the compensation placed on the Detroit River were removed, Lakes Michigan-Huron would be lowered by about 0.15 foot.

Moreover, there is some archeological evidence that indicates that the historic levels of Lakes Michigan-Huron extending back to about 1645 were not appreciably different from present day levels.[7] Never-the-less, the Milwaukee Harbor estuary study included an analysis of possible future water levels, assuming that Lake Michigan was indeed in a long-term rising trend. Thus, under the assumption that further increases in the level of Lake Michigan are as likely as not, an estimate was made of the annual mean lake levels that might be expected within the next 50 years under a continued rising lake level scenario. Wave-height frequency data—defined and presented in Chapter V of Volume One of this report—can be applied to these projected lake levels along with wave runup to develop design criteria for a range in levels of protection which can be considered on a site-specific basis in the design of new and modification of existing facilities and shore protection systems.

Analyses of water level records for the period 1915 through 1985 for Lake Michigan at Milwaukee adjusted to existing diversions and hydraulic outlet conditions during periods of rising levels were conducted to characterize relatively long-term rises. Differences in annual mean lake levels during periods of rise were computed for time lags of 1, 5, 10, 20, and 50 years. Frequency curves for the differences for each lag period are presented in Figure 100. Analysis of these rise data indicated that if the lake is higher in the year 2035, there is a 50 percent probability that it will be 2.1 feet higher, and a 10 percent probability that it will be 4.0 feet higher than in 1985. The corresponding annual mean elevations of the lake could be, respectively, about 584.1 feet NGVD or 582.8 feet IGLD, and 586.0 feet NGVD or 584.7 feet IGLD. It should be noted, in this respect, that a rise of 4.9 feet in the annual mean lake level was recorded in the 10-year period from 1964 to 1974. The 1964 lake level was the record low level for the period 1860 through 1985. The 1974 level was a 20th century record high prior to 1985. Therefore, the period 1964 to 1974 may represent a rare episode, the other independent 10-year rises all being less than 2.7 feet.

Preliminary computer modeling developed by the Lake Hydrology section of the Great Lakes Environmental Research Laboratory indicated that if a repeat of 1985 net increases in water supply to Lakes Michigan-Huron occurs for a number of years, the lakes may be expected to rise 1.5 feet higher than present records, or about two feet higher than the 1985 level. That modeling indicated further that if conditions provide 50 percent greater than normal water supplies, Lakes Michigan

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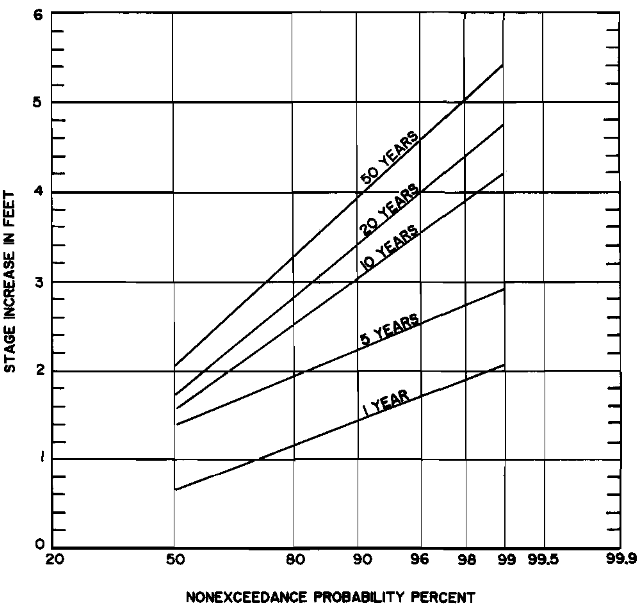
[6] *Curtis E. Larson, "Long-Term Trends in Lake Michigan Levels, a View from the Geologic Record," Proceedings of the First Indiana Dunes Research Conference, National Park Service, Indiana Dunes National Lakeshore, Porter, Indiana, U. S. Geological Survey, Reston, Virginia.*

[7] *Craig T. Bishop, Great Lakes Water Levels: A Review for Coastal Engineering Design, National Water Research Institute, Environment Canada, NWRI Contribution 87-18, August 1987.*

Figure 100

STAGE-INCREASE FREQUENCY CURVES FOR LAKE MICHIGAN AT MILWAUKEE FOR RISING LAKE SCENARIO FOR 1, 5, 10, 20, AND 50 YEARS AFTER PRESENT



Source: SEWRPC.

and Huron may be expected to rise each year to a stabilized level of about three and one-half feet higher than the 1985 levels after about 10 years.

In view of this analysis, it appears that the 100-year recurrence interval mean annual level of 582.9 feet NGVD; and instantaneous peak level of 584.5 feet NGVD should be used both for regulatory and emergency purposes. For the later, however, it may also be reasonable to consider a potential range of lake levels in designing new facilities or protecting or floodproofing existing buildings and structures. The consideration of this range of higher lake levels under the scenario wherein Lake Michigan is in a long-term rising trend should be made on a project-specific basis. The curves provided in Figure 100 can be used by project designers to consider the water level which is appropriate for a particular project.

Determination of Design Lake Levels

To select design water levels for Lake Michigan, the design life of the facility concerned is required, along with knowledge of the magnitudes of the annual, and of the more frequent, water level changes that have been observed to occur within given time periods. The range of water levels that could occur from the date a project is constructed —or from when a plan is completed—to the end of its design life—or through the end of a planning period—must then be estimated to determine the adequacy of the design or plan.

The stage and rise frequency curves presented in Chapter V of Volume One of this report were prepared to aid in determining design lake levels for hydrologic conditions statistically similar to those for the period 1915 through 1985, and for existing hydraulic outlet conditions. These conditions were used to develop the new recommended regulatory flood elevations. In addition, an advisory high lake level was developed for use in considering the impacts on land uses and on project facilities should Lake Michigan presently be in a long-term rising trend. Should a rising trend persist, the stage-frequency curves presented in Chapter V of Volume One would become inapplicable. The method recommended for determining conservatively high design lake levels assuming a long-term rising trend involves identifying and using the appropriate stage-increase frequency curve in Figure 100. The stage increase read from the appropriate curve can then be added to the most recently recorded annual mean water level to estimate a projected annual mean lake level. Once the projected annual mean level has been estimated, incremental seasonal changes shown in Figure 35 in Chapter V of Volume One of this report can be added along with the appropriate short-term rise determined from Figures 42, 43, and 44, also in that chapter.

If decreases in lake levels are of concern, the stage-frequency curves for monthly, daily, and instantaneous minimum water levels provided in Figure 45 in Chapter V of Volume One can be utilized in the determinations of design water levels. Offshore design wave information from Figure 31 in Chapter V of Volume One can be utilized along with site-specific geometry to estimate near-shore wave characteristics and wave runup utilizing methods described in the Shore Protection Manual.[8]

ANCHORAGE, DOCKAGE, AND SHORELINE PROTECTION

The principal problems related to anchorage, dockage, and shoreline facilities in the Milwaukee Harbor are associated with waves produced by high winds over Lake Michigan, and by thick ice cover within the McKinley Park anchorage area. Common, and some less common, methods of managing

[8] *Coastal Engineering Research Center, U. S. Army Corps of Engineers, Shore Protection Manual, Vols. I and II, 1984. For sale by Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.*

these types of problems are described below. A description of solutions for the problems of the Milwaukee Harbor then follows.

Regulation of Lake Michigan Water Levels

Regulation of Great Lakes water levels has been proposed as one method of helping to alleviate increased shoreline erosion caused by high water levels. Increased regulation of the water levels could be accomplished by increasing the dredging of the lakes' outlet channels, by modifying existing diversions into and out of the lakes, and by constructing new diversions.

As shown on Map 27, there are five major artificial diversions on the Great Lakes which change the natural supply of water to the lake or which permit water to bypass a natural lake outlet. These are the Long Lac, Ogoki, and Chicago diversions, the Welland Canal, and the New York State Barge Canal.

Although they are separate diversions, the Ogoki and Long Lac diversions are frequently considered together because they both divert into Lake Superior water from the Albany River Basin which would otherwise drain to Hudson Bay. Completed in 1941, the Long Lac diversion connects the headwaters of the Kenogami River with the Aguasabon River, which flows into Lake Superior. Completed in 1943, the Ogoki diversion diverts water from the Ogoki River to Nipigon Lake, which is located in the Lake Superior Basin. These diversions were developed for the purpose of generating hydroelectric power. The Long Lac diversion was also developed to help transport pulpwood logs southward.

The combined average flow for the Long Lac and Ogoki diversions is about 5,600 cubic feet per second (cfs). This diversion can be compared with the annual average outflow from Lake Superior of 76,000 cfs for the period 1900 to 1986.

It should be noted that the diversion of water from the Ogoki River has been temporarily reduced or stopped during the high water periods of 1951 through 1953 and 1972 through 1974, and most recently in 1985. The 1985 reduction is estimated to have caused about a 0.03-foot reduction in the level of Lake Superior.[9]

Water has been diverted from Lake Michigan through the Chicago diversion since 1848. This diversion serves to dilute sewage effluent from the Chicago Sanitary District and divert the effluent from Lake Michigan. The diversion also facilitates navigation on the Chicago Sanitary and Ship Canal and hydroelectric power generation in Illinois. The rate of flow is subject to the jurisdiction of the U. S. Supreme Court, the current average authorized flow being 3,200 cfs.

The Welland Canal diverts water from Lake Erie across the Niagara Peninsula to Lake Ontario, thereby bypassing the Niagara River and Niagara Falls, primarily for navigation and hydroelectric power generation. The canal was originally built in 1829 and has been modified and realigned several times. The rate of flow through the canal is about 9,200 cfs.

The New York State Barge Canal diverts water primarily for navigation purposes from the Niagara River at Tonawanda, New York, ultimately discharging it to Lake Ontario. The rate of flow varies seasonally; the average rate is estimated to be 700 cfs, and the maximum rate during the navigation season is estimated to be 1,100 cfs.

The theoretical effects of these diversions, other than the New York State Barge Canal, on Great Lakes water levels—as determined by the International Great Lakes Diversions and Consumptive Uses Study Board of the International Joint Commission—are indicated in Table 56. The New York State Barge Canal, it should be noted, has little effect on the water levels of the Great Lakes.

Water levels in the Great Lakes can be partially regulated by means of artificial outlet control structures. Presently, two of the Great Lakes, Superior and Ontario, are partially regulated under plans approved by the International Joint Commission. The regulation of Lake Superior affects the entire Great Lakes system, whereas the regulation of Lake Ontario does not affect the other lakes because of the sheer drop in water level at Niagara Falls. The outflow from Lake Superior is currently governed by Regulation Plan 1977. The basic objective of that plan is to balance the levels of Lake Superior and Lakes Michigan-Huron, maximizing benefits for riparian, navigation, and power generation interests.

Any reduction in high lake levels would help reduce high water-related shoreline erosion. However, the diversion or outlet modifications needed

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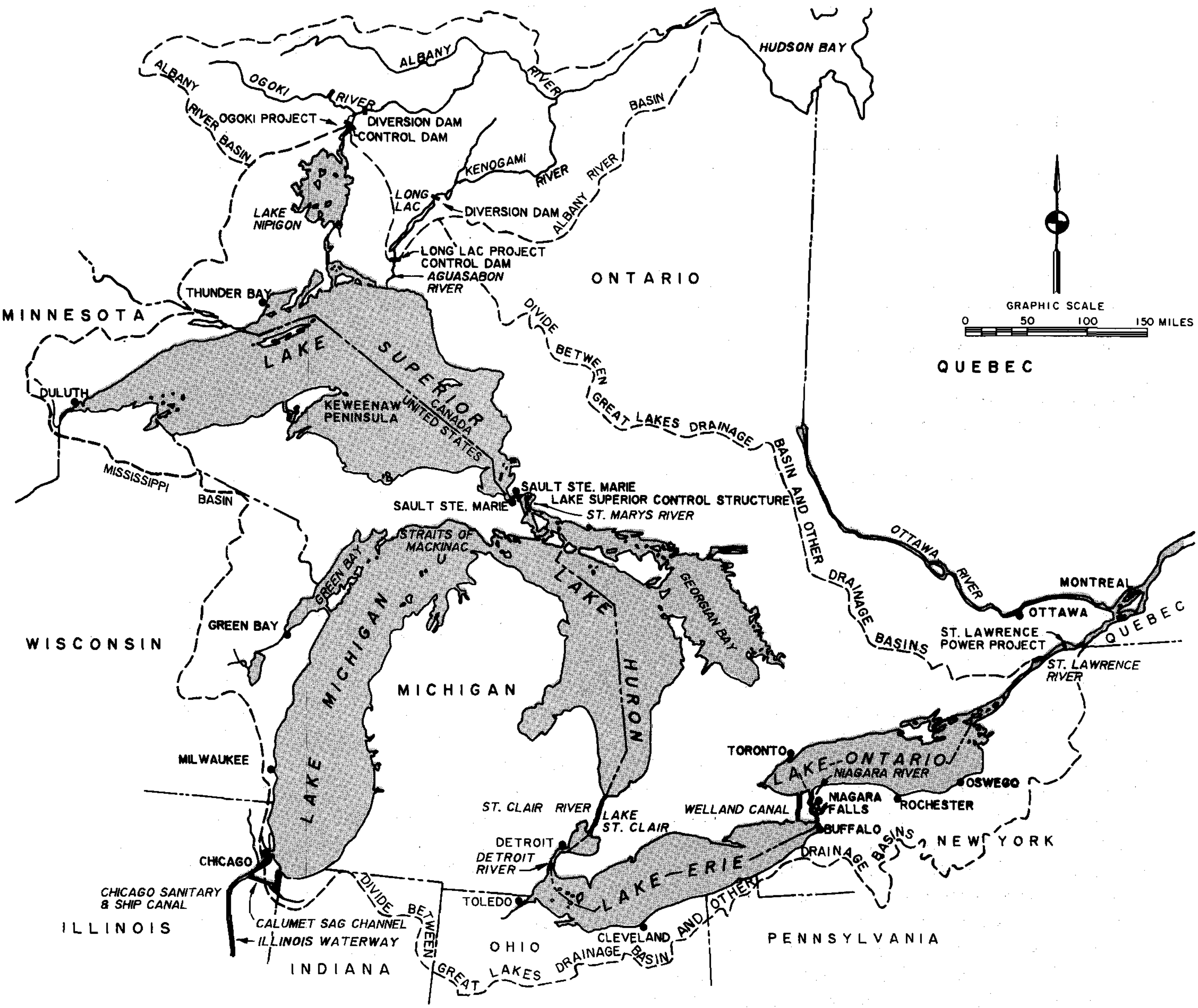
[9] *Great Lakes Commission, "Water Level Changes—Factors Influencing the Great Lakes," 1986.*

Map 27

GREAT LAKES DRAINAGE BASIN



The Great Lakes cover nearly 95,000 square miles and contain about 95 percent of the fresh surface water in the United States. The drainage area to the Great Lakes—201,000 square miles—is relatively small, only about twice the area of the lakes themselves. The lowermost lake, Lake Ontario, drains into the St. Lawrence River, which flows to the Gulf of St. Lawrence. There are five major artificial diversions on the Great Lakes which change the natural supply of water to the lake, or which permit water to bypass a natural lake outlet. These are the Long Lac, Ogoki, and Chicago diversions, the Welland Canal, and the New York State Barge Canal.

Source: U. S. Army Corps of Engineers.

to achieve a significant decline in lake levels would be very costly, and there would be concerns that the increased outflow of water from Lake Michigan and Lake Huron could adversely affect the shipping and hydroelectric industries and could lead to increased flooding downstream of some of the diversions.

As previously mentioned, the governments of the United States and Canada, in August 1986, requested that the International Joint Commission undertake a comprehensive study of methods of alleviating the adverse impacts of changing water levels, ranging from very high to very low levels, on the Great Lakes/St. Lawrence River Basin. The

Table 56

ESTIMATED THEORETICAL EFFECT OF EXISTING DIVERSION RATES ON GREAT LAKES WATER LEVELS

Diversion	Rate (cfs)	Effect on Mean Water Level (feet)[a]			
		Lake Superior	Lakes Michigan-Huron	Lake Erie	Lake Ontario
Long Lac/Ogoki	5,600	+0.21	+0.37	+0.25	+0.22
Lake Michigan at Chicago	3,200	-0.07	-0.21	-0.14	-0.10
Welland Canal.	9,400[b]	-0.06	-0.18	-0.44	0

[a]*A positive sign (+) indicates an increase in level; a negative sign (-) indicates a decrease.*

[b]*The effects on lake levels were evaluated for a rate of 9,400 cfs, slightly higher than the current rate of 9,200 cfs. An evaluation based upon the current rate would yield similar results.*

Source: International Great Lakes Diversions and Consumptive Uses Study Board of the International Joint Commission.

study involves two phases. The first phase of the study is to consider short-term alternatives—not involving major structural improvements—to minimize the adverse impacts of fluctuating water levels. The second phase, which is scheduled to be completed in 1989, will include a comprehensive evaluation of potential solutions, including structural improvements, land use planning, and other management activities. In this regard, it should be noted that the governors of the Great Lakes states, as members of the Council of Great Lakes Governors, in 1986 voiced support for preventing the diversion of water from the Great Lakes. Their concerns would have to be considered in the studies of the potential regulation of Lake Michigan. Because the results of these studies are not known and because the implementation of recommendations to provide for further controls will likely take many years, other, shorter term solutions are recommended to be considered.

Protection Methods

Methods for protecting anchorage areas, dockage, and shorelines exposed to wave and ice action include breakwaters, ice breaking, ice booms, deicing techniques, air screens, and a number of other structural measures. Brief descriptions of these methods are presented below. Additional details can be found in the references cited.

Protection from Storm Waves: Anchorage protection along an exposed coastline from storm-generated waves is most frequently, and perhaps most surely, provided by installation of an adequate breakwater which may be shore-connected, or detached from the shore as an offshore breakwater. Offshore breakwaters sometimes are used to protect harbor entrances from the direction of incoming waves that could move through the entrance unaffected, creating relatively high waves inside the harbor leeward of the entrance. Currents around offshore breakwaters can be treacherous during wave attack, however, and can make navigation through the harbor entrance hazardous.

Most breakwaters extend from the sea or lake bottom to some elevation above the design water level. Generally, the higher the breakwater, the less wave overtopping will occur, and the safer the anchorage area protected by the structure. However, the cost of a breakwater generally increases with the height. Permeable breakwaters can allow significant transfer of wave energy through the structure, whereas impermeable breakwaters do not. Impermeable breakwaters can be more expensive, however, and can create wave reflection problems on the windward side.

Breakwaters on exposed coastlines such as those of western Lake Michigan must be massive structures to withstand the wave regime of the lake. As stated in Chapter V of Volume One of this report, the 10-year recurrence interval deep water wave height offshore from Milwaukee was determined by the U. S. Army Corps of Engineers to be 16 feet, and the 100-year wave, 24 feet.

Another type of breakwater is a floating structure, frequently made of used rubber tires containing closed-cell, rigid urethane foam to provide buoyancy. These structures are less commonly used on exposed coastlines than in moderately sheltered areas, and as embayments, where wave heights and wave lengths are not so large. To be effective, the floating breakwater width should exceed one-half the length of the design wave, and the draft should exceed one-half the wave height.[10] Floating breakwaters are portable and can be towed once freed from anchor lines. They are more commonly used to protect relatively small, rather than large, areas. Floating breakwaters have also been made from other materials, such as in timber rafts. Floating breakwaters are effective for all water levels and interfere little with circulation and benthic life.

Another type of structure intended to control only the larger waves at a site is a submerged breakwater which "trips" only the larger incoming waves, forcing them to break farther offshore. The submerged structure can be relatively economical for two reasons. First, it is relatively small in size. Second, the waves do not break directly onto its face, and thus it requires a less massive armor layer. The location of a submerged breakwater is primarily affected by design wave length and water depth. Such structures may require navigational markers.

High-flow air screens theoretically can reduce wave heights.[11] An air screen is a wall of air bubbles released from a submerged horizontal perforated pipe connected to an air compressor. Air screens for ice control are more fully described later in this chapter. One potential advantage of an air screen for wave control is that the air bubbles do not act as a barrier to navigation for larger vessels. Another is that the air system only need be used during wave attack, and consequently would not act as a physical or visual barrier when it is not needed, as breakwaters do. Air screens are potentially less expensive than other means of wave control.

Many harbors and marinas are adversely affected by wave reflection from barriers forming the perimeter. Wave reflection can concentrate wave energy significantly, creating localized large waves. Plane vertical and impermeable barriers reflect most incoming wave energy, whereas nonplanar and permeable surfaces may reflect little. Structures especially designed to reduce wave reflection are commercially available. Design criteria for anchorage protection have been published by the U. S. Army Corps of Engineers.[12]

Protection from Ice Damage: Ice control in port and marina environments can be achieved in either or both of two general ways: controlling the ice after it has formed, or melting the ice before it can form a thick cover. Methods of controlling ice covers include icebreaking, ice booms, artificial islands, removable gravity structures, timber cribs, piling clusters, air screens, and breakwaters. Melting of ice has been achieved using air bubbling systems, thermal effluents, and artificial circulation.

Ice Breaking: Ice breaking is performed by ships specially equipped for the purpose. United States Coast Guard icebreakers capable of breaking ice more than two feet thick are operated on the Great Lakes. The use of such vessels in the Milwaukee Harbor has not been necessary because of the relatively thin ice cover at most port facilities.

Ice Booms: Ice booms are flexible floating structures used to retard the movement of ice and/or to cause early formation of a stable ice cover. Ice booms are more frequently used in rivers than in harbors, marinas, or lakes. Ice booms generally utilize flexible cable or wire rope attached to floats which act as barriers to ice passage. Figure 101 illustrates a typical ice boom arrangement. The most common ice booms are made of timbers attached to wire rope and restrained by buried anchors. Larger booms require pontoon-type

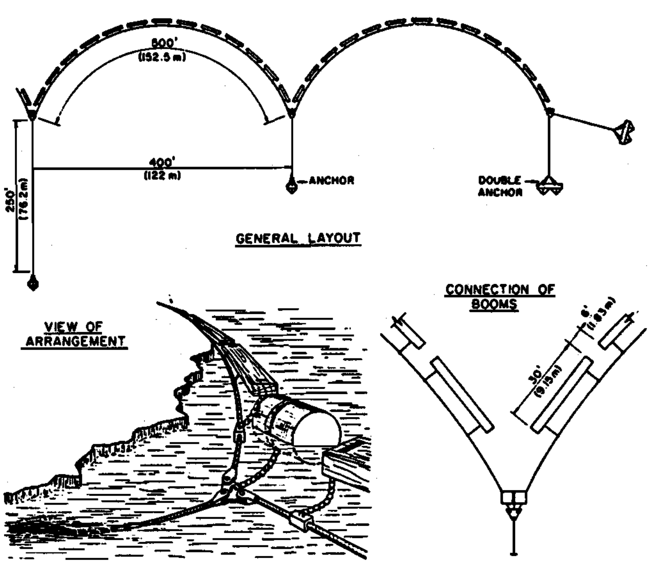
[10] *Volker W. Harms, Data and Procedures for the Design of Floating Tire Breakwaters, Water Resources and Environmental Engineering, Department of Civil Engineering, State University of New York at Buffalo, SUNY/Buffalo-WREE-7901, 1979.*

[11] *J. Philip Keillor, Coastal Engineer, Sea Grant Institute, Personal Communication, June 9, 1986.*

[12] *Coastal Engineering Research Center, U. S. Army Corps of Engineers, op. cit.*

Figure 101

SCHEMATIC OF TYPICAL ICE BOOM



Source: Proceedings, Third National Hydrotechnical Conference, May 30-31, 1977, p. 755.

floats to resist overturning by ice. Figure 102 shows various types of ice booms in use. Figure 103 shows various anchoring arrangements for ice booms.

Ice-boom sections are typically arc-shaped to reduce stress on the boom cable, the arc being from about 6 to 25 percent longer than the imaginary chord connecting the ends of the arc. Ice-boom anchor line lengths are recommended to be about 12 times the water depth to diminish the vertical component of the anchor line load on the boom. A large vertical component can submerge more or all of the boom and consequently allow ice passage.

Dominant forces acting on ice booms include water flow drag under the ice and wind drag on top of the ice, both of which are resisted by friction between the ice cover and the shoreline. More detailed information about ice booms is available from the Corps of Engineers.[13]

[13]*Roscoe E. Perham, Ice Sheet Retention Structures, U. S. Army Cold Regions Research and Engineering Laboratory, report CRREL 83-30, 1983.*

Deicing by Thermal Destratification Using Water Pumps: Artificial circulation has been utilized to eliminate winter thermal stratification in lakes and marinas to inhibit or prevent formation of ice cover at desired locations. Circulators pump warmer, denser water lying closer to the bottom to the surface to melt ice or to prevent its occurrence. Large units have been used to destratify lakes and reservoirs to enhance oxygen concentrations. Relatively large areas of open water surrounded by ice cover can be created by circulators.

Circulators in the form of small submersible electric pumps suspended below the water have been used to deice pier areas in ice-covered marinas.[14] At the Milwaukee Yacht Club, one small unit placed below very thick ice cover during the winter of 1985 to 1986 opened an area about 25 feet in diameter within a few days. The marina at the harbor in Port Washington, Wisconsin, reportedly has successfully used more than 100 small pumps for ice control. A power plant discharging a thermal effluent to the harbor may have enhanced the performance of the circulators. Much of the thermal effluent is diverted, however, to deice the condenser cooling water intake.[15] Circulating pumps used for deicing about 700 slips in the Waukegan Harbor have not generally produced satisfactory results.[16] The harbor water there is apparently too cold for the circulation system as installed to function as intended.

Circulation systems for ice control generally have been considered less cost-effective than diffused air systems which accomplish thermal destratification as air bubbles released near the bottom lift warmer water to the surface. However, energy requirements for circulation systems may not be significantly different from those for air diffusers, and the choice between the two approaches may best be made as a matter of preference or convenience.

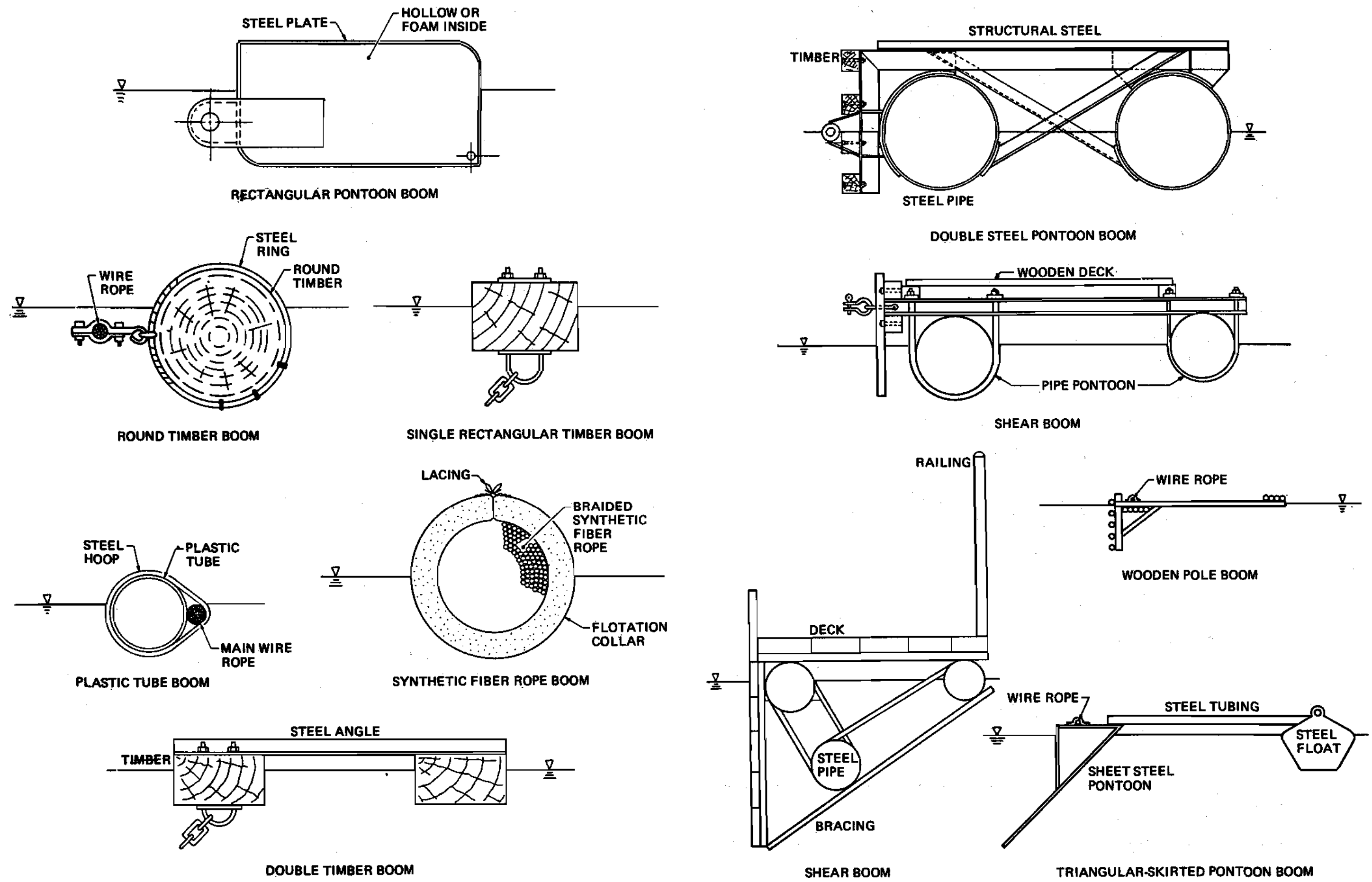
[14]*C. Allen Wortley, "Great Lakes Small-Craft Harbor and Structure Design for Ice Conditions," An Engineering Manual, University of Wisconsin Sea Grant Institute, report WIS-SG-84-426, 1984.*

[15]*J. Philip Keillor, Coastal Engineer, Sea Grant Institute, Personal Communication, June 9, 1986.*

[16]*C. Allen Wortley, Sea Grant Institute, Personal Communication, June 5, 1986.*

Figure 102

VARIOUS TYPES OF ICE BOOMS



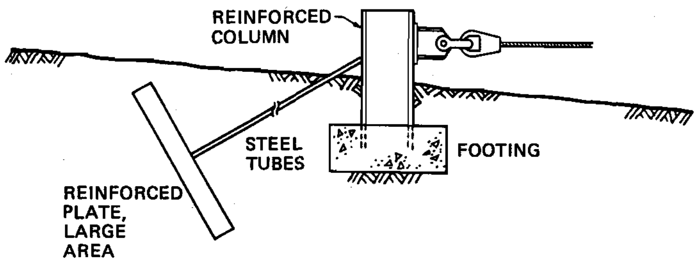
Source: U. S. Army Cold Regions Research and Engineering Laboratory.

Deicing by Thermal Destratification Using Compressed Air: Compressed air bubbling systems have been used to destratify lakes and inhibit ice cover formation for dissolved oxygen enhancement, to melt ice in marinas to mitigate ice damage to structures left in the water during the winter, and to provide winter wet storage area for boats. Two types of air bubbling systems are in general use—the point source bubbler and the diffused source bubbler.

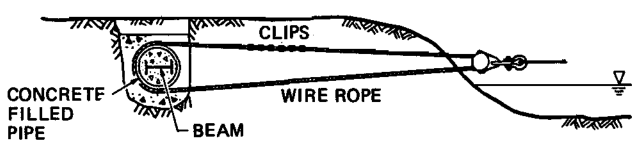
Point Source Compressed Air: Point source bubblers are merely air pumps which release air bubbles from a single orifice similar to that in a home fish aquarium. Such bubblers have been used to lift warmer water near the bottom of winter thermally stratified water bodies to the surface to impede or eliminate ice cover formation. The plume of air creates a flow of water from the bottom to the surface, as shown in Figure 104. The flow at the surface diverges, moving laterally and cooling off through contact either with cold air above or with the bottom of the ice cover. Flow at the bottom moves laterally toward the bubbler. In a small basin, the circulation induced by the bubbler can eventually produce a condition where all the water in the basin has been cooled virtually to the freezing point, the thermal reserve having been exhausted. Melting of ice can cease at that point, and an ice cover can re-form. Studies have indicated that for successful deicing by air bubblers in Great Lakes marinas, a water depth of about six feet is needed, along with adequate thermal reserve and water circulation.

Figure 103

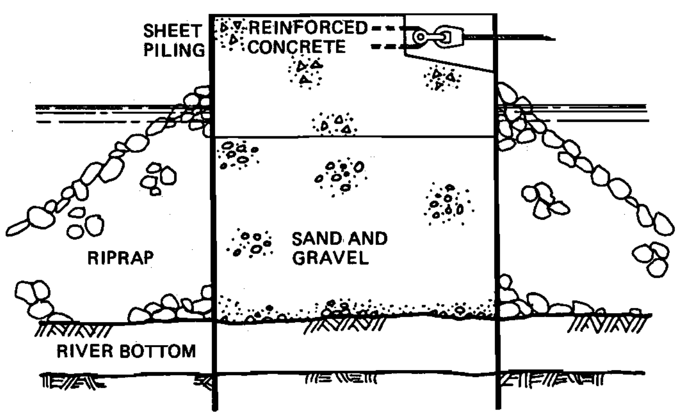
VARIOUS TYPES OF ANCHORING ARRANGEMENTS FOR ICE BOOMS



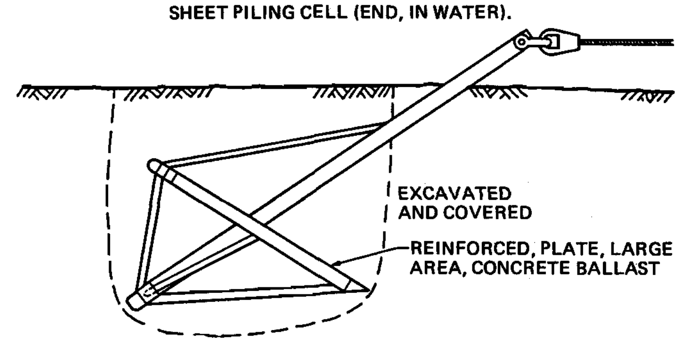
DEADMAN AND PEDESTAL (END, LAND).



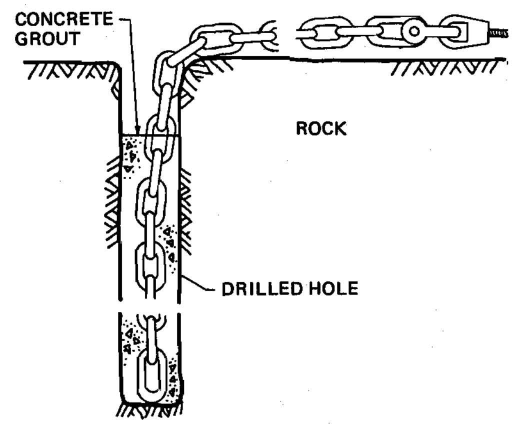
DEADMAN AND WIRE ROPE (END, LAND).



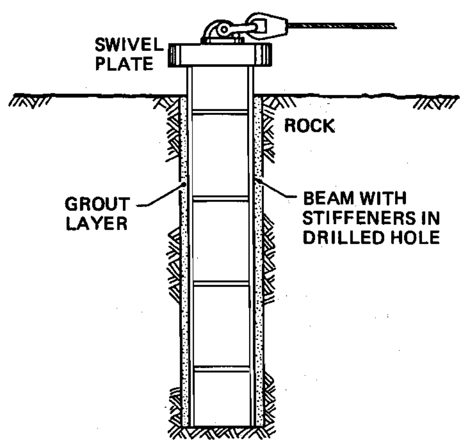
SHEET PILING CELL (END, IN WATER).



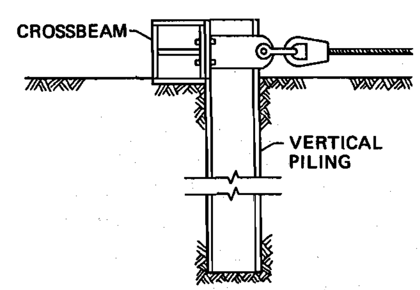
STEEL ANCHOR (MIDPOINT, IN WATER).



GROUTED CHAIN (MIDPOINT, IN WATER).



GROUTED WELDMENT (MIDPOINT, IN WATER).

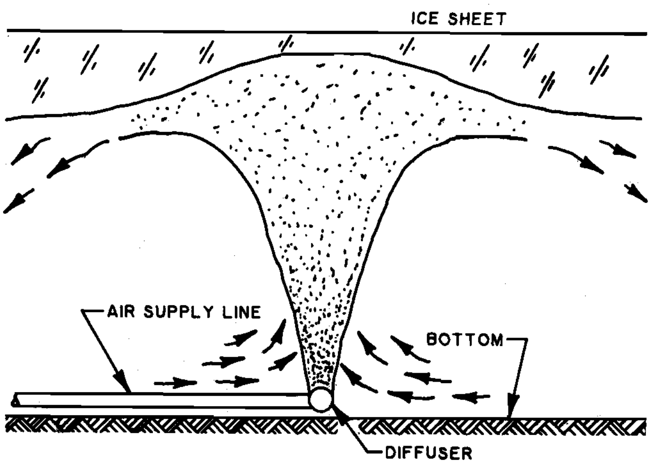


PILING AND CROSSBEAM (END, MIDPOINT, LAND, IN WATER).

Source: U. S. Army Cold Regions Research and Engineering Laboratory.

Figure 104

EFFECT OF POINT SOURCE AIR BUBBLER UPON WATER CIRCULATION



Source: University of Wisconsin Sea Grant Institute and SEWRPC.

The theory describing the processes described above is presented in a Corps of Engineers report which also contains the FORTRAN program for point source bubbler simulation.[17] The University of Wisconsin Sea Grant Institute also provides design information for compressed air deicing systems, both point source and diffuse source.

Diffused Source Compressed Air: Diffused source compressed air deicing systems function similarly to point source air bubblers, the major difference being that the compressed air is discharged by a shore-based compressor or blower into a perforated conduit, or array of conduits, lying on the bottom. Therefore, one motor supplies compressed air to numerous orifices, rather than to one orifice as in the point source bubbling method. Figure 105 shows a pier deiced by a diffused air bubbling system.

As is the case using the point source method, diffused air bubbling systems to melt ice in Great Lakes harbors are affected primarily by water temperature at the site. In Great Lakes harbors, water temperatures at the bottom under ice cover in the colder periods of the winter are commonly very close to the freezing point, within less than 0.5 degree unless a significant warmwater source such as a power plant is discharging nearby.[18] There is, however, sufficient heat left even at near-freezing temperatures to melt ice, provided air flow is adequate and the system layout and orifice spacing and sizing is carefully designed.

The theory supporting the application of air bubbling systems to melt ice, along with listings of computer programs to simulate melting for both diffuse and point source bubblers, is presented in Corps of Engineers and other publications.[19] Design information for diffused source air bubblers for application in Great Lakes harbors is provided in a University of Wisconsin Sea Grant Institute report.[20]

Diffused air systems have been used in a number of Wisconsin lakes as aerators to prevent winter fish kills under ice cover. Many of these systems have been designed fully or in part by the Wisconsin Department of Natural Resources.[21] Relatively large open-water areas have been maintained by these systems. Boat anchors have caused some problems with diffused air systems by pulling diffuser lines out of place and sometimes breaking lines as anchors were retrieved. These types of problems were diminished following a design change which called for use of steel re-bars strapped to the lines as continuous anchors, which held the lines closer to the bottom than the concrete blocks previously used. In some lakes, signs were posted with buoys where anchoring was prohibited.

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[17] *George D. Ashton, Point Source Bubbler Systems to Suppress Ice, U. S. Army Cold Regions Research and Engineering Laboratory, report CRREL 79-12, 1979.*

[18] *C. Allen Wortley, "Great Lakes Small-Craft Harbor and Structure Design for Ice Conditions," An Engineering Manual, University of Wisconsin Sea Grant Institute, report WIS-SG-84-426, 1984.*

[19] *George D. Ashton, "Numerical Simulation of Air Bubbler Systems," Canadian Journal of Civil Engineering, Vol. 5, 1978, pp 231-238; and George D. Ashton, Point Source Bubbler Systems to Suppress Ice, U. S. Army Cold Regions Research and Engineering Laboratory, report CRREL 79-12, 1979.*

[20] *C. Allen Wortley, "Great Lakes Small-Craft Harbor and Structure Design for Ice Conditions," An Engineering Manual, University of Wisconsin Sea Grant Institute, report WIS-SG-84-426, 1984.*

[21] *Thomas Worth, Wisconsin Department of Natural Resources, Personal Communication, May 22, 1986.*

Figure 105

PIER DEICED BY COMPRESSED DIFFUSED AIR BUBBLING SYSTEM

Source: Schramm, Inc.

Important design considerations for air systems include placement of the manifold below the water surface to reduce condensation problems. An insulated manifold might work even better. The air discharge pipe from the blower to the manifold should continually slope downward to prevent condensed water accumulation therein. Insulation for this pipe may also be desirable.

Air diffuser lines made of 1-1/2-inch-diameter PVC pipe have performed satisfactorily in lake aeration systems, have required little maintenance, have not required bleeding, and are easier to install and retrieve than metal pipe. Galvanized air diffuser pipe corroded severely in McKinley Marina and is not recommended for future use there.

Air flow rates on the order of 10 to 20 cubic feet per minute per acre of open water appear adequate for melting of ice.

Deicing by Thermal Effluents: Ice cover in rivers is commonly suppressed downstream from reservoirs and downstream from power plant thermal effluent discharges. Water from beneath an ice-covered reservoir will eventually freeze somewhere downstream from the reservoir after sufficient atmospheric contact has taken place. Similarly, heated water discharged from a power plant into a river will not freeze for some distance downstream, depending on the ratio of thermal discharge to river flow, the turbulence characteristics of the river, and meteorological conditions. Theory of suppression of ice downstream from reservoirs and downstream from thermal effluent discharges is presented in a Corps of Engineers report.[22]

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[22] *George D. Ashton, Suppression of River Ice by Thermal Effluents, U. S. Army Cold Regions Research and Engineering Laboratory, report CRREL 79-30, 1979.*

Ice suppression in an estuary or harbor by water warmer than 32.2°F is governed by natural phenomenan similar to that in rivers, except that the hydrodynamics of turbulent mixing are more complex.

Ice Retention by Air Screens: An air screen is a wall of bubbles released from an underwater diffuser to block the movement of ice or other floating debris. A schematic of an air screen at the Poe Lock on the St. Mary's Falls Canal at Sault Ste. Marie, Michigan, is shown in Figure 106.

High-flow, high-velocity air screens can remove ice being pushed by ships entering locks by creating a localized increase in water level that causes a strong current at the water surface which pushes floating ice and debris upstream away from the bubble barrier.[23]

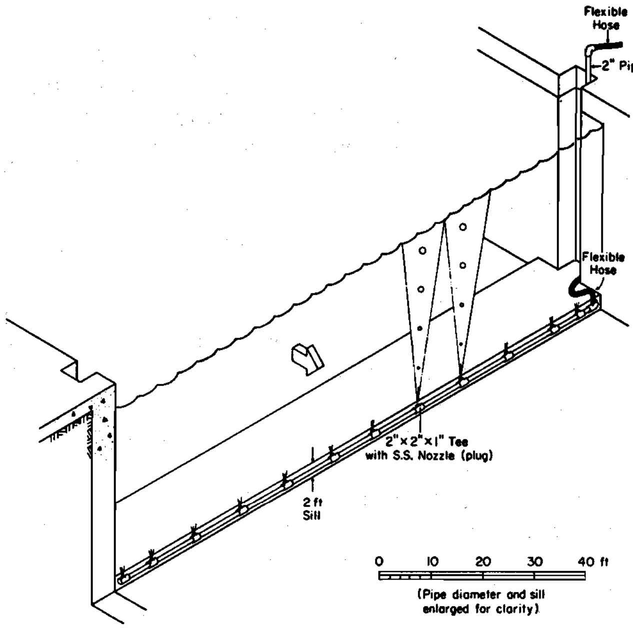
Parameters affecting air screen design are air supply volume and pressure, length and size of diffuser line, length and size of the supply line, depth of submergence of diffuser line, and orifice size and spacing. Air screen design is carried out by an iterative procedure. The air screen at the Soo Locks utilizes a compressor with an output of 1,150 cubic feet per minute at a pressure of 110 pounds per square inch. A two-inch-diameter line and supply line system is used. The diffuser orifices are 0.40 inch diameter and 10 feet apart. The diffuser line is placed at a depth of 34.5 feet and is about 104 feet long. The device has also been used in the summer to control floating debris. Air blowers can serve the purpose equally well and are less expensive to purchase and operate.

An air screen, theoretically, also can reduce progressive wave energy.[24] Therefore, an air screen designed for ice control might also be useful in the open-water season in reducing wave energy in leeward mooring areas, especially that associated with high-frequency waves.

Other Ice Retention Methods: Other means of ice control applicable to harbors and marinas are pier-mounted booms, groins, artificial islands,

Figure 106

SCHEMATIC OF AIR SCREEN COMPONENTS IN THE SAINT MARY'S FALLS CANAL



Source: U. S. Army Corps of Engineers.

removable gravity structures, timber cribs, and piling clusters.[25]

Pier-mounted booms are floating booms attached at both ends to permanent structures, and in appearance look like flashboard gates on a dam. The booms rise and fall with water level, however, collecting floating ice but allowing water flow underneath.

Groins for ice control are structures attached to shore extending into a water area to be shielded from moving ice. Such structures act much as breakwaters, but are intended for ice control.

Artificial islands act in similar fashion, but are not attached to shore. A network of islands can protect piers by absorbing much of the thermal load from ice cover and by blocking the movement of ice floes following breakup. The islands can be used in the boating season by the addition of mooring slips to increase marina capacity.

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[23] *U. S. Army Corps of Engineers, "Floating Ice Dispersion,"* *Ice Engineering, Engineering Manual EM 1110-2-1612, 1982, pp. 7-1 to 7-7.*

[24] *J. Philip Keillor, Coastal Engineer, Sea Grant Institute, Personal Communication, June 9, 1986.*

[25] *Roscoe E. Perham, op. cit.*

Gravity structures resist translation primarily by friction, and resist overturning by geometric design based on analysis of anticipated forces. Removable gravity structures act somewhat like groins or artificial islands in restraining ice cover forces and blocking ice floes. Such structures, however, are refloated, or lifted from the water so as not to interfere with navigation during the open-water season. Perham described a removable structure which was a scow sunk and secured by ship anchors, and refloated in the spring and moved away.[26] Another structure was made of reinforced concrete crane calibration weights which keyed together when stacked.

Timber cribs are permanent gravity structures having enclosed frameworks commonly made of timbers and filled with stone. Cribs are sometimes sloped on one side, and on poor foundation material, cribs are placed on timber pilings. Cribs are frequently used to control ice jams on rivers and have very long lives in that environment. Cribs have also been used as foundations for navigation light towers.

Piling clusters are structures driven to stabilize ice covers or to protect individual structures or areas from ice movement. Piles are driven closely together and bound by wire rope at the top.

Protection of Harbor and Shoreline Facilities by Higher Breakwater

The outer harbor of Milwaukee is formed by a 3.9-mile-long, shore-connected breakwater. This structure, however, provides less than a desirable level of protection to the anchorage area and shoreline in its lee. As already noted, waves frequently overtop the breakwater, creating hazardous conditions within the harbor for smallcraft seeking refuge, and generally limiting the use of the outer harbor for recreational boating to days when offshore winds prevail, or when onshore winds are relatively light. Hazardous and destructive conditions also occur at Port of Milwaukee facilities, at the Henry W. Maier festival grounds shoreline, and in the McKinley Park anchorage area, as described earlier in this chapter.

The design height of the breakwater was set by the U. S. Army Corps of Engineers at a time when lake levels were relatively low and when little long-term homogeneous water-level data were available for use in determining a design lake level. Also, at that time wave characteristics were yet to be accurately and systematically measured so that a realistic design wave could be selected. Consequently, the existing breakwater height is presently inadequate, and may become even more so if Lake Michigan continues to rise from the present levels. Therefore, analyses were made of the benefits and costs of modifying the breakwater under both existing lake level conditions and under a scenario whereby the lake levels would undergo a long-term rising trend.

Under present lake levels, and considering the revised 100-year recurrence interval lake levels previously presented, the damages to shoreline facilities and protective works may be expected to total $600,000 for a 100-year recurrence interval storm event. The average annual storm damages may be expected to total $54,000. If the breakwater were raised 8.7 feet above the present height, average annual damages would be reduced to about $10,000. The residual damages would be due to damages from waves passing through the gaps in the breakwater. The capital cost of installing an eight-foot-wide poured concrete wall to raise the breakwater 8.7 feet is estimated to be $30 million, with an equivalent annual cost of about $1.9 million, assuming an annual interest rate of 6 percent and a project life and amortization period of 50 years. Enclosing the entire existing breakwater within a new rubblemound breakwater built 8.7 feet higher than the existing structures would entail a capital cost of about $65 million, with an equivalent annual cost of about $4.1 million. Thus, the benefit-cost ratio would range from about 0.01 to 0.02. This confirms observations of the Harbor Commission staff that under present-day lake levels, the damages to piers and port facilities on Jones Island are not extensive enough to justify provision of further offshore protection measures, it being cheaper to repair the damages.

Under the long-term rising lake level scenario described earlier in this chapter, annual mean lake levels were determined to have the potential to rise to as high as four feet above present levels over the next 50 years. Under that scenario, wave heights in the outer harbor may also increase owing to increased energy transmission over the breakwater. Using the estimated annual mean lake level of 586.0 feet NGVD, or 584.7 feet IGLD, presented earlier in this chapter for 50 years hence should the rising lake level trend continue, wave heights in the outer harbor could increase by about two feet as compared to waves under present lake levels unless

[26] *Roscoe E. Perham, op. cit.*

the breakwater elevation is increased. Associated wave runup would also increase. Therefore, riparian landowners in the outer harbor should consider providing additional shoreline protection as the need arises, and should consider the potential effects of a long-term rising lake level trend in the planning and design of such protection. The long-term rising trend in lake levels and associated wave heights should be used in the design of major public and private works in or near the outer harbor to evaluate the marginal cost of constructing "fail safe" facilities. Because wave energy is proportional to the square of the wave amplitude, an increase in wave height of two feet can represent more than a 200 percent increase in wave energy in the outer harbor.

If the breakwater elevation is not increased, standing wave heights in the municipal slips may increase by up to four feet, and would be oscillating on a four foot higher lake level. Thus, the crests would be about eight feet higher than under present conditions. Pre-storm freeboard at the municipal piers in the outer harbor would be only about three feet. Thus, not only would the municipal slips become unsafe for mooring, but the piers and related facilities would be subject to serious damage by wave attack. It is probable under these conditions that the use of port facilities in the outer harbor would be impractical—except during fair weather—and that use of the inner harbor would have to be increased. Flooding of Jones Island from storm wave runup would become both more frequent and more extensive, requiring implementation of flood control measures to maintain the viability of port facilities as well as of the Milwaukee Metropolitan Sewerage District Jones Island sewage treatment plant.

Under the above scenario, the storm damages to piers and port facilities may be expected to increase to $900,000 on an average annual basis. If the breakwater were raised to 602.5 feet NGVD, or 601.2 feet IGLD—16.3 feet higher than the present structure—such damages would be eliminated to the extent practical, with the exception of damages caused by waves coming through the gaps in the breakwater. Enclosing the entire breakwater within a new rubblemound breakwater built 16.3 feet higher than the existing structures would entail a capital cost of about $150 million, with an equivalent annual cost of about $9.5 million. Also, additional protection would be necessary for the Henry W. Maier festival grounds since this area is more vulnerable to attack from waves moving through the main harbor entrance than from waves overtopping the breakwater.[27] Construction of the taller structure would result in a reduction of $890,000 in wave damage on an annual basis, for a benefit-cost ratio of 0.1. The taller structure would also provide a safe harbor of refuge for both smallcraft and ships, and facilitate waterborne commerce by the Port of Milwaukee.

It should be noted that in addition to having wave impacts, the high lake level expected under the continued rising lake level scenario will in itself cause substantial problems. Substantial flooding of land and facilities could take place. This impact is discussed for the entire estuary area in a subsequent section of this chapter.

In view of the above, it is concluded that while the benefit-cost ratio of the breakwater construction is higher under this scenario, it remains less than 1.0. Should indirect benefits be considered, it could approach 1.0. However, no construction is recommended at this time since the scenario under which it would equal or exceed 1.0 has not been confirmed. Rather, it is recommended that continued surveillance of this situation be carried out, and that contingency planning for both storm damage and flood conditions, which could result from a long-term rising lake level, be undertaken by the involved units of government. Such continued surveillance would entail an annual review of the lake level data provided for Milwaukee by the National Ocean Survey, with the situation to be reviewed in the contingency planning.

<u>Ice Breaking in the Inner Harbor</u>

Ice breaking in Milwaukee Harbor has been performed by the vessel <u>Harbor Seagull</u>, operated by the Port of Milwaukee. The Harbor Seagull is capable of breaking ice covers up to about eight inches thick. Ice thickness in the outer harbor seldom exceeds eight inches south of the McKinley Park anchorage area. Therefore, the <u>Harbor Seagull</u> is adequate to break ice as needed except in the McKinley anchorage area, where ice thickness frequently exceeds 24 inches.

In the inner harbor, the <u>Harbor Seagull</u> has occasionally been used to break ice in the Milwaukee River estuary, north of its confluence with the

[27] *Warzyn Engineering, Inc., "Milwaukee Lakefront Island Development, Technical Memorandum," Submitted to City of Milwaukee Department of City Development, September 15, 1983.*

Menomonee River, to allow release of snow that is dumped on the ice by the City of Milwaukee. Very little ice forms in the Menomonee River estuary owing to the large thermal load from the valley power plant condenser cooling water effluent. For the same reason, the Milwaukee River estuary downstream of the Menomonee River generally is ice free in the navigation channel. A relatively thick ice cover can develop in the Kinnickinnic River estuary, however. The Kinnickinnic River estuary is used for daily winter navigation by commercial fishing vessels, and the municipal turning basin is used for winter wet storage of ships after the Great Lakes shipping season ends. The fishing tugs are based along the Kinnickinnic River between Greenfield Avenue and Becher Street. The tugs generally are capable of maintaining an open channel through the ice in the Kinnickinnic estuary during milder winters because law requires that the fishing nets in the lake be examined daily, and the daily to and fro tug traffic usually inhibits formation of a thick ice cover in the navigation channel.[28] The Harbor Seagull, upon request, breaks ice for the fishing tugs during colder periods, however.

The ships moored over for the winter in the Turning Basin are allowed to "freeze in." The ice cover is used as a work platform for ship repair and painting, scaffolding being set up thereon. A number of marinas in the Kinnickinnic estuary provide dry-land winter storage for boats to protect them from ice damage. Therefore, there appears to be little need for additional measures to control ice in the Kinnickinnic estuary, and consequently no such measures are herein recommended. Ice breaking in the McKinley Park anchorage area would be beneficial only if the broken ice was immediately removed to prevent damage to smallcraft piers. Removal of the broken ice by natural processes is impeded by the restrictive geometry of the area. Removal of broken ice by artificial means is considered impractical. Therefore, ice breaking is not herein recommended for that area.

McKinley Park Anchorage Area Ice Control

Management of the ice problem in the McKinley Park anchorage area was evaluated to determine if cost-effective means could be identified to minimize the problem.[29] Assistance was provided by the Wisconsin Department of Natural Resources, the University of Wisconsin-Extension, and the U. S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory. Three alternative strategies for ice control were developed and tested for technical and economic feasibility: 1) melting of ice in the entire McKinley anchorage area using diffused compressed air; 2) melting of ice in the pier area by the same method, with retention of ice floes in the remaining area by an ice boom; and 3) melting of ice in the pier area, with retention of ice floes by an air screen. The costs and benefits of each of these alternatives are summarized in Table 57. The alternatives are discussed in detail below.

Other possibilities considered included reversing the flow of the Milwaukee River flushing tunnel during the winter to deliver warmer river water to the anchorage area to complement a diffused air deicing system, and the use of water circulators rather than air diffusers to inhibit the formation of ice cover. The former was considered impractical because the flushing tunnel carries water by gravity flow from the McKinley anchorage area to the river after the water is lifted to the tunnel by a large pump. There appeared to be no economically feasible means to move river flow against a negative slope to the anchorage area.

The use of water circulators was also considered impractical owing to the large number of relatively expensive units estimated necessary to accomplish the task in the relatively large area not occupied by piers. Numerous small circulating units in the pier area may provide economical and effective ice melting capability, but may be expected to be less cost-effective than diffused air systems. Small pumps could be used along with a diffused air system to provide additional capacity in some areas. Thermal effluent from the valley power plant is too far removed from the anchorage area to be economically transported.

Alternative 1—Ice Control by Diffused Compressed Air: Deicing of the entire McKinley Park anchorage area using a diffused air system has been deter-

[28] *Lawrence E. Sullivan, Civil Engineer, Port of Milwaukee, Personal Communication, June 9, 1986.*

[29] *In 1987, new piers were installed in the McKinley Marina, with pier elevations set at 586.6 feet NGVD or about two feet higher than the previous system and about two feet higher than the recommended 100-year recurrence interval lake level. Thus, the ice damage in that section of the anchorage area should be lower than the estimates based upon historical data.*

Table 57

COMPARISON OF COSTS AND BENEFITS OF ALTERNATIVE ICE CONTROL PLANS FOR THE MCKINLEY PARK ANCHORAGE AREA

Alternative	Costs				Benefits			Benefit-Cost	
	Capital Cost	Annual Operation	Annual Maintenance	Average Annual Cost	Average Annual Pier Damage	Net Winter Wet Storage Revenue	Average Annual Benefit	With Winter Wet Storage Revenue	Without Winter Wet Storage Revenue
Complete Deicing of McKinley Park Anchorage Area	$180,000	$ 2,000	$11,000	$32,000	$78,000	$73,000	$151,000	4.7	2.4
Pier Area Deicing and Ice Boom	640,000	14,000	13,000	93,000	78,000	73,000	151,000	1.6	0.8
Pier Area Deicing and Air Screen	320,000	11,000	7,000	45,000	78,000	73,000	151,000	3.4	1.7

Source: SEWRPC.

mined to be technically feasible. This conclusion was based on a review of the information on deicing systems in Wisconsin marinas and inland lake deicing systems for aeration, and on consultations with staff of the Wisconsin Department of Natural Resources, the University of Wisconsin-Extension, and the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL). Economic feasibility remained in question, however. A system was designed and cost estimates made for installation and operation thereof. These costs were compared with the average annual damage cost to determine the benefit-cost ratio. If boats were able to be stored in the slips of the McKinley Marina and the Milwaukee Yacht Club during winter, the benefits of this alternative could be enhanced.

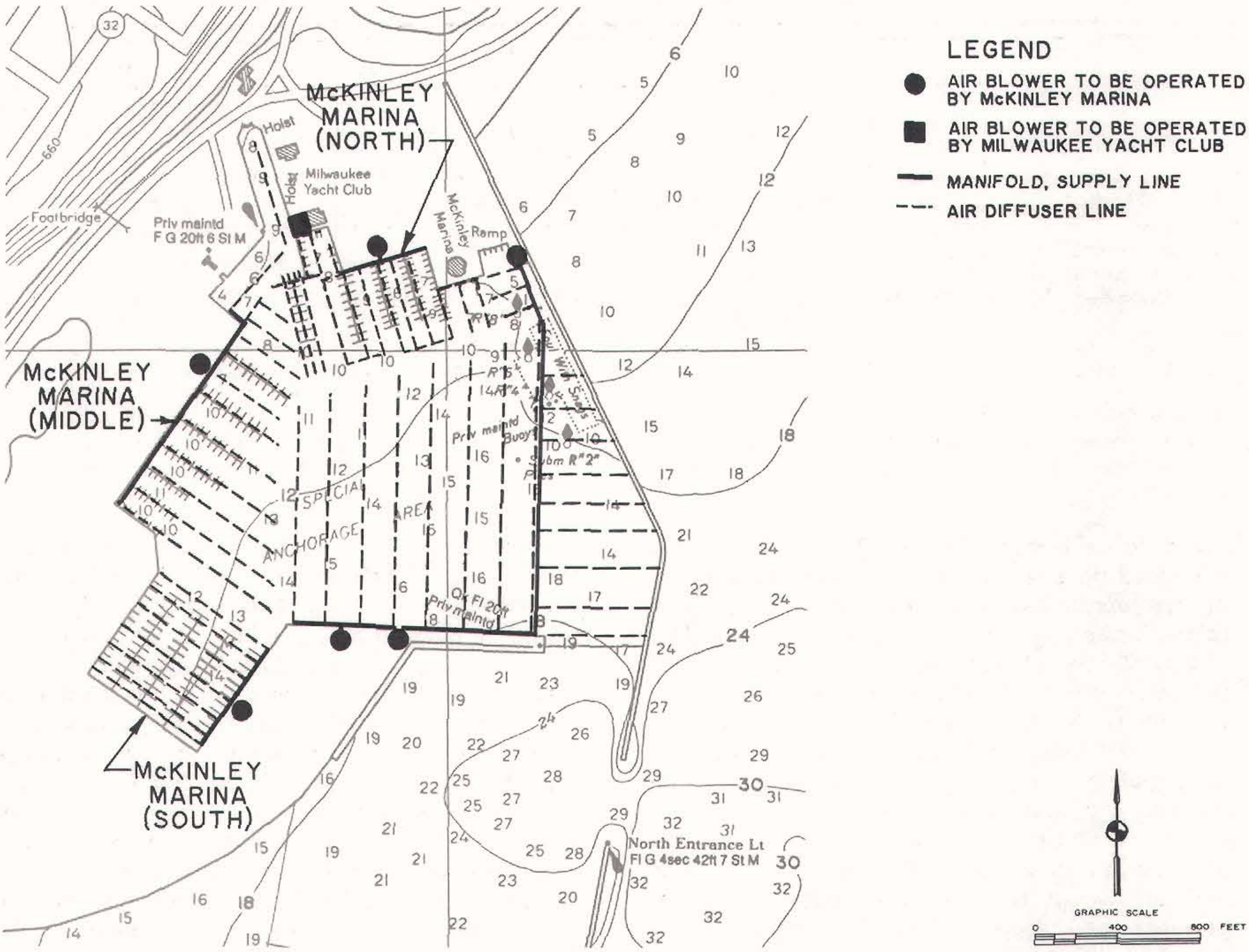
The diffused air system designed for the McKinley anchorage area was based upon published design manuals, and upon the findings of a review of the aeration systems used on Horsehead Lake in Oneida County, on Buckskin Lake in Oneida and Vilas Counties, and on the Big Eau Plaine reservoir in Marathon County. The air diffusing system for the anchorage area was laid out, as shown on Map 28, with the diffuser lines generally 150 feet apart and lying in parallel on the bottom. Six air blowers would be operated at the McKinley Marina and would range in normal operating rates from 140 cubic feet per minute (cfm) to 520 cfm. One blower would be operated at the Milwaukee Yacht Club and would have a normal operating rate of 120 cfm. The air flow requirements for the entire system were based on the assumption that 1 cfm is required for every 13 feet of diffuser line. The total length of diffuser lines would be 28,500 feet. Diffuser lines would be 1-1/2-inch PVC pipe, and would be laid out based on bathymetry, anchorage area geometry, and pier location. The cost of the system installed was estimated to be $180,000. The electric power cost was estimated to average $110 per day of operation, representing an average annual operation cost of $2,000. Based on seasonal use, the life expectancy of the blowers was assumed to be 15 years. Average annual maintenance costs were estimated to be $11,000. Therefore, the average annual cost of the system, utilizing an interest rate of 6 percent, was estimated to be $32,000.

The costs of repairing ice damage to McKinley Marina piers from 1981 to 1985 are presented in Table 58. Damage to the Milwaukee Yacht Club pier in 1985 was about $150,000. Average annual damages to piers at both the Marina and the Yacht Club were estimated to total $78,000, assuming that the lake levels and meteorological conditions for 1981 through 1985 are representative of the future conditions to be endured by the piers and structural elements.

Another benefit of the deicing system proposed for the McKinley Park anchorage area is that winter wet storage of boats would be available in the slip areas. Of the total of 655 slips in the Marina alone, it was estimated that 125 slips could be rented in the winter for storage of about one-half of the larger boats—boats 35 to 60 feet—which are more

Map 28

LOCATION OF PROPOSED DIFFUSED AIR DEICING SYSTEM FOR THE MCKINLEY PARK ANCHORAGE AREA



Under this alternative, 28,500 feet of 1-1/2 inch polyvinyl chloride pipe would be placed in the anchorage area to provide deicing by destratification and melting using an air diffusion system. Seven air blowers—with operating rates ranging from 120 cubic feet per minute (cfm) to 520 cfm—would operate from shore. The average annual cost of the system would approximate $32,000.

Source: SEWRPC.

difficult to move to land storage. It was estimated, that "winter" rates were equal to about 60 percent of the "summer" rates. Thus, a winter wet storage revenue of about $83,000 per year could be realized. Twenty-four-hour security and lighting would have to be provided and the road would need to be plowed in the winter for access by security personnel, at an estimated annual cost of $10,000. The net average annual revenue for winter wet boat storage was accordingly estimated to be $73,000.

The total annual benefit attributable to utilization of an air diffusion system to deice the entire McKinley anchorage area is therefore about $151,000, the sum of the damage abatement benefit and the winter boat storage revenue. The total average annual cost of the proposed system being $32,000, the benefit-cost ratio is 4.7, indicating that the proposal is economically feasible. Without winter boat storage revenue, the ratio would be 2.4.

Before fully implementing the deicing plan described above, it is recommended that a pilot application of the diffused air system be constructed and tested over a few winters. The results of each "experiment" should prove invaluable in further design and construction. The first experiment

Table 58

REPAIR COSTS FOR ICE DAMAGES TO MCKINLEY MARINA FOR 1981-1985

Year	Cost
1981	$ 20,517
1982	20,698
1983	4,997
1984	49,625
1985	146,573

Source: Milwaukee County.

might involve modifying the existing air diffusion system in the North Marina and then operating it a few winters.

Alternative 2—Ice Control by Diffused Compressed Air and Ice Booms: Following a review of information on the control of ice covers and ice floes, and following consultations with staff of the University of Wisconsin-Extension and the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL), it was concluded that deicing of the slips in the McKinley Park anchorage area using a diffused air system and stabilization of the ice cover offshore from the piers with an ice boom was technically feasible. Economic feasibility remained to be determined, however. A system was designed and cost estimates made for installation and operation thereof. These costs were compared with the average annual damage cost to determine the benefit-cost ratio. As already noted, enhancement of benefits could be realized by the availability of winter wet storage for boats in the slips of the McKinley Marina and the Milwaukee Yacht Club. A significant benefit of this approach would be that winter mooring conditions in the slips would be much calmer because of the wave dampening effect of the ice cover.

An ice boom to protect the piers in the anchorage area from ice floes was planned in consultation with CRREL. The proposed layout of the boom is shown on Map 29, along with an air diffuser system for deicing the pier area. The boom would be 2,800 feet long and composed of 14 sections. Preliminary calculations indicated that the unit load on the boom would be about 100 pounds per lineal foot. A factor of safety of 3.2, recommended by CRREL, was then applied to develop the preliminary design, which called for 7/8-inch-diameter wire rope in 220 foot lengths for the boom, and an additional 2,800 feet for 14 boom anchor lines. The boom itself would be constructed of 128 timber rafts, each 20 feet long. A cross-section of the proposed boom is shown in Figure 107.

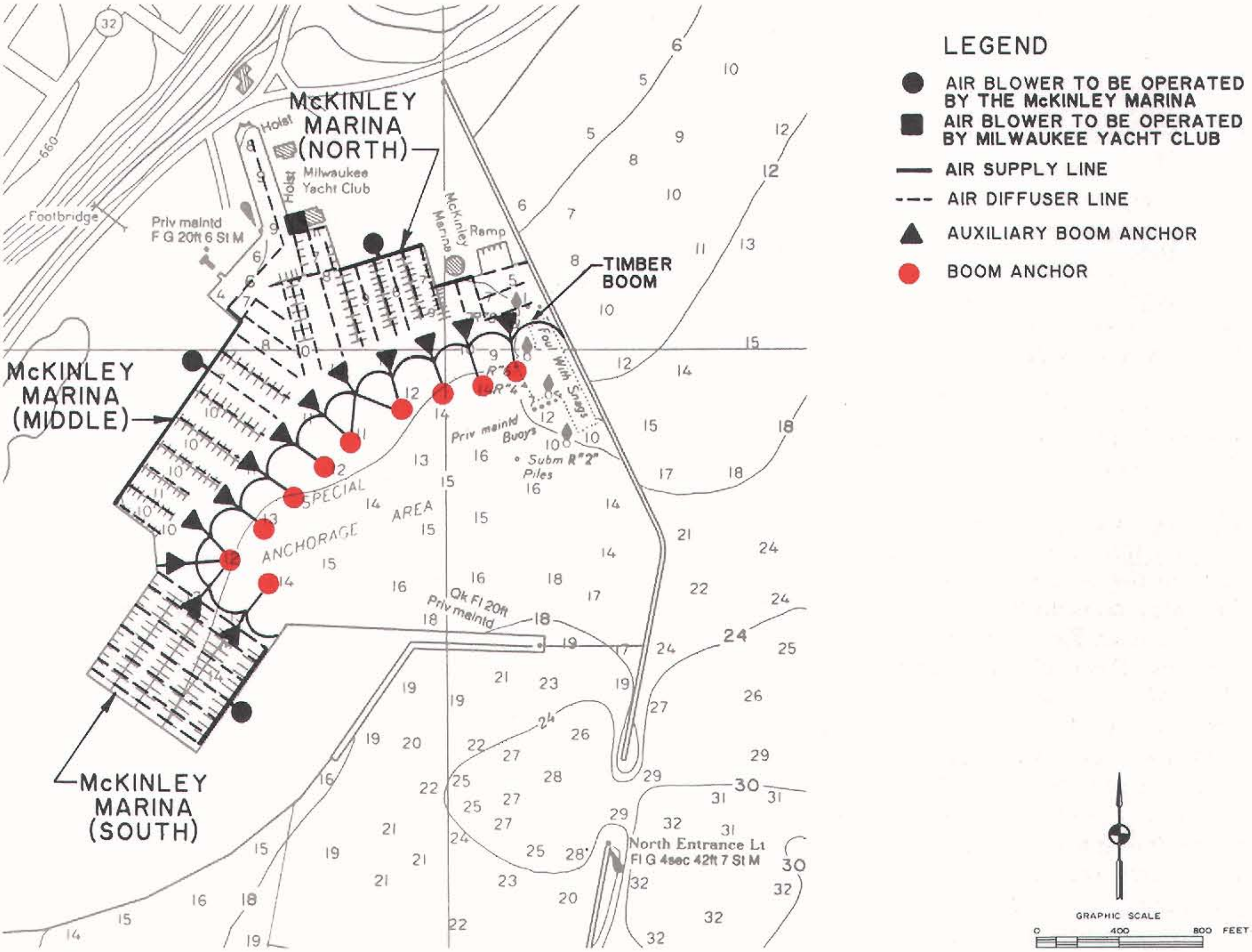
The boom anchors should weigh about 3,200 pounds each to prevent upward vertical movement. Where more than one line connects to an anchor, additional anchor weight is called for. Anchor design to prevent lateral movement should be based upon bottom sediment conditions in the anchorage area. The design horizontal load on the anchors would be about 30,000 pounds per anchor line. Map 29 shows the proposed locations of the main anchors as well as the auxiliary anchors on the opposite side of the boom to hold the boom in place until it freezes in. The auxiliary anchors should provide enough resistance to maintain the boom position in open water both at the beginning and end of the season.

The cost of the ice boom was estimated to be $200 per lineal foot installed, for a total capital cost of $560,000. The life expectancy of the proposed ice boom was estimated to be 15 years based on seasonal use and removal from the water for drying in the off-season. Annual installation and removal should require about five work days each. A barge-mounted crane and a workboat would probably be required for the work. The average annual operation cost was estimated to be $10,000, and the annual maintenance cost to be $11,000. Therefore, the average annual cost of the system, utilizing an interest rate of 6 percent, was estimated to be $79,000.

The air diffusion deicing system to be installed for use with the ice boom described above would have four blowers housed at different locations, as shown on Map 29. The largest blower should have a normal operating flow of 350 cfm. The smallest blower, located at the Yacht Club, would have a normal flow rate of 150 cfm. The total length of the 1-1/2-inch PVC diffuser line would be 13,000 feet. The cost of the air system was estimated to be $80,000 installed. The electric power costs during operation were estimated to average $50 per day. The average annual operation cost, therefore, would be about $4,000. The life expectancy of the blowers was estimated to be 15 years, based on seasonal use. Average annual maintenance costs were estimated to be $2,000. Therefore, the average annual cost of the system, utilizing an interest rate of 6 percent, was estimated to be $14,000.

Map 29

LOCATION OF PROPOSED ICE BOOM AND AIR DIFFUSER LINES IN THE MCKINLEY PARK ANCHORAGE AREA



This alternative would utilize a diffused air system to deice the marina slip areas, and an ice boom to stabilize the ice cover off-shore. The 2,800-foot-long boom would be comprised of 14 sections, each constructed of timber. The average annual cost of this alternative would be about $93,000.

Source: SEWRPC.

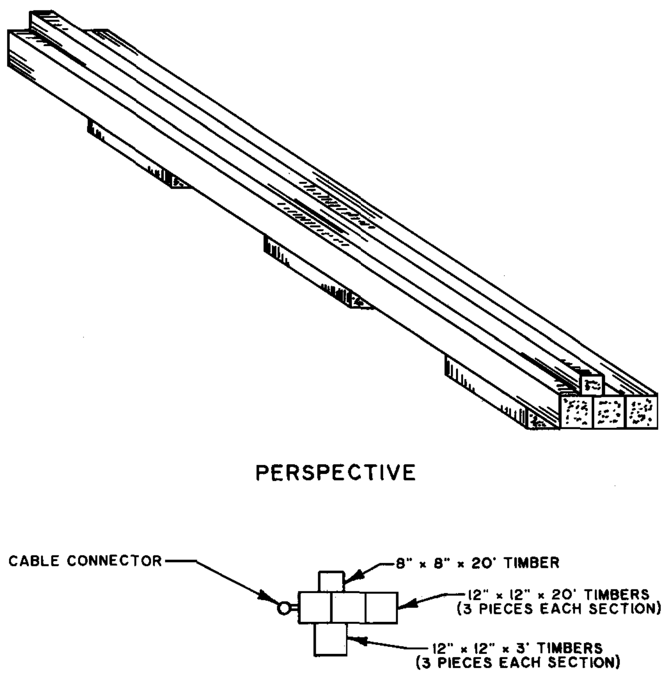
The total cost of the combined ice-boom/deicing system, therefore, was estimated to be $640,000; and the average annual cost of the system was estimated to be $93,000. The total benefits attributable to utilization of the proposed system are $151,000, which is the sum of the damage benefit and the winter boat storage revenue. Therefore, the benefit-cost ratio is 1.6, indicating that the proposal is economically feasible. However, without winter wet storage revenue, the ratio is 0.8.

As stated under Alternative 1, it is recommended that if this alternative is implemented, an experimental approach be taken in the actual design of the ice control system. For example, a short segment of ice boom could be installed at the North Marina along with modification of the air diffusion system there. These systems should be tested a few winters before proceeding with further design and construction.

Alternative 3—Ice Control by Diffused Compressed Air and Air Screens: Following a review of information on the control of ice covers and ice floes, it was concluded that it would be technically feasible to deice the slips in the McKinley Park anchorage area using a diffused air system and to stop the movement of ice floes into the pier area with an air

Figure 107

CROSS-SECTIONAL VIEW OF PROPOSED BOOM FLOAT FOR THE MCKINLEY PARK ANCHORAGE AREA



Source: U. S. Army Cold Regions Research and Engineering Laboratory and SEWRPC.

screen. Economic feasibility remained to be determined, however. A system was designed using U. S. Army Corps of Engineers criteria, and cost estimates made for the installation and operation thereof. These costs were compared with the average annual damage cost to determine the benefit-cost ratio. If boats were able to be stored in the slips of the McKinley Marina and the Milwaukee Yacht Club, the benefits of this alternative could be enhanced.

An air screen to protect the piers in the anchorage area from ice floes was planned, with the proposed layout of the system shown on Map 30, along with an air diffuser system for deicing the pier area. The screen would be 2,800 feet long and composed of 11 sections. Eleven 187-horsepower air blowers with normal discharge capacities of 2,500 cfm each at 15 pounds per square inch (psi) would be utilized, one for each of the 11 sections of air screen. These units are currently the largest made. The air supply lines and diffuser lines would remain in place permanently, but the blowers could be brought in and connected to the system in late winter to await breakup. The system would be activated at that time, pending wind conditions, and could be disconnected when the threat from ice floes was over for storage, or for utilization elsewhere in the off-season. If left connected, the system could also be utilized during the boating season during storms to impede movement of waves into the slip areas.

The cost of the air screen installed was estimated to be $240,000, equivalent to about $85 per lineal foot. The life expectancy of the proposed air screen was estimated to be 25 years, based on about five days of operation each year. The daily electric power costs were estimated at $1,300, for an average annual operation cost of $7,000. The average annual maintenance costs were estimated to be $5,000. Therefore, the average annual cost of the system, utilizing an interest rate of 6 percent, was estimated to be $31,000.

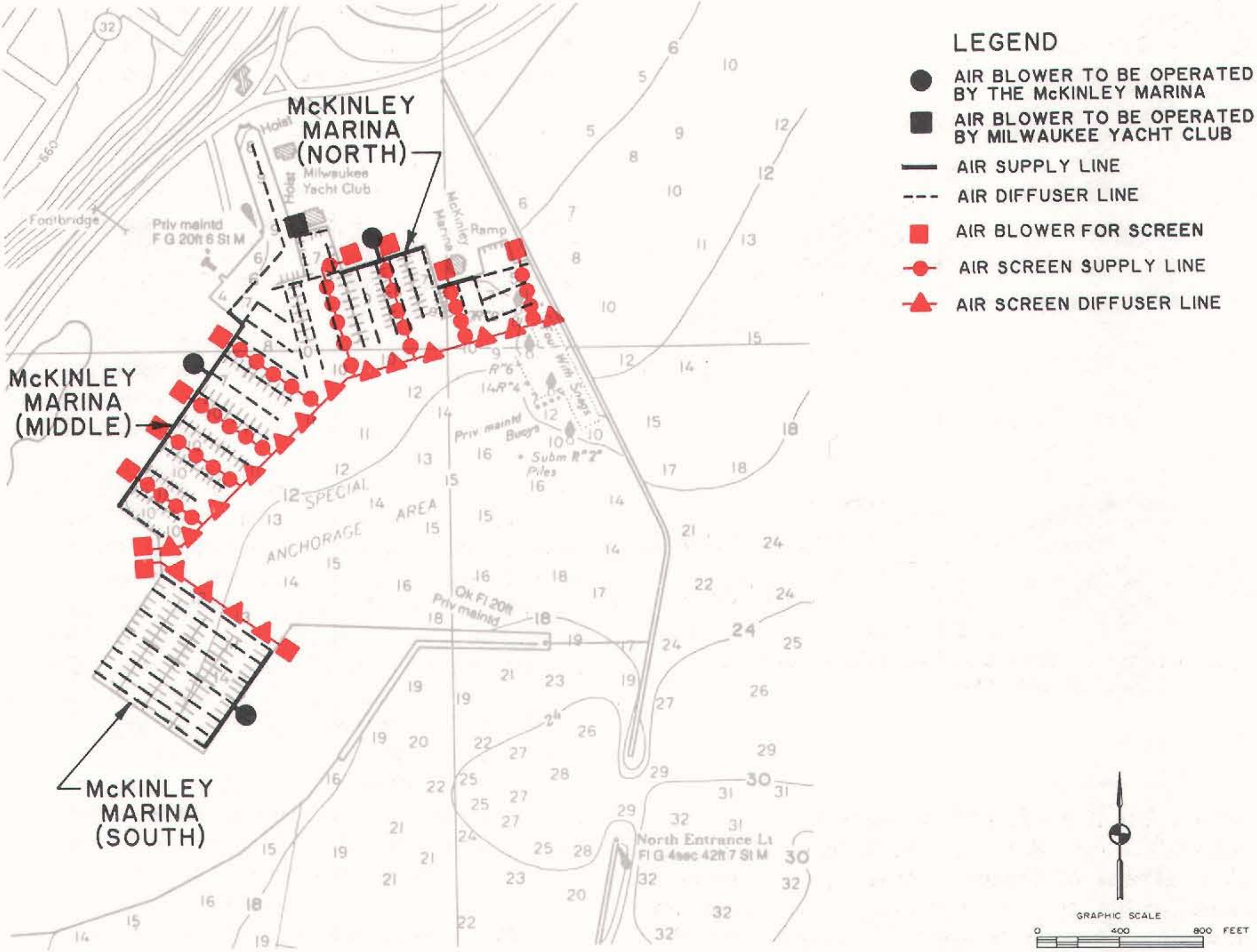
The air diffusion deicing system to be installed for use with the air screen described above is the same as that described under Alternative 2. The average annual cost of the system was estimated to be $14,000. The total cost of the combined air screen-deicing system was estimated to be $320,000. The average annual cost of the system was estimated to be $45,000. The total benefits attributable to utilization of the proposed system are $151,000, which is the sum of the damage benefit and the winter boat storage revenue. Therefore, the benefit-cost ratio is 3.4, indicating that the proposal is economically feasible. The ratio is 1.7 without winter wet boat storage revenue, however.

It is again recommended that should the system described above be selected for implementation, an experimental approach be utilized for system design. For example, a short section of air screen could be installed at the North Marina, along with modification of the existing air diffusion system there. The system then should be tested a few winters before proceeding with further design and construction.

Based upon review of the alternatives considered, it is recommended that the alternative providing for ice control by the use of diffused air be considered further by constructing and operating a pilot application. This pilot application could involve modifying the existing air diffuser system in the North Marina. Concurrently, it is recommended that a pilot system be operated in the central anchorage area.

Map 30

LOCATION OF PROPOSED AIR SCREEN AND AIR DIFFUSER LINES IN THE MCKINLEY PARK ANCHORAGE AREA



This alternative would use a diffused air system to deice the marina slip areas, and an air screen to prevent movement of off-shore ice floes into the slip area. The air screen would be 2,800 feet long and utilize eleven 187-horsepower air blowers. The average annual cost of this alternative would approximate $45,000.

Source: SEWRPC.

FLOOD PROTECTION

Flood control studies for the Kinnickinnic, Menomonee, and Milwaukee River estuaries were made and the findings and recommendations published by the Regional Planning Commission in 1978, 1976, and 1971, respectively,[30] as parts of the comprehensive planning studies for the entire watersheds of these three rivers. Since the completion of these reports, levels of Lake Michigan equaling, or almost equaling, the 100-year recurrence interval values utilized in those studies have been experienced, as indicated in Table 59. Therefore, it was concluded that a reevaluation of the flood protection elevations for the three river estuaries was warranted.

[30] *SEWRPC Planning Report No. 32, A Comprehensive Plan for the Kinnickinnic River Watershed, 1978; SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volumes One and Two, 1976; SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed, Volume One, 1970, Volume Two, 1971.*

Table 59

COMPARISON OF FORMER AND REVISED 100-YEAR RECURRENCE INTERVAL FLOOD STAGES IN THE MILWAUKEE HARBOR ESTUARY WITH STAGES OBSERVED IN 1985 AND 1986

Location	Former 100-Year Regulatory Flood Stage[a]	Maximum Observed in Outer Harbor in 1985-86[a,c]			Revised 100-Year Regulatory Flood Stage
		Annual Mean[b]	Monthly Mean	Instantaneous	
Kinnickinnic River Estuary from Mouth to Mile 2.2	583.8	582.0	582.8	583.7	584.5
Menomonee River Estuary from Mouth to Mile 1.8	583.8	582.0	582.8	583.7	584.5
Milwaukee River Estuary from Mouth to Wisconsin Avenue	583.0-583.7[d]	582.0	582.8	583.7	584.5

[a]*Stages in feet above NGVD. Stages are from SEWRPC comprehensive watershed plans. The federal flood insurance study for the City of Milwaukee utilized the Lake Michigan 100-year recurrence interval stage of 583.7 feet NGVD.*

[b]*1985.*

[c]*Through July 1986.*

[d]*The 100-year profile of the Milwaukee River rose from 583.0 feet at the mouth to 583.7 feet at Wisconsin Avenue.*

Source: SEWRPC.

In addition, the Milwaukee River watershed study recommended that the channel capacity of the Milwaukee River estuary be maintained to pass the 100-year peak flood discharge following discontinuance of dredging upstream of Buffalo Street by the U. S. Army Corps of Engineers. This recommendation has not been acted upon, and consequently, that reach of the Milwaukee River estuary decreased in depth an average of 4.2 feet between 1955 and 1983. Therefore, new hydraulic analyses were conducted to determine the degree to which regulatory flood stages may have been affected by this shoaling of the channel.

Kinnickinnic River Estuary

The 100-year recurrence interval flood stages for the Kinnickinnic River estuary presented in Planning Report No. 32 were revised following analysis of additional stage data collected for Lake Michigan at Milwaukee since completion of the watershed study. The results of the updated Lake Michigan stage-frequency analysis were presented earlier in this chapter. The revised 100-year recurrence interval instantaneous maximum stage for Lake Michigan at Milwaukee of 584.5 feet NGVD, or 583.2 feet IGLD, is 0.7 foot higher than the 100-year stage presented in SEWRPC Planning Report No. 32 for the lower Kinnickinnic River estuary. This stage was extended from the mouth of the Kinnickinnic River upstream until it intersected the flood profile for the 100-year recurrence interval peak flood discharge for the river, as shown in Figure B-1 in Appendix B. Combined hydraulic and joint probability analyses found that no other single or joint 1 percent probability event produced higher stages in the Kinnickinnic River estuary. Figure B-1 also presents the former regulatory flood profile for comparison. The recommended revised regulatory floodplain boundary is compared with the former boundary on Map B-1 in Appendix B. The number of structures in the inundation area increased from 12 to 31.

Prior to revising the 100-year flood profile to incorporate the effects of the updated stage-frequency analysis for Lake Michigan, peak-flood discharges for the Kinnickinnic River estuary developed under the Kinnickinnic River watershed study, as described in SEWRPC Planning Report No. 32, were reviewed by conducting a new frequency analysis incorporating streamflow records collected through 1985 by the U. S. Geological Survey. The resulting flood discharges were found to be not significantly different from those set forth in Planning Report No. 32. Consequently, no changes in flood discharges are indicated in this study.

Based on the analyses described earlier in this chapter, flood stages of 585.9 and 587.9 feet NGVD could occur in the Kinnickinnic River estuary as a result of rising Lake Michigan water levels. These elevations were determined using the stage increases for the 50 percent and 10 percent exceedance frequencies under the long-term rising lake level scenario. This provided for 2.0-foot and 4.0-foot increases in lake level, which were then added to the 1985 annual mean lake level at Milwaukee—582.0 feet NGVD—to estimate the annual mean stages 50 years hence. The 100-year recurrence interval annual instantaneous maximum rise—1.9 feet—as shown in Figure 42 in Chapter V of Volume One of this report, was then added to these sums. Combined hydraulic and joint probability analyses of lake levels and river flood flows found that no other single or joint 1 percent probability event produced higher stages. This profile is also presented in Figure B-1 in Appendix B.

The floodplain boundary for the range of levels under the long-term rising lake level scenario was then delineated, as shown on Map B-1 in Appendix B, which also shows the recommended revised regulatory floodplain boundary for present-day lake levels. As the map indicates, a much larger area—namely 300 acres—is contained within the floodplain and many more structures—184—would be in the inundation area under the long-term rising lake level trend. This increase in area subject to flooding is entirely attributable to the assumed change in the Lake Michigan level and not at all to changes in flood flows from the Kinnickinnic River watershed. The storm conditions that would produce this lake stage may be expected to diminish within a day or so, whence the water level may be expected to recede about 1.9 feet to a pre-storm level in the estuary.

<u>Menomonee River Estuary</u>

The regulatory 100-year flood profile for the Menomonee River estuary was revised in a manner similar to that described for the Kinnickinnic River estuary. Regulatory flood stages previously developed for the reach upstream of N. 25th Street were not affected by the revisions, however. The flood discharges used were those described in SEWRPC Planning Report No. 26, since the streamflow records maintained since the completion of that report through 1985 had insignificant effects upon the results of the discharge-frequency analysis. The former and revised regulatory flood profiles are compared in Figure B-2 in Appendix B. The former regulatory floodplain boundary is compared with the revised boundary on Map B-2 in Appendix B. The number of structures therein increased from 39 to 84. Flood profile computations for the long-term rising lake level scenario for the Menomonee River estuary and the affected reach upstream were made in the same manner as for the Kinnickinnic River estuary. Subsequently, the floodplain boundary for the rising lake level scenario was drawn as shown on Map B-2 in Appendix B, which also shows the recommended revised regulatory floodplain boundary for present-day lake levels. As the map indicates, a significantly larger area—440 acres—is contained within the floodplain and many more structures—302—are in the inundation area under the projected lake level. This increase in flooding is entirely attributable to the assumed change in the Lake Michigan level, and not at all to flood flows from the Menomonee River watershed. The storm conditions that would produce this lake stage should diminish within a day or so, whence the water level may be expected to recede about 1.9 feet to a pre-storm level in the estuary.

<u>Milwaukee River Estuary</u>

In the Milwaukee River estuary upstream of Buffalo Street, the channel depth decreased about 4.2 feet on the average between 1955 and 1983 owing to cessation of dredging of the former federal navigation channel which had extended up to Humboldt Avenue. The flood profiles computed for this reach of river under the Milwaukee River watershed study, completed by the Regional Planning Commission in 1971, were checked utilizing channel cross-sections sounded in 1983 by the U. S. Army Corps of Engineers to determine if dredging was required to maintain flood flow capacity.

The starting elevations and hydraulic structures for the flood profile computations and the corresponding flood discharges initially analyzed were those used for the watershed study; this enabled changes in flood stages attributable solely to channel changes to be calculated for comparison. The comparison of the 100-year flood profiles representing old and new channel geometry and assuming rigid bed conditions indicated that stage increases occurred, but only in the reach upstream of the Holton Street bridge, where a maximum increase of 0.5 foot was computed. This increase was entirely attributable to channel deposition. However, average flood velocities in this reach of river channel range from 2.9 to 5.5 feet per second (fps), with nearly all the flow contained in the main channel. Because the bed material is composed primarily of fine-grained flocculent organic material about two feet thick, as described in Chapter VI in Volume One of this report, the bed of the river should be erodible under the flow velocities attained during a 100-year flood. Channel scour may therefore be expected to occur until the flow velocity decreases to about 2.0 fps. Calculations indicated that several feet of scour would occur before this mean channel velocity is reached. Hydraulic model calculations indicate that only about 1.0 foot of scour would lower the 100-year flood profile to coincide with that published in the watershed study. Consequently, channel deposition would not cause 100-year flood stages in the Milwaukee River estuary above Holton Street to be higher than those presented in the Milwaukee River watershed study, or in the federal flood insurance study of the City of Milwaukee which was based upon the earlier Commission work. Thus, dredging of the channel does not appear necessary to maintain flood flow capacity.

Prior to revising the 100-year flood profile to incorporate the effects of the updated stage-frequency analysis for Lake Michigan, flood discharges for the Milwaukee River estuary developed under the Milwaukee River watershed study, as described in SEWRPC Planning Report No. 13, were reviewed by conducting an updated frequency analysis of streamflow records collected at the U. S. Geological Survey gaging station in Estabrook Park through water year 1984, as described in Chapter V of Volume One of this report. The resulting flood discharges were found to be not significantly different from those set forth in SEWRPC Planning Report No. 13. Consequently, no changes in flood discharges are indicated in this study.

The regulatory 100-year flood profile for the Milwaukee River estuary was revised in a manner similar to that described above for the Kinnickinnic and Menomonee River estuaries. Regulatory flood stages previously developed for the reach upstream of the Cherry Street bridge were found to be unaffected by the revisions. The former and revised regulatory flood profiles are compared in Figure B-3 in Appendix B. The former regulatory floodplain boundary is compared with the revised boundary on Map B-3 in Appendix B.

Flood profile computations for the long-term rising lake level scenario for the Milwaukee River estuary were made in the same manner as those for the Kinnickinnic and Menomonee estuaries. The resulting profiles are also shown in Figure B-3 in Appendix B for comparison. The instantaneous maximum stage of Lake Michigan of 587.9 feet NGVD would extend all the way to the North Avenue dam as the highest single or joint lake level and river flow 1 percent probability event.

The inundated area for this scenario was delineated and compared with that for the revised 100-year floodplain boundary shown on Map B-3 in Appendix B. A much larger area—300 acres—would be in the floodplain under the projected high lake level conditions. The number of structures in the inundation area would increase from 5 to about 137.

The floodplain boundary and associated stages representing the effects of the worst case rising Lake Michigan scenario are not recommended to be used in determining regulatory floodplain boundaries and stages, however, because, as stated earlier, it is just as likely that lake levels will not increase, and may even decrease. However, it is recommended that the worst case flood boundary and stages be presented, along with regulatory flood information, to alert all concerned of the implications of the lake level rising four feet above 1985 levels, as it may do.

SUMMARY

The facilities in use in the Milwaukee Harbor for recreational and commercial watercraft have been developed over a long period of time, beginning with the construction of a breakwater in its present location in 1929. The major facilities in addition to the breakwater include the City Harbor Commission North Piers, the Port of Milwaukee piers and terminals in the outer harbor, and the municipal mooring basin and the City Heavy Lift Dock in the inner harbor. While these various facilities provide a relatively safe anchorage for both smallcraft and larger vessels during ordinary Lake Michigan storm events, larger storms can produce wave conditions in the outer harbor, including the McKinley Park anchorage area, that can damage both smallcraft and larger commercial vessels berthed at municipal piers. Protection of the shoreline and riparian facilities behind the breakwater forming the outer harbor of Milwaukee has become increasingly important as the number of facilities has increased and as the level of Lake Michigan at Milwaukee has risen to, and above, previous records for the 20th century.

Damages in the outer harbor are caused by both the movement of large waves through the breakwater gaps and wave energy transmission over the breakwater. Larger commercial vessels can safely moor in the open water of the outer harbor during large storms, but berthing at the municipal piers can be hazardous during very severe storms. The most severe conditions are associated with onshore winds—particularly from the northeast.

The McKinley anchorage area is better protected from the northeast winds than the facilities to the south, and damage to recreational crafts and harbor facilities is not a major problem during the boating season. Boats are removed during the off-season. The most severe damage generally is to piers and is caused by two phenomena. One is associated with the ice sheet which annually covers the entire 98-acre McKinley Park anchorage area, and the second is associated with the movement of ice floes following breakup. Available anchorage and potential marina development in the inner harbor is limited owing to the confining geometry of the inner harbor channels, the relatively high shoaling rates in the federal channels, the limited area for potential dockage of larger vessels, and the aesthetic unsuitability of certain land uses along the waterways for marina development.

Essential to the analysis of the means by which to provide for anchorage, dockage, shoreline, and flood protection measures is knowledge of lake levels as characterized by analyses of historical data. Consideration has been given in this report to the present-day lake levels, and to a revised 100-year recurrence interval flood elevation—584.5 feet NGVD, or 583.2 feet IGLD—that is 0.8 foot higher than that developed by the U. S. Army Corps of Engineers and 0.7 foot higher than that developed previously by the Regional Planning Commission. This increase is due to the inclusion of more recent lake level data in the data base.

In addition to present-day lake level considerations, this chapter presents the findings of an analysis made of projected water levels, should Lake Michigan be in a long-term rising trend. This long-term trend analysis was conducted in order to provide additional information for use in the design of major public and private works in and near the harbor estuary. Owners considering major capital improvements can use this long-term high water level elevation to evaluate the marginal cost of constructing "fail safe" facilities. Analyses indicated that if the lake is in a long-term rising trend, there is a 10 percent probability that it will be four feet higher 50 years hence than it is at the present time. Therefore, by the year 2035, the mean elevation of the lake might reach 586.0 feet NGVD, or 584.7 feet IGLD. This lake level is a long-term potential condition and should be considered only in evaluating the potential to make major private and public works projects relatively fail safe from the rising lake levels. It should not be substituted for a 100-year recurrence interval or regulatory lake level.

Methods considered for protecting anchorage areas, dockage, and shorelines exposed to wave and ice action primarily included breakwaters, ice breaking, ice booms, deicing techniques, and air screens. Analyses were conducted of using a higher breakwater and of implementing ice control measures within the McKinley Park anchorage area. In addition, consideration was given to alternative means of ice breaking in the Milwaukee Harbor. However, it was determined that the existing methods of ice breaking in the harbor—that is, the use of the Harbor Seagull vessel operated by the Port of Milwaukee—were adequate for all areas except the McKinley anchorage area, where ice thickness frequently exceeds 24 inches.

The potential costs and benefits of constructing a higher breakwater were considered both under existing lake level conditions and under the scenario whereby the lake would continue upward under the long-term rising trend. Under present lake levels, it was concluded that the damages to piers and port facilities on Jones Island are not extensive enough to justify the provision of further protection measures since it is less expensive to repair the damages as they occur than to construct a higher breakwater at a cost of about $22 million. Damages are estimated to approximate $600,000 for a 100-year recurrence interval storm event, with average annual storm damages being about $50,000. The average annual cost of increasing the breakwater by about 8.7 feet would be $1.9 million, yielding a benefit-cost ratio of less than 0.1.

Under the long-term rising lake level scenario, the damages to the piers and port facilities would increase to about $900,000 on an average annual basis. In order to minimize or reduce damages to only those resulting from waves coming through the gaps in the breakwater, it would be necessary to raise the structure by about 16 feet, at a cost of about $150 million. The average annual cost of this project is estimated to be $9.5 million, yielding a benefit-cost ratio of just under 0.1. Indirect benefits, which were not considered in these benefit-cost ratios, include the provision of a safe harbor of refuge for both smallcraft and ships, and facilitation of waterborne commerce by the Port of Milwaukee.

In view of these considerations, it was recommended that the breakwater structure not be substantially modified at this time, but rather that the lake levels continue to be monitored and that contingency planning be initiated by the involved units of government to determine what actions would need to be taken should the lake-level rise continue. That contingency planning should consider not only the potential construction of breakwater improvements to reduce wave-induced damage, but also the flooding conditions that will occur throughout the estuary area as a result of the lake levels.

With regard to the McKinley Park anchorage area ice control, three alternatives were considered in detail—melting of ice in the entire anchorage area using diffused compressed air; melting of ice using diffused compressed air near the piers, with retention of ice floes in the remaining area using an ice boom; and melting of ice near the piers, with retention of ice floes using an air screen. The benefit-cost ratios for these alternatives were computed with and without revenue from wet winter boat storage, and ranged from 0.8 to 4.7. The alternative with the highest benefit-cost ratio was ice control using diffused compressed air. The capital cost of the equipment needed to implement that plan was estimated at $180,000, with an annual operation and maintenance cost of $13,000. It is recommended that portions of that system also be incorporated into the other two alternatives if additional facilities such as an ice boom are required. Thus, it is recommended that a pilot application of the diffused air system be constructed and operated over a few winters. The results of each pilot test will provide the information needed for detailed design and construction. The first experiment could involve modifying the existing air diffusion system in the North Marina and testing that system a few winters. Concurrently, it is recommended that a pilot system also be operated in the central anchorage area.

Since the completion of the studies evaluating flood control alternatives for the Kinnickinnic, Menomonee, and Milwaukee River estuaries, levels of Lake Michigan equaling or almost equaling the 100-year recurrence interval values utilized in those studies have been experienced. These episodes of high levels indicate that a reevaluation of the flood protection elevations for the three river estuaries is warranted. A revised 100-year recurrence interval maximum stage for Lake Michigan of 584.5 feet NGVD, or 583.2 feet IGLD, was used in this analysis. Revised recommended regulatory flood profiles were developed. The recommended floodplain boundary is mapped on Maps B-1, B-2, B-3, and B-4 in Appendix B. With the revised regulatory flood information, the number of structures included in the inundation area has increased from 55 to 120.

In addition, an analysis was conducted of the area inundated under the long-term rising lake level scenario. That floodplain is shown on Maps B-1, B-2, B-3, and B-4 in Appendix B, and indicates that a much larger area—about 1,045 additional acres—is contained within the potential long-term flood elevation, and that about 500 structures would be in the inundation area in addition to those included in the recommended new regulatory flood elevations described previously. The floodplain boundary and associated stages representing the effects of the worst case rising Lake Michigan scenario are not recommended to be used in determining regulatory floodplain boundaries and stages. However, as stated earlier, it is recommended that this flood boundary and the stages be considered in order to alert all concerned of the implications of the lake level rising over the next 50 years.

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Chapter VII

RECOMMENDED COMPREHENSIVE PLAN

INTRODUCTION

The Milwaukee Harbor estuary planning program was designed to identify the nature and extent of the water pollution, flooding, dredging, storm damage, and shoreline protection problems within the estuary; to evaluate the effectiveness of alternative water pollution and flood damage abatement measures, alternative dredging and spoils disposal practices, and alternative storm damage prevention and shoreline protection techniques; and to recommend a comprehensive set of specific actions devised so as to ensure the enhancement and preservation of the estuary environment as a significant resource in a highly urbanized setting.

Based upon the inventories presented in Volume One of this report and the analyses, forecasts, objectives, and alternative plan evaluations presented in this volume, a recommended plan for ensuring the preservation and enhancement of the estuary water resources environment was developed. The selection of the recommended plan followed an extensive review by the Technical Advisory Committee of the technical feasibility, economic viability, environmental impacts, potential public acceptance, and practicality of the various alternative water resources management plans considered.

The comprehensive plan for the Milwaukee Harbor estuary is comprised of four major elements: 1) a water quality management plan element; 2) a dredging and spoils disposal element; 3) a shoreline storm damage and flood protection element; and 4) a toxic substances management element. Each of these plan elements contains several subelements as described in the following sections. The recommended plan set forth in this chapter represents a refinement of the preliminary recommended plan elements set forth in Chapters IV, V, and VI of this volume.

The water quality management plan element and the toxic substances management plan element are considered an extension of the adopted areawide water quality management plan. The dredging and spoils disposal element represents a logical extension of the water quality management plan element owing to the relationship between the sediment and water quality, but also relates to estuary navigation and dredged material considerations which have not been previously addressed in any regional plans. The shoreline storm damage and flood protection element represents an extension and refinement of the comprehensive watershed plans developed for the Kinnickinnic, Menomonee, and Milwaukee River watersheds.

This chapter describes the recommended comprehensive plan for the Milwaukee Harbor estuary as synthesized from the best of the alternatives considered, and presents the attendant costs. In addition, the chapter evaluates the ability of the recommended plan to meet the adopted water resource management objectives and supporting standards, and discusses the likely consequences of not implementing the plan. It should be noted that this chapter describes the recommended plan as presented for public hearing. The public reaction to this plan and the subsequent action of the Milwaukee Harbor Estuary Technical Advisory Committee to adjust the plan based upon the results of the hearing are discussed in Chapter IX of this volume.

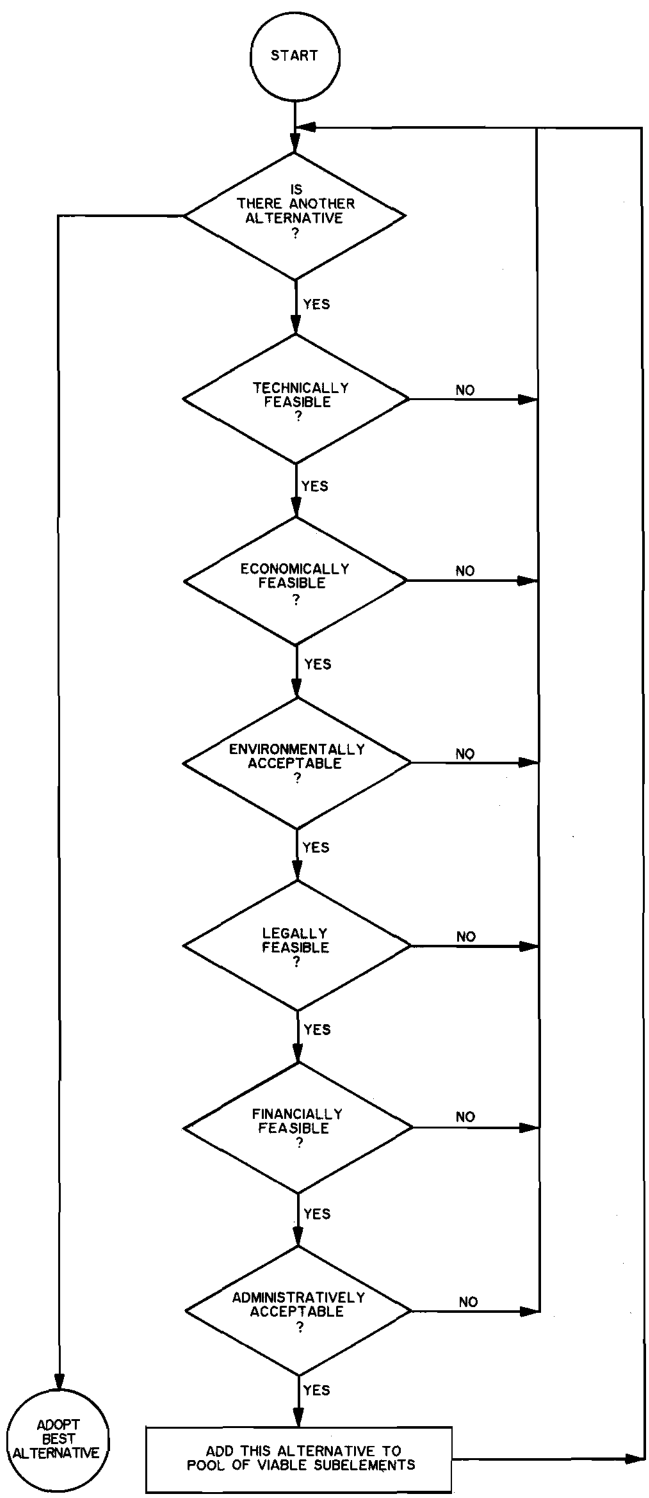
BASIS FOR PLAN SYNTHESIS

The water resource management objectives which the comprehensive plan for the Milwaukee Harbor estuary 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 the plan proposals to meet the stated objectives.

The three preceding chapters described the alternative plans considered for the resolution of the water resource-related problems of the Milwaukee Harbor estuary, and identified the best water quality management, dredging and spoils disposal, and shoreline storm damage and flood protection alternatives for inclusion in a comprehensive water resources management plan. Figure 108 illustrates the manner in which a plan element or subelement was sequentially subjected to several levels of

Figure 108

TEST AND EVALUATION OF A PLAN SUBELEMENT



Source: SEWRPC.

review and evaluation, including technical and economic feasibility; financial, legal, and administrative feasibility; and political acceptability. Devices used to actually test and evaluate alternative subelements ranged from the mathematical models used to simulate river performance to informal interagency meetings and formal public hearings.

No water resource plan element can fully satisfy all desirable water resource objectives. The recommended comprehensive plan must, therefore, consist of a combination of individual plan elements, with each plan element contributing to the extent practicable toward the satisfaction of the development objectives. It should be noted that many of the alternative plan elements were specifically designed to satisfy certain water resources objectives, and therefore, the selection from among the alternatives depended largely upon analysis of the attendant costs. The various recommended plan elements are complementary in nature, and the recommended water resource management plan represents a synthesis of carefully coordinated individual plan elements which together should achieve the adopted development objectives.

WATER QUALITY MANAGEMENT PLAN ELEMENT

The areawide water quality management plan for southeastern Wisconsin was completed by the Regional Planning Commission in 1979. The adopted plan consists of five major plan elements: a land use element, a point source pollution abatement element, a nonpoint source pollution abatement element, a sludge management element, and a water quality monitoring element. The findings and recommendations of the areawide water quality management plan are set forth in SEWRPC Planning Report No. 29, A Regional Wastewater Sludge Management Plan for Southeastern Wisconsin, and in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000. Because of the complex nature of the Milwaukee Harbor estuary hydraulics and other factors such as sediment oxygen demand affecting water quality, it was recommended in the areawide plan that the Milwaukee Harbor estuary be considered in more detailed site-specific studies. This water resources management plan represents the results of one such study for the Milwaukee Harbor estuary.

The water quality management plan element of the Milwaukee Harbor estuary plan is thus intended to further refine and detail the areawide water quality management plan with respect to the water pollution abatement measures required to achieve recommended water use objectives and supporting water quality standards in the Milwaukee Harbor estuary. More specifically, this element of the Milwaukee Harbor estuary plan refines and details the point source, nonpoint source, and water quality monitoring recommendations set forth in the areawide plan, and evaluates certain pollution abatement measures—such as the required level of protection for combined sewer overflow abatement and the need to abate pollution from in-place pollutants—which were not specifically addressed in the areawide water quality management plan. Thus, the Milwaukee Harbor estuary study serves to refine and detail, as well as extend, the areawide water quality management plan by identifying the water quality problems of the Milwaukee Harbor estuary; identifying the sources of those problems; designing and assessing alternative means for mitigating those problems; selecting a recommended pollution abatement plan; and identifying means for implementing that plan.

This section describes the recommended water quality management plan element. The description covers the four subelements of this plan element, including a point source pollution abatement plan subelement, a nonpoint source pollution abatement plan subelement, an instream water quality measures subelement, and an auxiliary plan subelement. This recommended water quality management plan subelement is shown in graphic summary form on Map 31.

Point Source Pollution Abatement Plan Subelement

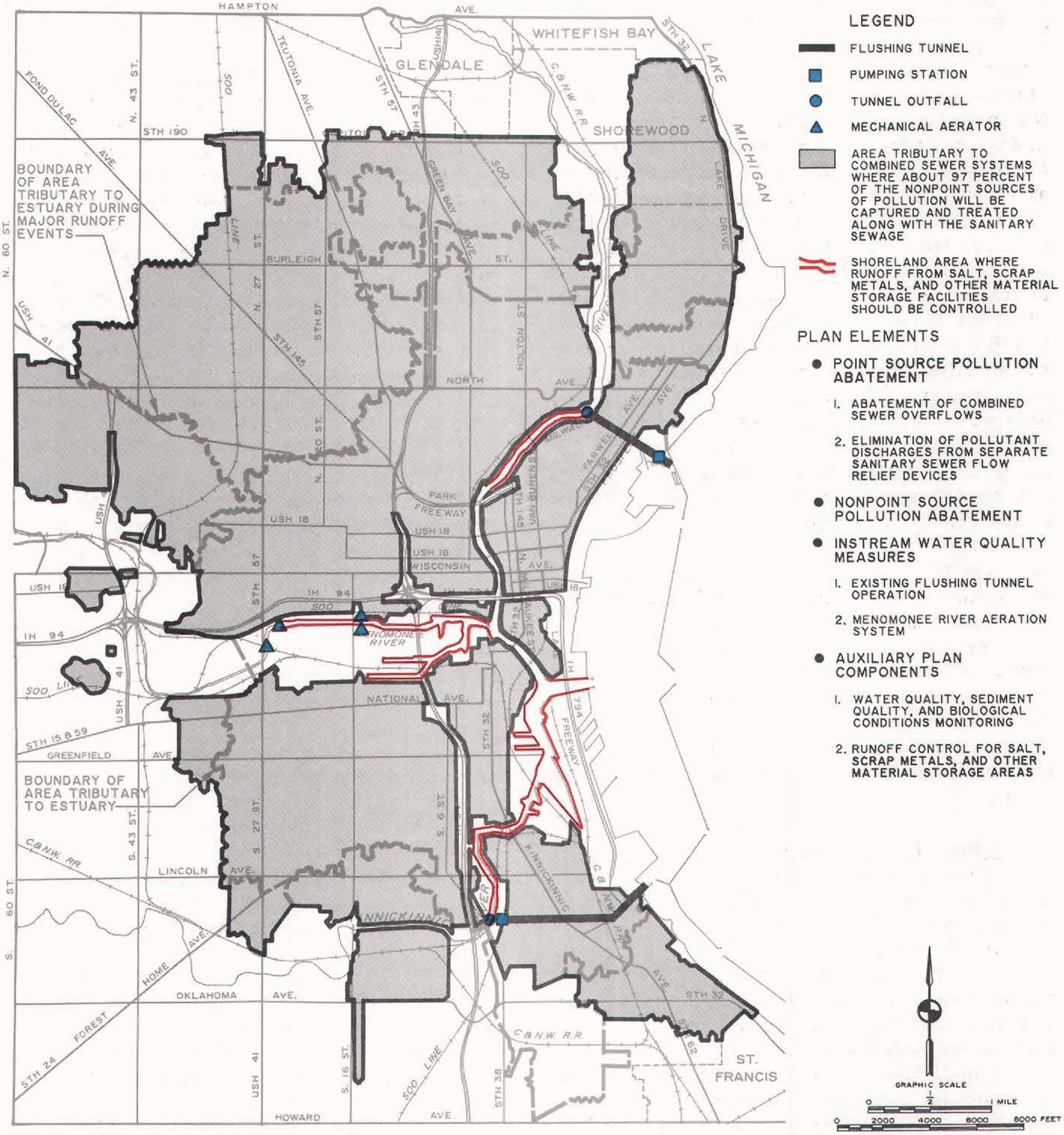
Point sources of water pollution include sewage treatment plant outfalls, industrial wastewater outfalls, and combined and separate sewer system flow relief devices. Because pollutants associated with urban stormwater runoff have discharge characteristics related to the tributary land uses and associated land management practices, urban storm sewer system discharges are considered nonpoint, or diffuse, sources of water pollution and are addressed under the subelement relating to the abatement of pollution from such sources. The recommended point source pollution abatement plan subelement addresses sewage treatment plant outfalls, industrial wastewater outfalls, and combined and separate sewer system flow relief devices. All of these pollution sources were addressed in the areawide water quality management plan. Thus, this new study represents a refinement and an extension of that earlier study.

The Milwaukee Metropolitan Sewerage District's adopted water pollution abatement program shares objectives with the areawide water quality management plan and the Milwaukee Harbor estuary planning program. The water quality impacts of several elements of the District water pollution abatement program—such as the abatement of pollution from sanitary sewer flow relief devices and combined sewer overflows—are directly addressed in the Milwaukee Harbor estuary study. The harbor estuary study also addresses certain issues raised during the conduct of the District water pollution abatement program. These issues include the establishment of water use objectives and supporting water quality standards for the Milwaukee Harbor estuary; the required reduction in pollutant loadings from point and nonpoint sources discharged to the stream network upstream of the estuary; the determination of whether toxic conditions are affecting desired uses of the estuary; the level of protection needed for the abatement of pollution from combined sewer overflows; and the need for, and methods of, abating in-place pollutants. Consequently, the Milwaukee Harbor estuary study is closely related to certain aspects of the District water pollution abatement program, and the study findings and recommendations are intended to help shape and amend, as well as help implement, that program.

With regard to industrial wastewater outfalls, the study found that no significant sources of pollution exist within the Milwaukee Harbor estuary, or within the watersheds tributary to that estuary. There are, however, 14 public sewage treatment plant outfalls located in the tributary watersheds as described in Chapter IV. In addition, the outfall of the Milwaukee Metropolitan Sewerage District Jones Island sewage treatment plant discharges directly to the outer harbor. The recommendations relating to sewage treatment plants and industrial wastewater outfalls are the same as those set forth in the areawide water quality management plan. The plan recommendations set forth in that earlier plan were designed to meet the adopted water use objectives in the stream system located upstream of the Milwaukee Harbor estuary. The Milwaukee Harbor estuary study evaluated the need to provide increased pollution abatement levels for sewage treatment plants and industrial wastewater discharges. However, the analyses indicated that

Map 31

RECOMMENDED WATER QUALITY MANAGEMENT PLAN ELEMENT OF THE MILWAUKEE HARBOR ESTUARY PLAN



The recommended water quality management plan for the Milwaukee Harbor estuary includes abatement of combined sewer overflows at a 0.7-year level of protection, elimination of pollutant discharges from separate sanitary sewer flow relief devices; abatement of rural nonpoint sources of pollution and construction erosion upstream of the estuary; continued operation of the existing Milwaukee and Kinnickinnic River flushing tunnels; construction and operation of a new instream aeration system within the Menomonee River estuary; and runoff control for selected material storage areas located along and draining directly to the harbor estuary. It is also recommended that a water resources monitoring program be developed and that a further study of toxic substances be conducted.

Source: SEWRPC.

increased levels of pollutant control from those sources need not be provided as a component of the recommended water quality management subelement of the Milwaukee Harbor estuary plan. Thus, recommendations regarding the number and location of, and effluent limitations for, sewage treatment plants and industrial wastewater discharges as set forth in the areawide water quality management plan are confirmed and recommended to be left unchanged by the Milwaukee Harbor estuary study. The costs of these previously recommended actions are, accordingly, not included in the cost of the water quality management element of this plan.

Analysis of the inventories of the existing sources of the pollutant loadings to the Milwaukee Harbor estuary, as documented in Volume One of this report, indicates that relocation of the Jones Island sewage treatment plant outfall would substantially reduce the loadings of pollutants—with the largest impact being on phosphorus and ammonia loadings. However, the analysis indicated that these pollutant loadings to the outer harbor, while significant, do not preclude the attainment of desired water use objectives within the outer harbor. Water quality analyses reported in Chapter IV of this report indicate that no violations of the standards are expected outside the immediate vicinity of the outfall. Occasional violations of the chronic toxicity standard for ammonia may occur within or near the mixing zone of the Jones Island plant. The acute toxicity standards would not be violated.

With regard to the abatement of pollution from combined and sanitary sewer overflows, the recommended water quality management plan element includes the provision of facilities to abate combined sewer overflows at a 0.7-year level of protection and the abatement—virtual elimination—of pollutant discharges from all separate sanitary sewer flow relief devices within the tributary watersheds. The abatement of pollutant discharges from combined and separate sanitary sewers is interrelated in the Milwaukee metropolitan sewerage system. During wet-weather periods, overflows of combined stormwater runoff and raw sanitary sewage occur at 109 outfalls within the combined sewer service area. These overflows occur on an average of 50 times each year. In addition, discharges of raw sanitary sewage may occur at approximately 470 bypasses, or relief pumping facilities, that have been constructed in the separate sewerage system to relieve surcharging of the separate sanitary sewers and attendant basement flooding.

The recommended water quality management plan element includes the abatement of combined sewer overflows by the measures recommended in the Regional Planning Commission's Milwaukee River watershed plan, adopted in 1972, and areawide water quality management plan, adopted in 1979, as those recommendations were subsequently refined and detailed in the facility planning efforts conducted by the Milwaukee Metropolitan Sewerage District. In the preparation of the system and facility plans, a wide range of alternatives for the abatement of combined sewer overflows was considered. These alternatives included, among others, the provision of centralized tunnel storage, decentralized near-surface storage, treatment at outfalls, sewer separation, and various combinations of these measures. The adopted plans recommended that a deep tunnel inline storage system be constructed in conjunction with a shallow relief sewer system to abate excessive infiltration and inflow problems in the separately sewered area and to help relieve the metropolitan interceptor sewer system during wet weather, as well as to provide storage for combined sewer overflows. The level of protection to be provided by this system was not finally determined in the District facility plan, but rather was left to be determined as part of the Milwaukee Harbor estuary study.

One function of the inline storage system is the temporary storage of combined sewer overflows until the Jones Island or South Shore sewage treatment plants can accept and treat the wastewater. As initially designed and based upon a size needed to convey and store flows from the separately sewered areas, the tunnels comprising the inline storage system will also provide for the storage of combined sewer overflows at an approximately 0.7-year level of protection. If additional storage capacity would be required for the overflows in order to meet water quality objectives for the Milwaukee Harbor estuary, the deep tunnel inline storage and conveyance capacities would need to be increased by excavating additional storage capacity.

Approximately 1,140 acre-feet of storage is to be provided for combined sewer overflows and excessive flows from the separately sewered area. As a part of the study, a mathematical flow control and storage routing simulation model was used to estimate the volume, duration, and frequency of overflows which may be expected to occur after the storage facilities are constructed. The simulation model applications used rainfall records from 1940 through 1979. That 40-year period included a rainfall event which was estimated to have an 80-year recurrence interval—and which was considered to approximate a 100-year recurrence interval event. The modeling indicated that overflows may be expected to occur on the average of once every 0.7 year. The minimum, mean, and maximum volumes of overflows occurring over this 40-year period would be 4 and 832 and 4,313 acre-feet, respectively. The mean duration of an overflow would be about 12 hours. About 51 percent of the overflows may be expected to occur during the summer months of June, July, and August; about 24 percent during the spring months of March, April, and May; about 18 percent during the fall months of September, October, and November; and about 7 percent during the winter months of December, January, and February. Even during major storm events, the initial runoff, which may be expected to contain the highest concentrations of pollutants, would be captured before the system overflowed. The overflow would be discharged through the existing combined sewer outfalls.

With the initially designed inline storage system, approximately 97 percent of the combined sewer pollutant loadings would be captured and treated at the District's sewage treatment facilities. As reported in detail in Chapter IV, evaluations were made, including water quality simulation analyses, of the water quality impacts of totally eliminating the pollutant loadings discharged from combined sewer overflows. The analyses indicated no significant improvement in overall water quality when compared to the alternative of providing a 0.7-year level of protection as recommended. The potential improvements resulting from total abatement related only to water quality impacts during the overflow events which are expected to occur about once every eight months. The contribution of organic material to the sediments during these occasional overflow events was not deemed significant enough under future conditions to impact water quality conditions during low-flow periods, when the sediment-related dissolved oxygen problems are potentially the most severe.

Within the tributary watershed areas of the Milwaukee Harbor estuary outside the area served by the Milwaukee metropolitan sewerage system, there are no combined sewer systems. Furthermore, the virtual elimination of discharges from the separate sanitary sewerage system was recommended in the adopted areawide water quality management plan in order to achieve the desired water use objective for the receiving waters upstream of the estuary. Elimination of the flow-relief devices would be accomplished by expansion of wastewater treatment plants, construction of new trunk sewers, and other sewerage system improvements. Emergency bypass structures will need to be retained to protect sewerage facilities and prevent basement flooding in the event of power outage or equipment failure. These bypasses, however, would be used only in extreme emergencies, and therefore very infrequently. This recommendation of the areawide plan remains unchanged, and no costs have been included in the plan for separate sanitary sewer overflow pollution abatement outside the area served by the Milwaukee metropolitan sewerage system.

Nonpoint Source Pollution Abatement Plan Subelement

The nonpoint source pollution abatement plan subelement provides for implementation measures in both the rural and urban areas of the tributary watershed areas. With regard to rural nonpoint source pollution abatement measures, a level approximating 50 percent of the maximum achievable level is recommended. Such a program would include application of control measures to both livestock waste and agricultural land runoff, as summarized in Table 18 of Chapter IV. This program would provide for the treatment of about 15 percent of the rural land with selected land management practices, including conservation tillage, contour plowing and cropping, grassed waterways, terracing, diversions, and area stabilization systems, as well as a public participation program. In addition, livestock waste control measures would be provided for about 30 percent of the systems in the tributary watersheds. The areas and systems to be covered by practices would be selected based upon an assessment of the severity of the pollution sources and landowner willingness to participate in the program. Implementation of the recommended nonpoint source control practices may be expected to result in phosphorus loading reductions of approximately 30 percent and 15 percent, from livestock waste and agricultural land runoff, respectively.

With regard to nonpoint source pollution control in urban areas, it was concluded that only construction erosion control measures should be included in the recommended plan because of the modest costs entailed and the potential effectiveness in improving water quality within the Milwaukee Harbor estuary. As noted in Chapter IV, other urban nonpoint source control measures such as increased street sweeping, increased catch basin cleaning, stormwater storage, and stormwater infiltration systems were considered but not recommended for purposes of improving water quality conditions in the estuary. However, it was recognized that the ongoing nonpoint source planning work being conducted by the Wisconsin Department of Natural Resources (DNR) as part of the Milwaukee and Menomonee River Priority Watersheds Program may lead to determinations to implement additional urban nonpoint source pollution abatement measures to achieve desired water use objectives in receiving surface waters upstream of the estuary and in Lake Michigan. In this event, improvement of water quality conditions in the estuary would be a secondary benefit of such urban nonpoint controls.

In the case of both the urban and rural nonpoint source pollution abatement recommendations, it is further recommended that the detailed second level plans be completed as part of the Milwaukee and Menomonee River Priority Watersheds Program. The priority watersheds program would refine, and build upon, the abatement levels and measures recommended in the adopted systems level plans by identifying the cost-effective nonpoint source abatement measures needed to achieve water use objectives throughout the basin. In the case of the rural nonpoint source controls, the priority watersheds program can directly develop the abatement measures to be implemented, with assistance from the county land conservation committees and the U. S. Soil Conservation Service. In the urban areas, the most cost-effective nonpoint source control measures should be determined within the context of stormwater management system plans prepared as a part of the priority watershed planning process. These stormwater management system plans should address existing and probable future water quantity and quality problems. The plans should be based upon an integrated approach, considering drainage and flooding problems as well as nonpoint source pollution problems. Each plan would be designed to consider a logical subwatershed area and should evaluate alternative stormwater collection, conveyance, storage, diversion, and infiltration systems to help resolve flooding, drainage, and water pollution problems. In most cases, these plans would have to be prepared through intergovernmental planning efforts because of the need to recognize logical subwatershed boundaries, as shown on Map 32. These stormwater management system plans should serve as a basis for the design and implementation of stormwater management measures, including quality control measures. In cases where these subwatersheds are located in more than one community, it is recommended that the stormwater management plan be prepared *jointly* by the communities involved.

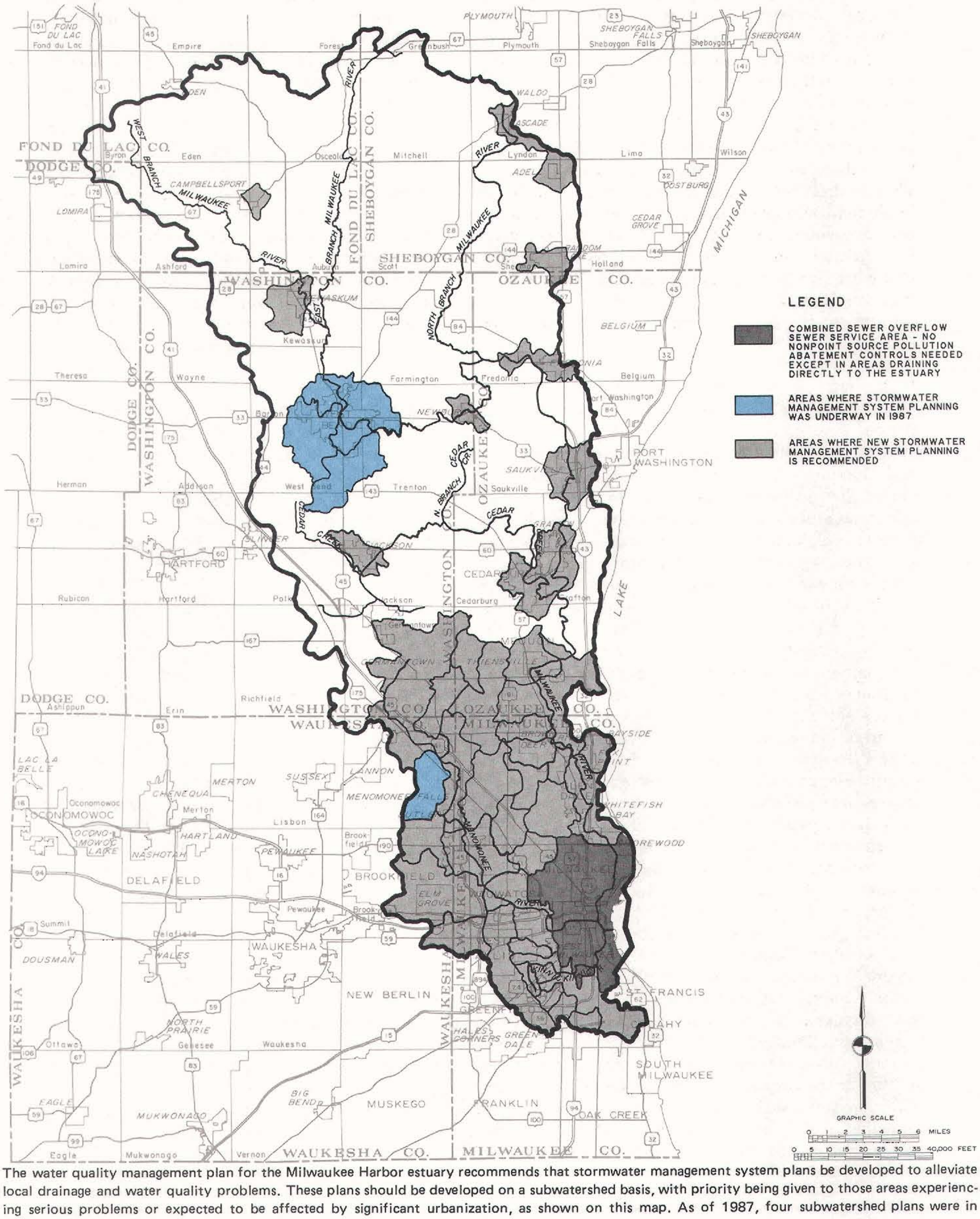
The recommendations set forth above for nonpoint source controls are also considered to be a refinement of the recommendations set forth in the areawide water quality management plan. In the case of the recommendations for rural areas, the recommendations included herein are essentially the same as those set forth in the earlier plan. In the case of the recommendations for urban areas, the findings of this study have concluded, based upon costs and effectiveness, that urban nonpoint source controls, other than construction erosion control, are not justified for purposes of achieving water use objectives in the Milwaukee Harbor estuary. However, since such controls may be determined to be needed and justified for other purposes such as improved water quality in the upstream reaches, or in Lake Michigan, it is not proposed to modify the recommendations of the areawide water quality management plan in this regard.

Instream Water Quality Measures Subelement

The instream water quality measures subelement includes provisions for continued operation of the existing flushing tunnels which discharge to the Milwaukee and Kinnickinnic River portions of the estuary and the installation and operation of an aeration system in the Menomonee River estuary. It is recommended that the existing flushing tunnels be operated at existing capacities—600 cfs for the Milwaukee River flushing tunnel, and 350 cfs for the Kinnickinnic River flushing tunnel—whenever it appears the instream dissolved oxygen standards for a warmwater fishery would be otherwise violated. The decision to operate the Milwaukee River flushing tunnel should be based in part on continuous water quality monitoring data collected by the Milwaukee Metropolitan Sewerage District for the Milwaukee River at St. Paul Avenue. The decision to operate the Kinnickinnic River flushing tunnel should be based in part on the continuous water quality monitoring data collected by the District for the Kinnickinnic River at S. 1st Street. The operation of the tunnels will require consideration of conditions throughout the estuary as well as at the selected control stations. This will require operational experiences and analyses of

Map 32

SUBWATERSHED LOCATIONS FOR STORMWATER MANAGEMENT PLANS



The water quality management plan for the Milwaukee Harbor estuary recommends that stormwater management system plans be developed to alleviate local drainage and water quality problems. These plans should be developed on a subwatershed basis, with priority being given to those areas experiencing serious problems or expected to be affected by significant urbanization, as shown on this map. As of 1987, four subwatershed plans were in preparation.

Source: SEWRPC.

the data which have been collected under this study and have continued to be collected by the Milwaukee Metropolitan Sewerage District. Based on projected dissolved oxygen levels, to meet the herein recommended water use objectives and standards it is estimated that the flushing tunnels would need to be operated 60 percent of the days and 40 percent of the time from May through September, or about 1,500 hours per year. This operational period estimate, which is higher than the estimate included in Chapter IV of this report, was based upon a reevaluation of the modeling and sample data. The more detailed evaluation estimated the tunnel operation times based upon the occurrence of dissolved oxygen deficits at any of the stations in each of the two reaches of the estuary concerned. The previous estimates were based upon deficits at a single station on each river. In order to achieve the existing Wisconsin Department of Natural Resources dissolved oxygen standard associated with the recommended objective for the maintenance of a warmwater fishery—a minimum of 5 milligrams per liter (mg/l) at all times—the tunnels would need to be operated about 70 percent of the days and 45 percent of the time from May through September, or about 1,700 hours per year.

To increase the dissolved oxygen levels in the Menomonee River estuary, it is recommended that four 25-horsepower mechanical aerators be placed in the Menomonee River. One aerator would be located at the Soo Line—former Chicago, Milwaukee, St. Paul & Pacific Railroad Company—bridge, located just upstream of S. 25th Street; one aerator would be located at the S. 25th Street bridge; and two aerators would be located at the N. 16th Street bridge. The aerators would be operated whenever the instream dissolved oxygen standards for a warmwater fishery would be otherwise violated. The decision to operate the aerators should be based, in part, upon the continuous water quality monitoring data collected by the District for the Menomonee River at Muskego Avenue. With an assumed design oxygen transfer efficiency of two pounds of dissolved oxygen per horsepower-hour, the aerators would be capable of providing up to 180 pounds of dissolved oxygen per hour of operation. In order to achieve the herein-recommended water quality standards, it is estimated that all aerators would be operated for 2,000 hours per year. To achieve the existing Wisconsin Department of Natural Resources dissolved oxygen standard for the maintenance of a warmwater fishery of a minimum of 5 mg/l at all times, the aerators would be operated for approximately 2,200 hours per year.

For cost purposes in this study, it was assumed that low-speed surface aerators would be utilized. However, prior to implementation of this proposal, it is recommended that in the required facility planning phase, the options of a pure oxygen diffusion system and of other types of surface aerators be reevaluated.

The instream water quality improvement measures subelement does not include recommendations for removal of sediments, or other measures to reduce the in-place pollutants in the sediments. The analyses conducted as part of the Milwaukee Harbor estuary study concluded that, with respect to conventional pollutants, there was no need to dredge the bottom sediments for water quality management. That possibility had been raised in the District water pollution abatement facility planning program. It had been hypothesized that sediment oxygen demand was causing severe problems due to scour at the outfalls during wet-weather periods. However, the analyses made under the Milwaukee Harbor estuary study concluded that the wet-weather depletions which occasionally occur were attributed to other phenomena, including the inhibition of photosynthetic oxygen production by algae. This study also concluded that while sediment oxygen demand was the primary cause of dissolved oxygen depletions under low-flow, dry-weather conditions, once the combined sewer overflows are abated, the bottom sediments may be expected to decompose and stabilize within a two-year period. Thus dredging of the bottom sediments in the inner harbor would not significantly increase the dissolved oxygen levels in the inner harbor following abatement of combined sewer overflows. Low dissolved oxygen levels do not occur in the outer harbor.

In addition to considering conventional pollutants, the Milwaukee Harbor estuary study considered the water quality and sediment problems associated with toxic substances. Analyses were conducted of the potential release of 83 toxic organic substances from the sediments to the interstitial water. That analysis indicated that 11 substances could potentially violate the established criteria. In this regard, it should be noted that these criteria are presently undergoing review by the State and the U. S. Environmental Protection Agency (EPA). Furthermore, once the combined sewer overflows are abated, the loading of toxic organic substances on the estuary should be substantially reduced, and the bottom sediments should be covered by cleaner sediments. However, as the organic carbon content of the bottom sediments declines as the sediments decompose and stabilize, a greater portion of the sediment-adsorbed toxic organic substances may be released to the interstitial water. It should be noted that some of these toxic substances may also be decomposed over time, albeit at rates much slower than the rate of decomposition of carbonaceous organic matter. Because of these complex interactions, it cannot be determined at this time whether it will be necessary to dredge, or otherwise modify, the bottom sediments to abate the toxic effects on benthic organisms which reside in the sediments, or on their predators. This issue is addressed further in the section of the chapter describing the toxics management element of the plan.

The instream water quality measures set forth in this section represent a logical extension of the areawide water quality management plan since specific measures designed to achieve water use objectives in the Milwaukee estuary were not included in that earlier plan.

Auxiliary Water Quality
Management Plan Subelement

The following recommendations relate to additional actions which should be undertaken to help ensure the achievement of water use objectives in the Milwaukee Harbor estuary under the recommended water quality management plan. These additional recommendations address the issues of runoff from salt and scrap metal storage yards, and water quality, sediment, and biological monitoring.

Materials Storage Yard Runoff: Measures should be taken to prevent contamination of surface water with stormwater runoff from scrap metal, salt, and other material storage sites located within the direct drainage area. Alternative methods of controlling the stormwater runoff from these areas may include providing modified stormwater drainage systems which eliminate or reduce the volume of water which contacts the storage areas; stormwater treatment by sedimentation or infiltration; removal of the stored material; covering of the operations to eliminate contact with stormwater; or connection of the drainage system serving the area to the combined sewer system. This latter option could require the installation of new stormwater drainage facilities, as well as modification of existing facilities. In some cases, the viable means for reducing stormwater pollutant discharges are limited in that certain storage operations are dependent on being located adjacent to shipping channels, thus eliminating the potential for moving the operations to remote locations. In other cases, the operations require the use of high cranes, making covering of the operations impractical. In all cases, it is recommended that the best alternatives be developed for each area determined to need modification by conducting a detailed second level plan to be conducted as part of the Wisconsin Department of Natural Resources Priority Watersheds Program in cooperation with the affected landowners and facility operators.

Water Quality, Sediment, and Biological Monitoring: The above-recommended plan components should provide substantially improved water quality conditions within the Milwaukee Harbor estuary. It is also important that a sound program for continuing water quality monitoring be established to document the extent to which desired water use objectives are being met over time. The intent of the monitoring program would be to analyze the achievement of the water quality standards supporting the recommended water use objectives, as well as the potential to raise those objectives; to help characterize any long-term trends in water quality conditions; and to demonstrate the specific benefits of the recommended operation of the existing flushing tunnels and proposed instream aerators.

It is recommended that the baseline water quality sampling program which was conducted by the Milwaukee Metropolitan Sewerage District from 1981 through 1984 be continued in order to monitor the impacts of the recommended plan on the Milwaukee Harbor estuary. This water quality sampling program should be coordinated with similar sampling programs which may be developed to assess the water quality conditions of surface waterways upstream of the estuary, and to evaluate the impacts of discharges from the District's sewage treatment plants on the outer harbor and Lake Michigan. The sampling should be conducted at three upstream river stations, nine inner harbor stations, and four outer harbor stations as listed in Table 46 of Chapter IV, and shown on Map 31. The sampling should be conducted on a monthly basis from October through April—except when precluded by ice conditions—and on a weekly basis from May through September. All samples should be analyzed for temperature, pH, dissolved oxygen, fecal coliform organisms, total solids, total suspended solids, volatile suspended solids, total phosphorus, soluble phosphorus, ammonia nitrogen, 5-day biochemical oxygen demand, chlorophyll-a, cadmium, copper, lead, and zinc. Both acid-soluble and total concentrations of the metals should be measured. Mid-depth water samples should be collected at the upstream stations; and surface, mid-depth, and bottom water samples should be collected at the inner harbor and outer harbor stations.

In addition to the above continuing monitoring program, it is recommended that a more intensive monitoring program be conducted at five-year intervals. This more intensive program should consist of sampling on a weekly basis, for a one-year period, all 34 baseline sampling stations listed in Chapter IV of Volume One of this report. These samples should be analyzed for all of the water quality and biological indicators listed for the baseline sampling program in Chapter IV. In addition, it is recommended that the bottom sediments be sampled at five-year intervals. Sediment core samples should be collected at the eight inner harbor stations and the two outer harbor stations listed in Table 47 of Chapter IV and shown on Map 13. All sediment core samples should be analyzed for total solids, total volatile solids, total organic carbon, chemical oxygen demand, total Kjeldahl nitrogen, ammonia nitrogen, total phosphorus, lead, zinc, copper, cadmium, and polychlorinated biphenyls (PCB's).

In addition to the water quality monitoring recommendations set forth above, it is recommended that a biological monitoring program be conducted at five-year intervals. This program would consist of the conduct of a fishery survey and an inventory of the other biota, including benthic invertebrates, zooplankton, and algae; and a review of the habitat characteristics existing within the estuary, including stream bank vegetation, bottom scouring and deposition, and bottom substrate. These surveys should be conducted at locations similar to those used in the biological survey described in Chapters IV and VI of Volume One of this report. Habitat evaluation should be conducted throughout the estuary.

It is further recommended that the findings of the monitoring program be set forth in reports prepared on an annual basis by the agencies responsible for the data collection. At a minimum, it is recommended that the monitoring data be made available to agencies involved in plan implementation in a form that is readily usable. The agencies may desire to prepare summary data suitable for public presentation.

The recommendations for monitoring set forth herein may have to be expanded in order to consider toxic organic pollutants. Such additional monitoring recommendations will be developed as part of toxic substances management studies as described in the toxic substances management element section of this chapter.

DREDGING AND DREDGED MATERIALS DISPOSAL PLAN ELEMENT

In order to develop a dredging and dredged material disposal plan, information was collected under the study on the characteristics of the existing channels and of the sediments underlying those channels. In addition, information regarding historical maintenance and new construction dredging activities was collected and analyzed in conjunction with estimates of historical and probable future sedimentation rates following implementation of the water quality management element of this plan. The findings of these inventories and analyses were reported in Chapter V of this volume.

Dredging and the disposal of the dredged materials is presently carried out within the Milwaukee Harbor estuary only for maintenance of adequate water depths for commercial navigation, and for very limited construction of new port facilities. Dredged materials are presently disposed of at the confined disposal facility constructed by the U. S. Army Corps of Engineers in 1975 along the shoreline of the southern portion of the outer harbor, as shown on Map 33. That facility covers about 53 acres and has a capacity of about 1.6 million cubic yards—sufficient to contain the amount of material anticipated to be dredged from the Milwaukee Harbor until at least 1993.

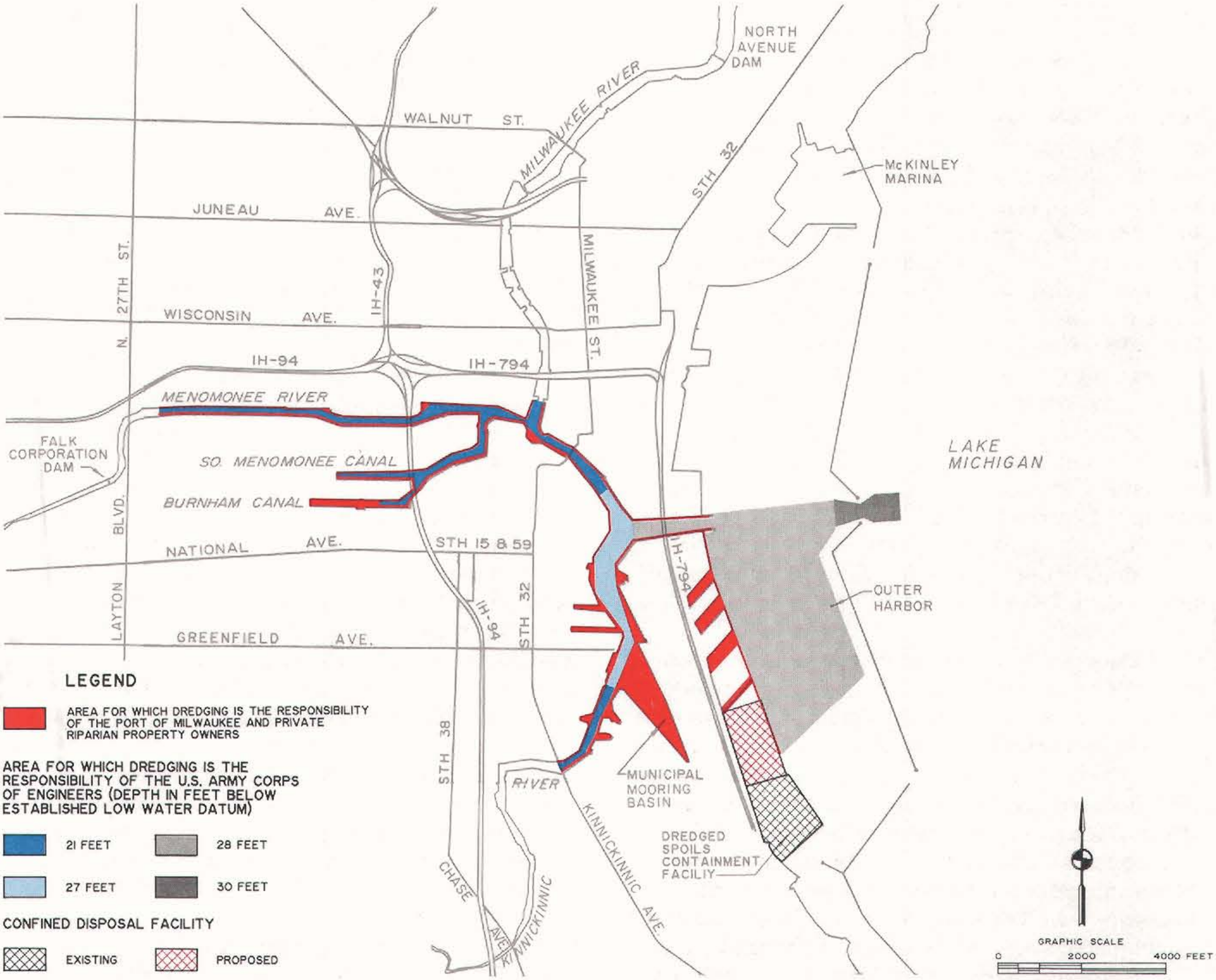
This section of the report describes the recommended dredging and dredged material disposal plan element. Included is a discussion of the four subelements of this plan element: a dredging needs subelement; a dredging methods subelement; a dredged material processing and transportation subelement; and a dredged material disposal subelement. The recommended dredging and dredged material disposal plan is summarized graphically on Map 33.

Dredging Needs Subelement

The need for dredging in the Milwaukee Harbor estuary is determined primarily by the need to maintain commercial navigation. That need may, however, also be determined by the need for the construction of new port facilities; the need to provide for water quality improvement by reducing the impacts of polluted sediment on the water

Map 33

RECOMMENDED DREDGING AND DREDGED MATERIAL DISPOSAL PLAN ELEMENT OF THE MILWAUKEE HARBOR ESTUARY PLAN



The recommended dredging and dredged materials disposal plan for the Milwaukee Harbor estuary includes the continued dredging and disposal of dredged materials within project limits established by the U. S. Army Corps of Engineers to maintain commercial navigation; the provision of a gravity dewatering system to increase the solids content of the dredged spoils; the continued filling of the existing confined disposal facility in the outer harbor; and the construction of a new, 1.4-million-cubic-yard disposal facility just north of the existing facility for use after the existing facility is filled by about 1993. The study indicated that widespread dredging to improve dissolved oxygen conditions or improve aquatic habitat conditions is not needed.

Source: SEWRPC.

column and on the flora and fauna of the area; and the need to improve aquatic habitat. Each of these potential needs was carefully considered in this study.

Materials deposited by sedimentation in the inner harbor and outer harbor, if not removed by dredging, become a hindrance to commercial navigation and related activities in the Port of Milwaukee. Commercial vessels cannot operate at full capacity —or in extreme cases, at all—if shallower waters that are the result of sediment accumulation in the channels, mooring basin, and outer harbor must be negotiated. In order to accommodate the draft of large lake- and sea-going commercial vessels, the channels of the St. Lawrence Seaway are intended to be uniformly constructed and maintained at 27 feet below established low water datum. Since the viability of the Port of Milwaukee and industries along portions of the estuary depend, in part, upon the economical operation of such lake- and sea-going vessels, the Milwaukee Harbor estuary should be maintained at similar depths. The extent of the dredging recommended for navigation maintenance is shown on Map 33, which also shows the depths to be maintained by dredging.

For maintenance of navigation, about 115,000 cubic yards per year of dredged spoils, measured in place, should be removed from the Milwaukee Harbor estuary under existing conditions. Once the combined sewer overflow pollution abatement measures described in the previous section are implemented, the sedimentation rates may be expected to be significantly reduced, and the dredging need for navigation will be reduced to an average of 65,000 cubic yards per year, an almost 50 percent reduction.

No substantial additional dredging for new construction work is presently envisioned in the Milwaukee Harbor estuary. Should projects develop requiring such work, additional dredged materials will be generated. However, such quantities would likely be limited and would have a minimal effect on the recommended dredging methods and dredged material disposal facilities.

Dredging for water quality improvement is not recommended at this time. It was determined in the study that little water quality improvement with respect to conventional pollutants may be expected to be achieved by sediment removal. The sediments presently are the primary cause of dissolved oxygen depletion under low-flow, dry-weather conditions. However, it was found through specially designed laboratory analyses conducted under the estuary study that once the combined sewer overflows are abated, the bottom sediments may be expected to decompose and stabilize relatively quickly—within a period of approximately two years. Thus, dredging of the bottom sediments would not significantly increase dissolved oxygen levels in the water column. Furthermore, the analysis indicated that the short-term, wet-weather dissolved oxygen depletion problems that do occasionally occur are not being caused by sediment oxygen demand resulting from scour of sediment—as once believed—but rather are the result of other phenomena, including, particularly, the inibition of algal photosynthetic oxygen production as a result of turbid conditions.

Analyses were also conducted of the potential sediment and related water quality problems associated with toxic substances. Those analyses are described in Chapter V, and because of the relationship to water quality, were also discussed in the previous section of this chapter. The analyses indicated that some toxic substances may be adversely affecting benthic organisms within the sediments. In particular, the analyses indicated that the criteria for 11 toxic organic substances may be exceeded within the sediment interstitial waters, namely: chlordane, dichloromethane, endrin, gamma-BHC, neptachlor, naphthalene, polychlorinated biphenyls (four forms of PCB's), and phenols. The analyses further indicated that the concentrations of 44 toxic substances within the interstitial water would not exceed the chronic and acute standards. Another seven pollutants were found to be borderline cases where the future fluctuations in the bottom sediment organic carbon content could result in problems. These pollutants are acenaphene, dichloro-diphenyl dichloro-ethane (DDD), dichloro-diphenyl-trichloro-ethane (DDT), dieldrin, floranthene, toluene, and one form of PCB. Complete analyses of toxic metal concentrations within the interstitial water were not possible, since the procedures necessary to make those calculations are presently being developed by the U. S. Environmental Protection Agency. Accordingly, the analytic procedures required probably could not be undertaken for some time. In view of these findings, it is recommended that the toxic effects of pollutants in the sediments be considered in a subsequent study. This issue is addressed further in a section of this chapter describing the toxic substances management element of the plan.

Another consideration regarding dredging is the need to improve aquatic habitat within the estuary. Detailed inventories of the existing habitat were conducted as part of this study, and the findings documented in Chapter VI of Volume One of this report. Review of the existing conditions indicates that no widespread dredging should be undertaken to improve aquatic habitat. This conclusion was reached because the inventories found that there are adequate localized areas within the inner harbor that provide suitable feeding, cover, and spawning habitats for warmwater fish and aquatic life, even though habitat conditions for a desirable fishery throughout most of the inner harbor are generally poor. For example, in the reach of the Milwaukee River from the North Avenue dam to N. Humboldt Avenue, there are numerous scoured areas with a substrate of rocks, sand, and hard clay. Inventory data indicate that many warmwater fish species, including walleye, smallmouth and largemouth bass, northern pike, bullhead, catfish, suckers, carp, and sunfish, currently spawn in this reach. Similarly, there are localized shallow areas in the upper ends of the Menomonee and Kinnickinnic River estuaries, as well as in the upper ends of the Burnham and South Menomonee Canals, that support rooted aquatic vegetation that is used for spawning by northern pike, yellow perch, carp, and sunfish. Many of the fish that spawn in the inner harbor migrate in from Lake Michigan during spring and summer. Furthermore, as the organic matter in the sediments decomposes once combined sewer overflows are abated, the organic content of the sediments may be expected to decrease substantially, and the existing sediments should, in time, be covered by cleaner sediments with less organic matter. Thus, existing localized areas providing habitat may be expected to be improved for the maintenance of a limited, yet diverse, population of warmwater fish within the inner harbor once combined sewer overflows are abated.

Within the outer harbor, the existing bottom sediments, although in some locations classified as heavily polluted, are known to be conducive to the successful propagation of diverse populations of warmwater fish and aquatic life.

It is possible that further site-specific analyses will indicate that it would be desirable to dredge or otherwise modify selected small areas within the estuary in order to improve habitat for aquatic life. However, it is recommended that such limited dredging be considered only if site-specific evaluation or findings support such a need. In this regard, consideration of such projects should include recognition that the duration and effectiveness of selected area dredging or other aquatic habitat management measures will be improved at such time as the combined sewer overflow discharges are abated as recommended in the water quality management plan element.

In view of the above, it is recommended that dredging be limited primarily to the areas and depths noted on Map 32. This will result in the removal of about 115,000 cubic yards of material per year up until the completion of the combined sewer overflow pollution abatement project in about 1996, with the quantity of materials requiring removal by dredging thereafter estimated to be 65,000 cubic yards per year.

Dredging Methods Subelement

Several types of dredges can be used, including mechanical dredges such as dragline, dipper, or clamshell dredges, or hydraulic dredges such as cutterhead and hopper dredges. The dredging method to be used depends on several factors, including access to the shoreline, shore characteristics, type of disposal site, water depth and depth of dredging, volume and type of materials to be removed, and equipment availability. Clamshell or dipper dredges will be typically used to dredge areas near boat slips or bulkhead walls because of their maneuverability. Both of these types of dredges, together with the hydraulic hopper dredge which is less mobile and would be more suitable for larger open areas, have been used in the Milwaukee Harbor estuary and are considered suitable methods of dredging. It is recommended that the type of equipment to be used be specified on a project-by-project basis by the sponsor of the project and the dredging contractor, as is the present practice. Such evaluation should consider the environmental impacts both during and immediately following the dredging. Negative water quality impacts associated with increases in turbidity, resuspension of contaminants, and decreases in dissolved oxygen should be minimized. This consideration will become even more important as the water quality of the estuary is improved. Thus, the length of the project period and time of year that dredging is to be carried out should be carefully evaluated in conjunction with the type of equipment to be used.

Dredged Material Processing and Transportation Subelement

The means of processing and transporting dredged material is dependent upon several factors, including the distance between the dredging operation and the disposal site, the quality and quantity of the material, and the types of dredging equipment and disposal facility to be used. With regard to processing, it is recommended that a gravity dewatering system be considered for use in conjunction with the existing and planned confined disposal facilities in order to increase sediment solids content and maximize the life of the facility. Because of the character of the existing confined disposal facility, it is recommended that dredged material mounding be used for dewatering to maximize the life of the existing and new confined disposal facilities. Solids mounding at the existing facility could be expected to increase the sediment content of dredge spoils to approximately 50 percent total solids.

Acceptable methods for transporting materials dredged from the Milwaukee Harbor estuary include pipeline and belt conveyor transport for shorter distances and truck and barge transportation for longer haul distances. The selection of the best transportation method is dependent on a number of factors, including haul distance, the quality and quantity of the material, and the type of dredging equipment to be used. It is recommended that the means of transporting the material be considered on a project-specific basis by the project sponsor and contractor.

Dredged Material Disposal Subelement

The dredged material disposal subelement provides for disposal of dredged material at the existing confined disposal facility until about 1993, and at a new confined disposal facility to be constructed in the outer harbor just north of, and adjacent to, the existing facility through the remainder of the plan period. The locations of these facilities are shown on Map 33.

As of 1986, the existing confined disposal facility had a remaining capacity of approximately 800,000 cubic yards of dredge spoils. Assuming an average annual dredge spoil quantity of 115,000 cubic yards, the existing facility should be filled by about 1993. During 1986, this facility was upgraded by reconstructing portions of the outer walls to provide for better filtering of the effluent leaving the facility. Portions of the facility filtering system were apparently not providing adequate treatment. It is further recommended that a new confined disposal facility be constructed in the outer harbor just north of the existing facility, as shown on Map 33. This facility would be designed with a site life of about 20 years, and would have a capacity of about 1,400,000 cubic yards of dredged material. It was assumed for costing purposes that this facility would be constructed using either a clay or synthetic liner to minimize the potential for leakage of partially filtered effluent.

SHORELINE STORM DAMAGE AND FLOOD PROTECTION ELEMENT

The problems associated with shoreline protection and flooding within the Milwaukee Harbor estuary can be grouped into the following four categories:

- Windstorm Damage in Anchorage Areas. Anchorage within the inner harbor is relatively safe for both smallcraft and larger vessels. Anchorage in the outer harbor of Milwaukee is relatively safe during ordinary Lake Michigan storm events. Larger storms, however, and particularly larger storms with winds from the northeast, can produce wave conditions in the outer harbor which can damage not only moored smallcraft but also larger commercial vessels berthed at municipal piers.

- Ice Damage in Anchorage Areas. Within the McKinley Marina anchorage area, the severe damage to piers is caused by the horizontal and vertical movement of winter ice cover and also by ice floes occurring during various combinations of storm waves, winds, and lake levels. Damage from ice became more severe as record high lake levels developed in 1985 and 1986. Should lake levels continue to rise, ice damage could become significantly more severe.

- Wind Storm and High Water Damage of Shoreland Facilities. Several shoreland facilities located behind the breakwater forming the outer harbor of Milwaukee sustain damage during storms. Damage from high water levels, particularly during storms, has become more frequent years as the number of damage-prone facilities has increased, and as the level of Lake Michigan at Milwaukee has risen to and above previous records for the 20th century.

- High Water Levels and Flooding within the Inner Harbor. The record high-water levels of 1985 and 1986 make reevaluation of the flood control and high water level recommendations of the comprehensive watershed plans for the Kinnickinnic, Menomonee, and Milwaukee River estuaries necessary.

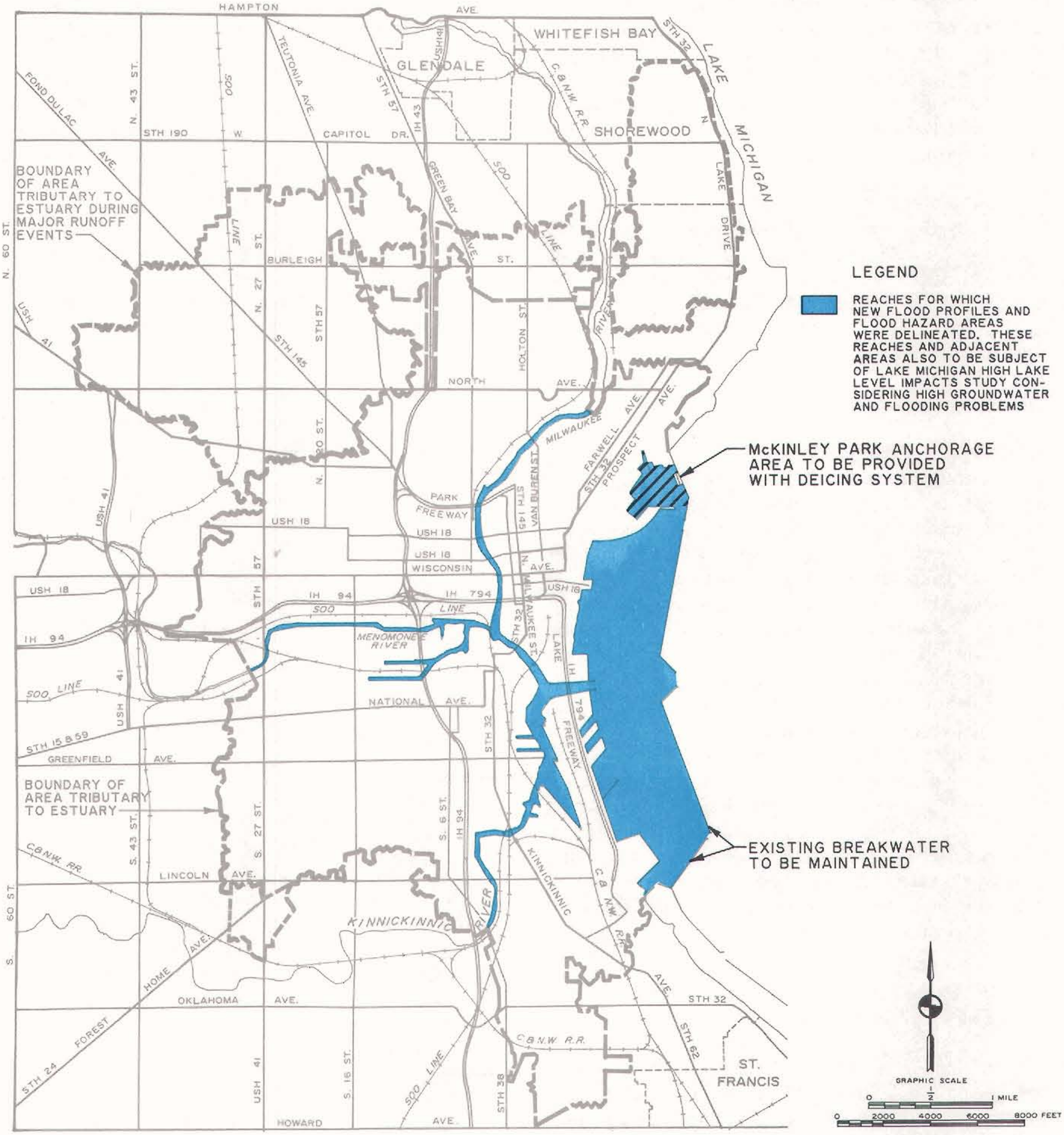
Each of these shoreline protection and flood problems and related design lake levels is addressed in the following section. Included in the discussion are four subelements of this plan element: a design lake level subelement; an anchorage area and shoreline facilities windstorm protection subelement; an ice control subelement; and an inner harbor high water and flood protection subelement. The recommended shoreline storm damage and flood protection plan element is shown in graphic summary form on Map 34.

Design Lake Level Subelement

The design lake level plan subelement sets forth recommendations regarding lake levels to be used

Map 34

RECOMMENDED SHORELINE DAMAGE AND FLOOD PROTECTION PLAN ELEMENT OF THE MILWAUKEE HARBOR ESTUARY PLAN



The recommended storm damage and flood protection plan includes the use by architects and engineers of new recommended regulatory flood elevations developed for Lake Michigan and the inner harbor under the study; the construction and repair of shore protection measures such as revetments, bulkheads, dock walls, and floodproofing; the installation of a diffused compressed air system in the McKinley anchorage area to prevent ice accumulation and associated damages; and the preparation of a contingency plan to address flooding and high groundwater problems related to high Lake Michigan water levels.

Source: SEWRPC.

in the design of public and private works along the Milwaukee Harbor estuary. The recommended design lake levels are based upon statistical analyses of recorded lake levels at Milwaukee, incorporating the most recent high lake levels and considering potential levels should Lake Michigan be in a long-term rising trend.

Essential to any consideration of anchorage, shoreline, and flood protection measures is information on lake levels as provided by analyses of historic data. Protective works should be designed to perform well under a range of water levels. Thus, in the design of protective works, performance should be considered under lake levels ranging from a low water level to the instantaneous maximum water level. The latter must be selected for a given recurrence interval based upon project-specific considerations. The former may be low water datum—elevation 578.1 feet National Geodetic Vertical Datum (NGVD)—which serves as a plane of reference to which navigation charts and project depths are referenced. The low water datum represents the level recorded in 1955. The minimum instantaneous level recorded elevation is 575.5 feet NGVD recorded on January 23, 1926.

Under the Milwaukee Harbor estuary study, it was determined that the 100-year recurrence interval mean annual level of Lake Michigan at the Milwaukee Harbor was 582.9 feet NGVD, while the 100-year recurrence interval maximum instantaneous, or flood, level—which would include the effects of seiche and wind setup during storms—was 584.5 feet NGVD. The latter level is 0.7 foot higher than the 100-year recurrence interval peak flood stage of 583.8 feet NGVD previously developed by the Commission as part of its comprehensive watershed planning programs completed in 1978, 1976, and 1971, respectively, for the Kinnickinnic, Menomonee, and Milwaukee River watersheds. The difference in the instantaneous peak flood stages is due primarily to the longer period of record available for the Milwaukee Harbor estuary analysis. It should be recognized that there is a measure of uncertainty inherent in the establishment of a 100-year recurrence interval stage for Lake Michigan. The period of record for the levels of Lake Michigan at Milwaukee is relatively short, and, as the period of record increases and additional data become available, the 100-year recurrence interval stage for Lake Michigan, determined through established statistical methods, may be expected to change somewhat. For this reason, it is important that flood stages for the Milwaukee Harbor estuary be periodically reexamined.

It is the opinion of some practitioners that in light of the relatively short period of record available, the selection of design high-water levels for new projects along the Lake and estuary should not be based solely on consideration of recorded water levels. In accordance with good engineering practice, the flood stages described above, and the related flood profiles along the three rivers concerned, are based upon statistical analysis of water levels in the Milwaukee Harbor as systematically recorded at Milwaukee since 1915.[1]

Geological evidence is believed by some to indicate that within the last 1,000 years, there have been at least two episodes in which Lake Michigan levels have exceeded the 1985 record high annual mean level of 582.0 feet NGVD—580.7 feet International Great Lakes Datum (IGLD)—by about four feet. These episodes of high water may have lasted for many decades, perhaps centuries. The interpretation and application of this evidence is complicated, however, by differential crustal movement within the Great Lakes Basin, and by man-made changes in the level of Lakes Michigan-Huron. Moreover, there is some archeological evidence to indicate that the level of Lakes Michigan-Huron have not changed appreciably since at least 1645.

Never-the-less, in addition to present-day lake level considerations, this chapter presents the findings of an analysis made of projected water levels, should Lake Michigan be in a long-term rising trend. This long-term rising trend water level analysis was conducted in order to provide additional information for consideration in the design of major public and private works along the harbor estuary. Designers considering major capital improvements can use this long-term data to evaluate the marginal cost of constructing facilities based upon a more conservative elevation. Analyses conducted under the study indicate that, if the lake is in a long-term rising trend, there is a 50 percent probability that by the year 2035 the lake level will be about 2.0 feet higher than the annual level of 582.0 feet NGVD recorded in 1985, and a 10 percent probability that it will be 4.0 feet higher. Therefore, 50 years hence, the corresponding annual mean elevations of the lake could be, respectively, 584.0 feet

[1] *Lake levels have been systematically recorded at Milwaukee since 1860; however, in order to be consistent with previous frequency analyses of the Corps of Engineers which covered the period 1915 through 1974 and for which data were adjusted to represent existing diversion and outlet conditions, the data from 1915 through 1985 were used in this updated study.*

NGVD and 586.0 feet NGVD; and the corresponding instantaneous peak elevations of the lake could be 585.9 feet NGVD and 587.9 feet NGVD, respectively.

Mathematical simulation computer modeling studies by the Great Lakes Environmental Research Laboratory tend to support the Regional Planning Commission conclusions, indicating that rises in Lake Michigan of from 2.0 to 3.5 feet over 1985 levels are possible under assumptions of increased water supplies to the lake, which vary from a continuation of 1985 water supply levels to water supply levels that are 50 percent greater than normal.

In view of these analyses, it is recommended that designers consider on a project-by-project basis a range of lake levels from 2.0 to 4.0 feet higher than 1985 levels, in addition to the recommended 100-year recurrence interval levels determined by statistical analyses of recorded historic lake levels at Milwaukee. The range of elevations recommended to be considered is set forth in Table 60. However, each designer must select the water levels which are appropriate for design of his particular project.

Table 60

100-YEAR RECURRENCE INTERVAL REGULATORY FLOOD STAGE AND FLOOD STAGES AT THE MILWAUKEE HARBOR ASSUMING A LONG-TERM RISING LAKE LEVEL TREND

Actual Lake Levels	
Mean Lake Level: 1900-1986	579.6 Feet NGVD
Annual Mean Lake Level: 1985	582.0 Feet NGVD
Annual Mean Lake Level: 1986	582.5 Feet NGVD
Instantaneous Maximum: 1985	583.7 Feet NGVD
Instantaneous Maximum: 1986	584.1 Feet NGVD
Recommended Regulatory 100-Year Recurrence Interval Instantaneous Maximum Stage	584.5 Feet NGVD
Flood Stages, Assuming that Lake Michigan is in a Long-Term Rising Trend[a]	
Instantaneous Maximum Level, Assuming a Two-Foot Increase in the Mean Lake Level over 1985[b]	585.9 Feet NGVD
Instantaneous Maximum Level, Assuming a Four-Foot Increase in the Mean Lake Level over 1985[b]	587.9 Feet NGVD

[a] *The stages attendant to a long-term rising trend lake level scenario are intended to be advisory to engineers and architects involved in project design and are not intended to be used for regulatory purposes.*

[b] *These stages are derived by adding the 2 or 4 feet rise to the annual mean levels for 1985 and then adding 1.9 feet to account for the difference between the annual mean level and the instantaneous maximum level. The 1.9 feet reflects the effects of seiche, wind set up, and seasonal variations.*

Source: National Ocean Service and SEWRPC.

Outer Harbor Anchorage Area and Shoreline Facilities Windstorm Protection Subelement

The anchorage area and shoreline facilities windstorm protection subelement includes recommended provisions for the increased protection of anchorage areas and shoreline facilities along the Milwaukee Harbor estuary. Potential damage due to waves and high water levels is a problem in anchorage areas and for shoreline facilities. The outer harbor of Milwaukee is formed by a 3.9-mile-long, shore-connected breakwater. During periods of high water, this structure provides a less than desirable level of protection to the anchorage area and shoreline facilities in its lee.

Anchorage in the inner harbor of Milwaukee is safe, but is limited because the area is relatively confined. Anchorage in the outer harbor is spatially adequate, but not as safe as may be desired. The McKinley anchorage area is better protected from the northeasterly winds than the facilities to the south, and damage to recreational crafts and harbor facilities is not a major problem during the boating season. Boats are removed during late fall, winter, and early spring when major storms from the northeasternly direction may occur.

As described in detail in Chapter VI, major storms generate large waves which overtop the breakwater with sufficient energy remaining to create hazardous conditions for smallcraft in the outer harbor south of McKinley Park. Larger commercial vessels can safely moor in the open water of the outer harbor during major storms, but berthing at the municipal piers during major storms can be hazardous. Storm waves moving nearly unimpeded through the main harbor entrance and the resulting standing waves at dock walls can tax mooring lines and can repeatedly push moored vessels into the pier walls, causing severe damage to both vessels and walls.

In addition to the anchorage problems, shoreline facilities are impacted by high water and waves. The large standing waves generated by storms from the northeast at the dock walls of the municipal piers have caused flooding of Jones Island. Crests of these waves can peak higher than the top of the dock walls. Strong onshore winds cause these waves to break over the top of the walls and into adjacent buildings. Portions of the Milwaukee Metropolitan Sewerage District Jones Island sewage treatment plant located east of the Daniel Webster Hoan Memorial Bridge are susceptible to such flooding. In addition to potential wave damage to the Jones Island facilities, flooding of portions of the McKinley Marina area, including the boat launch ramp, parking areas, and the Milwaukee Yacht Club building located at that site, has occurred. A portion of the Henry W. Maier festival grounds located just north of Polk Street extended is also subject to wave damage, as is the Milwaukee County War Memorial Center located at the foot of E. Mason Street.

Elevated groundwater levels may cause damage to the foundations of existing structures in the affected areas. While most such problems occur in the inner harbor, such a problem currently exists at the Milwaukee County War Memorial Center. The elevation of the water table beneath the building is almost the same as the level of Lake Michigan. The high groundwater levels have increased the hydrostatic pressure on the building foundation walls, threatening structural damage and flooding of basement storage areas.

The design height of the breakwater was set by the U. S. Army Corps of Engineers at a time when lake levels were relatively low and when little long-term water level data were available for use in determining a design lake level. At that time, wave characteristics were yet to be accurately and systematically measured so that a realistic design wave could be selected. Consequently, the existing breakwater height is presently inadequate, and may become even more so if Lake Michigan continues to rise. Therefore, analyses were conducted of the benefits and costs of modifying the breakwater both under existing lake level conditions and under a scenario whereby the lake levels would undergo a long-term rising trend. Under present lake levels, it was concluded that the damages to port facilities and shoreline structures are not extensive enough to justify further protection measures in that it is less expensive to repair the damages as they occur than to construct a higher breakwater.

In view of these considerations, it was recommended that the breakwater structure not be substantially modified at this time, but rather that facilities in the outer harbor be protected by the construction and repair of individual protection structures, including revetments, bulkheads, dockwall improvements, and other floodproofing measures.[2] If justified by cost analyses and consideration of other benefits, this could include the construction of offshore measures such as the island that has been proposed for recreational use and shore protection of the Henry W. Maier festival grounds.

It is further recommended that the lake levels continue to be monitored, and that contingency planning be initiated by the involved units of government to determine what actions should be taken if the lake level rise continues. That contingency planning should consider not only the potential construction of breakwater improvements to reduce wave-induced damage, but also the flooding conditions that could occur throughout the estuary area as a result of the higher lake levels.[3]

Ice Control Subelement

The ice control subelement includes recommendations for ice control in both the inner and outer harbors, The plan recommends no changes in the existing ice control system within the estuary except in the McKinley Park anchorage area. Below is a brief description of the existing system, and of the recommended new methods of ice control in the McKinley Park anchorage area.

Ice breaking in the Milwaukee Harbor is presently performed by the vessel Harbor Seagull, operated by the Port of Milwaukee. The Harbor Seagull is capable of breaking ice covers up to about eight inches thick. Ice thickness in the outer harbor seldom exceeds eight inches south of the McKinley Park anchorage area. Therefore, the Harbor Seagull is adequate to break ice as needed except in the McKinley anchorage area, where ice thickness frequently exceeds 24 inches. The Harbor Seagull has occasionally been used to break ice in the Milwaukee River estuary, north of its confluence with the Menomonee River, to allow release of snow which is dumped on the ice by the City of Milwaukee, and in the Kinnickinnic River estuary to assist fishing tugs during colder periods, when the ordinary daily traffic of the fishing tugs is not adequate to inhibit the formation of thick ice. Very little ice forms in the Menomonee River estuary owing to the large thermal load from the

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[2]*Following completion of the analyses leading to this recommendation, such projects were initiated, including the construction of wave-attenuating structures into the north wall of Municipal Slip No. 1 to help dampen wave impacts at Jones Island along that reach.*

[3]*In May 1987, at the request of the Milwaukee County Board of Supervisors, the Regional Planning Commission initiated the preparation of a prospectus to document the need for and feasibility of preparing a high lake level protection plan for the downtown Milwaukee area.*

valley power plant condenser cooling water effluent. For the same reason, the Milwaukee River estuary downstream of the Menomonee River generally is ice free in the navigation channel. A relatively thick ice cover can develop in the Kinnickinnic River estuary, however. The ships moored over the winter in the Turning Basin are allowed to "freeze in." The ice cover is used as a work platform for ship repair and painting, scaffolding being set up thereon. A number of marinas in the Kinnickinnic estuary provide dry-land winter storage for boats to protect them from ice damage. Therefore, there appears to be little need for additional measures to control ice in the Kinnickinnic estuary. Should lake levels rise over the long term above the 1986 levels, ice control problems in the Kinnickinnic, Menomonee, and Milwaukee River portions of the inner harbor and outer harbor should not substantially increase. Ice breakup, coupled with higher lake levels and associated storm waves, however, could become a more serious problem in the anchorage areas of the outer harbor.

There are three recreational boating facilities located within the McKinley Park anchorage area—the McKinley Marina, the Milwaukee Yacht Club, and the Milwaukee Community Sailing Center—providing a total of 719 boat slips. Significant damage, and in some years major damage, has occurred as a result of the movement of ice in the pier areas. Ice damage to the Marina and Yacht Club piers is caused by two phenomena. One is associated with the ice sheet which annually covers the entire 98-acre McKinley Park anchorage area, and the other is associated with the movement of ice floes following breakup. Ice cover in the McKinley Park anchorage area frequently exceeds 24 inches in thickness, whereas ice in the outer harbor to the south generally does not exceed six to eight inches in thickness. The thick cover in the McKinley anchorage area remains intact for most of the winter.

The thick ice sheet in the McKinley anchorage area also forms under the piers and around the pilings supporting the piers. Thermal expansion and contraction of the sheet with air temperature fluctuations can exert large horizontal loads on pier pilings. Gravity loads due to water level declines caused by seiching can also exert large vertical loads as ice hangs on the pilings unsupported from below. However, designs have taken these forces into account, and thus these phenomena generally do not cause significant damage at either the Marina or the Yacht Club. When lake levels are very high, however, the surface of the ice cover is very close to the bottoms of the piers. The seiche can lift the ice cover, which in turn can lift the piers off the pilings, causing extensive damage. Damage from ice became more severe as record high lake levels developed in 1985 and 1986. Should lake levels continue to rise, ice damage could become significantly more severe.

Another ice phenomenon causing damage in the McKinley anchorage area is the formation of ice collars. Ice collars have formed around pier pilings above the main ice sheet as water shoots up through the annular space around the round pilings from below the ice sheet, and then freezes on the pilings and on top of the main ice sheet. When lake levels are relatively high, the collar can form up to the bottom of the pier, and as that collar moves, it can damage the pier above. Ice rubble, formed around pilings as ice attached to the pilings breaks on a receding cycle of the seiche, can damage piers in a similar fashion.

The piers in the McKinley Marina constructed in 1987 have been placed with pier elevations at 586.6 feet NGVD, or about two feet higher than the previous system and about two feet above the recommended 100-year recurrence interval lake level. Thus, the problem of the ice cover being lifted, as well as the ice collar problem, should no longer be a major concern.

The most serious damage in the McKinley achorage area has been caused by ice floes. Ice floes form as the ice cover breaks up in late winter or early spring. If a large, late winter windstorm occurs, the ice cover in the anchorage area can be broken up early in the season. The resultant floating ice, sometimes more than two feet thick, may be much thicker than that associated with the normal spring breakup, which is affected by melting. The thick ice floes, driven by winds, currents, long swells, and seiche, can cause extensive damage to piers in both the Marina and the Yacht Club.

The recommended ice control system for the McKinley anchorage area provides for the installation of a diffused compressed air protection system, as shown on Map 34. The air diffuser system for the anchorage area, as initially designed at the systems planning level, would provide diffuser lines located about 150 feet apart and lying in parallel on the bottom. Six air blowers would be operated at the McKinley Marina, with operating rates ranging from 140 cubic feet per minute (cfm) to 520 cfm. One blower would be operated at the Milwaukee Yacht Club and would have a normal operating rate of 120 cfm. The total length of diffuser lines would be about 28,500 feet. Diffuser lines would be one- to two-inch-diameter PVC pipe, and would be laid out based on consideration of bathymetry, anchorage area geometry, and pier location. The cost analysis developed for this deicing system included consideration of the desirability of winter wet storage of boats in the slip areas.

As a first step in implementing this alternative, it is recommended that a pilot application of the diffused air system be constructed and operated over a few winters. The results of such a test would provide information for detailed design and construction. One phase of the pilot operation could involve modifying the existing air diffusion system in the North Marina. Concurrently, it is recommended that a pilot system also be operated in the central anchorage area.

Inner Harbor High Water and Flood Protection Subelement

The inner harbor high water and flood protection subelement includes the provision of newly developed flood stages and profiles for the estuary portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers and recommendations to resolve the high-water and flooding problems in the inner harbor area.

As already noted, a new 100-year recurrence interval stage of Lake Michigan at the Milwaukee Harbor was determined under the study, that stage being 584.5 feet NGVD. That stage is 0.7 foot higher than the 100-year recurrence interval stage of 583.8 feet NGVD developed by the Commission as part of its comprehensive watershed planning programs completed in 1978, 1976, and 1971, respectively, for the Kinnickinnic, Menomonee, and Milwaukee River watersheds. The difference in flood stages is due primarily to the longer period of record available for the Milwaukee Harbor estuary analysis. Because flood stages in portions of the Milwaukee Harbor estuary are directly related to Lake Michigan water levels, it was necessary to revise the 100-year recurrence interval flood stages and profiles for the estuary portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers. The previously established 100-year recurrence interval stages were developed based upon a Lake Michigan flood stage of 583.8 feet NGVD. The location and extent of the 100-year recurrence interval flood hazard area along the harbor estuary attendant to the revised flood stages are set forth on Maps B-1, B-2, B-3, and B-4 in Appendix B. The flood stage profiles are shown in Figures B-1, B-2, and B-3 of Appendix B.

Flood stages, river profiles, and areas of inundation were also developed for the Milwaukee Harbor estuary to show the range of flood levels that could occur, and the potential areas of inundation, should Lake Michigan be in a long-term rising trend—as has been hypothesized by some hydrologists, geologists, and climatologists. Data are provided in Chapter VI for a range of conditions that could result from a 2.0-foot and a 4.0-foot rise in Lake Michigan over 1985 conditions. Those levels were determined to have a 50 percent and 10 percent chance of occurring in 50 years if the lake is in a long-term rising trend. These elevations and/or inundation areas are intended to be advisory to engineers and architects involved in project design and are not intended to be used for regulatory purposes. Consequently, the advisory levels are higher than the regulatory level indicated, which is based upon a statistical analysis of the lake level data systematically collected at Milwaukee over the period 1915 through 1985. Each individual designer can ultilize the data to determine what lake levels should be used in the design of a particular project.

The flood hazard area mapping completed under this study indicates that the revised 100-year recurrence interval flood hazard area along the Kinnickinnic, Menomonee, and Milwaukee Rivers within the direct drainage area of the Milwaukee Harbor estuary encompasses about 211 acres. About 168 structures are located wholly or partly within the flood hazard area.

It should be noted that in addition to the structures lying within the flood hazard area, many additional structures may be adversely affected by elevated groundwater levels. In this regard, the City of Milwaukee has estimated that more than 1,300 properties are so situated as to be potentially affected by high water—either overland flooding or elevated groundwater—during a flood event under conditions where the level of Lake Michigan is 2.0 feet above the 1985 levels.[4] Elevated groundwater

[4] *These properties consist of those lands along the estuary that are located less than nine feet above the flood stages hypothesized under a long-term rising lake level scenario, resulting in a Lake Michigan water level that is 2.0 feet higher than 1985 levels. As shown in Table 60, this results in an instantaneous maximum level of 585.9 feet NGVD. Nine feet was selected in order to take into account potential groundwater and sewer backup problems for buildings with basements nine feet below ground level when surface waters are at the hypothesized flood stages.*

levels contribute to increased infiltration of clear water into basements, into the combined sewer system, and potentially into other underground utility systems, including electric power supply and telephone facilities, and the tunnels through which the Wisconsin Electric Power Company provides steam for space-heating purposes to major commercial structures in the Milwaukee central business district.

The overland flooding problems that are expected to occur during a 100-year recurrence interval flood event using the proposed new regulatory stage of 584.5 feet NGVD, if considered in and of themselves within the inner harbor areas of the Milwaukee Harbor estuary, could best be resolved by floodproofing individual or selected areas. This is due to the scattered location of the problems and the relative shallowness of the flooding. These protection measures would be designed on a site-specific basis considering the facilities to be protected and the available options. However, the related groundwater problems are much more difficult to resolve and will require further, more detailed studies, as will the contingency planning for considering the potential for even higher lake levels. In view of this, it is recommended that a more detailed study of the problems be undertaken. That study would address the high lake level impacts, including flooding and high groundwater-related problems. Consideration would be given to the impacts on utilities, including the Jones Island sewage treatment plant and the combined and separate sewer system, transportation facilities including city streets and bridges, and port facilities. A Southeastern Wisconsin Regional Planning Commission report entitled Milwaukee High Lake Level Impacts Study Prospectus, published late in 1987, sets forth the need for such a study, the organization for the study, and the scope and content of, and cost of, such a study.

Each of the elements in this more detailed study would involve data collection and analysis leading to an assessment of the potential impacts of a range of high Lake Michigan water levels. To the extent practicable, that assessment would distinguish between short-term impacts attendant to episodic high water levels—for example, flooding resulting from Lake Michigan storm surges—and long-term impacts attendant to prolonged periods of high water. Based upon the findings of that assessment, contingency measures intended to mitigate adverse high lake level impacts would be identified under each plan element. Implementation of those measures would be tied to the lake reaching various threshold levels.

TOXIC SUBSTANCES MANAGEMENT PLAN ELEMENT

As reported in Chapter VI of Volume One, and in Chapters IV and V of this volume, the bottom sediments of the Milwaukee Harbor estuary were found to be polluted with certain toxic metals and organic substances at levels which exceed standards. Furthermore, fish captured in the estuary were found to contain detectable levels of 14 toxic materials. A fish consumption limitation advisory is now in place for fish from the estuary owing to PCB contamination. Accordingly, the water quality management element and the dredging and dredged material disposal element of the recommended plan, as described earlier in this chapter, both include a recommendation that the pollution of the bottom sediments by toxic substances be further studied. This study should address the following topics: in-place sediment and water quality standards relating to toxic substances; the presence and the release of toxic substances in the sediments to the water column and biota; the sources of the toxic substances present in the sediments; and necessary corrective measures.

Contaminated sediments represent a potential residual source of toxic substances within the Milwaukee Harbor estuary. The magnitude of this source, the effects on the environment, and the attainment of water use objectives need to be further assessed. Any abatement measures which should be undertaken to permit the water use objectives to be more fully achieved can then be identified. The adsorptive capacity of sediment for insoluble and hydrophobic compounds is well known. As these contaminated sediments are redistributed by physical processes, spatial differences occur in the areal distribution and depth of the polluted sediments, as well as in the concentrations of toxic substances in the sediments. Under certain conditions, the toxic substances may be released to the overlying water column and to benthic biota and the associated food chain. In addition, the estuary may continue to be a source of contaminants to Lake Michigan itself, as fine-grained sediments are washed into the lake.

The need for further evaluation of the problem of toxic substances is demonstrated by the inventory findings and the analyses conducted under the Milwaukee Harbor estuary study. These findings were described in Chapter VI of Volume One and in Chapters IV and VI of this volume, and are briefly summarized under three categories below.

- Fish Tissue Sampling—Concentrations of toxic organic substances and metals in the tissue of fish caught in the inner and outer harbors were measured. Fourteen toxic substances, including four metals and 10 organic substances, as shown in Table 61, were found in the tissue of fish. With respect to human health, the greatest known hazard is related to the consumption of fish containing excessive levels of polychlorinated biphenyls (PCB's). In most cases, the fish tissue concentrations of PCB's exceed the U. S. Food and Drug Administration standard of 2.0 parts per million. In light of this finding, the DNR has issued a health advisory for persons consuming fish from the Milwaukee, Menomonee, and Kinnickinnic River estuaries, and the outer harbor. A similar advisory is in effect for Lake Michigan. As shown in Table 62, in general, PCB concentrations were highest in the tissue of fish taken from the Milwaukee River estuary, followed by the concentrations in the tissue of fish taken from the Kinnickinnic estuary, the Menomonee estuary, and the outer harbor. The concentrations of PCB's found within the estuary fish were generally higher but of the same order of magnitude as the concentrations found in Lake Michigan fish.

- Bottom Sediment Pollutant Levels—As shown in Table 61, the measured levels of six toxic materials, including PCB's and five metals, resulted in the sediments being classified as heavily polluted, based on EPA sediment quality guidelines used for dredged material disposal. An analysis of the amounts and rates of release of toxic organic substances from the sediments to the interstitial water was also conducted under this study for those pollutants for which preliminary standards and procedures were available. That analysis found that 11 toxic organic substances, as shown on Table 61, including four PCB forms, could be released into the interstitial water at levels that exceed the acute and/or chronic toxicity standards for surface water.

- Surface Water Pollutant Level—Analysis of water column samples indicated that three toxic substances, including one organic substance and two metals, were found at levels in the overlying surface water to exceed the chronic standards. A special faunal toxicity survey was conducted to provide additional information on acute and chronic toxic conditions within the estuary. The survival and reproduction of the zooplankton Ceriodaphnia affinis/dubia were studied using water samples from the estuary collected under both wet-weather and dry-weather conditions. The toxicity test results suggested the occurrence of chronic toxicity, which reduced the production of young Ceriodaphnia. These toxic conditions were more likely to occur during wet-weather conditions than during dry-weather conditions. Acute toxic conditions, which affect the survival of the adult Ceriodaphnia over a short time period, also appeared to occur, and more often during wet-weather conditions than during dry-weather conditions, especially in the Menomonee River.

  As summarized in Table 61, in total, 27 toxic substances, including 20 organic substances and seven metals, appear to be of specific concern in the Milwaukee Harbor estuary based upon the data collected as part of the Milwaukee Harbor estuary study. As shown in Table 61, the Great Lakes Water Quality Board, International Joint Commission, has recommended that seven of these 27 toxic substances, including five of the organics and two metals, be studied in all second level toxic studies in the Great Lakes.[5]

It is accordingly recommended that a second level, detailed study of the problems associated with toxic substances in the bottom sediments of the Milwaukee Harbor estuary be conducted. While the detailed specifications for such a study should be set forth in a subsequent study design, a general approach is herein recommended. Two interrelated, yet different, types of problems should be addressed in the study. The first relates to direct acute and chronic toxicity to fish and other forms of aquatic life. Such toxicity may result in the illness and/or death of organisms from short- or long-term contact with the polluted sediments or overlying polluted water column. The second type

[5] *Great Lakes Water Quality Board, International Joint Commission, Guidance on Characterization of Toxic Substances Problems in Areas of Concern in the Great Basin, 1987.*

Table 61

TOXIC SUBSTANCES DETERMINED TO BE OF PRIMARY CONCERN IN THE MILWAUKEE HARBOR ESTUARY

Toxic Substance	Recommended by the IJC Water Quality Board[a]	U. S. FDA Human Health Standards (action levels available)	Estuary Sediments Heavily Polluted Based on Comparison to U. S. EPA Sediment Quality Guidelines[b]	Chronic Toxicity Standards Violated by Concentrations in Estuary Water[c]	Acute or Chronic Toxicity Standards Violated in the Interstitial Water of the Bottom Sediments of the Estuary[d]	Detectable Levels Measured in the Tissue of Fish Caught in the Estuary[e]
Organic Substances						
1. Aldrin	--	X	--	--	--	--
2. Bis (2-ethylhenyl)phthalate	--	--	--	X	--	--
3. Chlordane	--	X	--	--	X	X
4. DDE	--	--	--	--	--	X
5. DDT	X	X	--	--	--	X
6. Dichloromethane	--	--	--	--	X	--
7. Dieldrin	X	X	--	--	--	X
8. Di-n-butyl phthalate	--	--	--	--	--	--
9. Endrin	--	X	--	--	X	--
10. Gamma-BHC	--	--	--	--	X	--
11. Heptachlor	--	X	--	--	X	--
12. Hexachlorobenzene	X	--	--	--	--	X
13. Kepone	--	X	--	--	--	--
14. Mirex	X	X	--	--	--	--
15. Naphthalene	--	--	--	--	X	--
16. PP-DDD	--	--	--	--	--	X
17. Pentachloroanisol	--	--	--	--	--	X
18. Phenols	--	--	--	--	X	--
19. Polychlorinated Biphenyls	X	X	X	--	X[f]	X
20. Polynucleal Aromatic Hydrocarbons	X	--	--	--	--	--
21. T-Nonachlor	--	--	--	--	--	X
22. 2,3,7,8-Tetrachlorodibenzo-p-dioxin	X	X	--	--	--	--
23. 2,3,7,8-Tetrachloro-dibenzofuran	X	--	--	--	--	--
24. Toxaphene	X	X	--	--	--	X
Metals						
1. Arsenic	--	--	X	--	--	--
2. Cadmium	--	--	X	X	--	--
3. Chromium	--	--	--	--	--	X
4. Copper	--	--	X	--	--	X
5. Lead	X	--	X	--	--	--
6. Mercury	X	X	--	X	--	X
7. Zinc	--	--	X	--	--	X

[a]Critical substances recommended to be considered in all toxic substances studies on the Great Lakes by the Great Lakes Water Quality Board, International Joint Commission, Guidance on Characterization of Toxic Substances Problems in Areas of Concern in the Great Lakes Basin, 1987.

[b]See Table 85, p. 327, of Volume One of this report.

[c]See Table 64, p. 251, of Volume One of this report, and U. S. Environmental Protection Agency and Wisconsin Department of Natural Resources, Environmental Impact Statement, Milwaukee Metropolitan Sewerage District, Water Pollution Abatement Program, Final Report, Appendix VII, April 1981, p. VII-104.

[d]See Chapter VI of Volume One.

[e]See Tables 93, 103, 110, and 117 on pp. 336, 347, 353, and 360, respectively, of Volume One of this report.;

[f]Four forms of PCB found to be a potential problem.

Source: SEWRPC.

of problem relates to the bio-accumulation of the toxic substances in the bodies of aquatic and terrestrial organisms. This type of problem may result in human as well as animal health hazards. Review of the inventory data collected and analyses conducted under the Milwaukee Harbor estuary study indicate that the second type of problem is the more serious in the estuary.

The entire study should consist of four recommended major elements. Additional elements may be recommended as the study design is prepared. The first element of the study would entail the collation and documentation of standards associated with each of the 126 priority pollutants. The second element would entail the verification and updating, as necessary, of the current information

Table 62

MEAN CONCENTRATIONS OF POLYCHLORINATED BIPHENYLS (PCB'S) IN THE TISSUE OF FISH WITHIN THE MILWAUKEE HARBOR ESTUARY: 1970-1983

Fish Species	Inner Harbor						Outer Harbor		Lake Michigan	
	Milwaukee River		Menomonee River		Kinnickinnic River					
	Number of Samples	Mean Concentration (ppm)	Number of Samples	Mean Concentration (ppm)	Number of Samples	Mean Concentration (ppm)	Number of Samples	Mean Concentration (ppm)	Number of Samples	Mean Concentration (ppm)
Carp	3	26.6	3	36.4	5	17.6	--	--	--	--
Northern Redhorse	2	4.8	--	--	1	2.7	--	--	--	--
Northern Pike	1	16.0	--	--	--	--	--	--	--	--
Bluegill	1	9.1	1	3.5	1	6.2	--	--	--	--
White Sucker	1	15.0	1	1.2	1	6.2	2	3.8	--	--
Gizzard Shad	1	13.0	--	--	--	--	--	--	--	--
Goldfish	--	--	1	1.0	1	21.0	--	--	--	--
Alewife	--	--	--	--	--	--	2	2.0	--	--
Yellow Perch	--	--	--	--	--	--	2	2.4	--	--
Brown Trout	--	--	--	--	--	--	2	3.2	--	--
Chinook, Coho Salmon, and Lake Trout	--	--	--	--	--	--	--	--	12	2.2

NOTE: U. S. Food and Drug Administration Standard is 2.0 ppm.

Source: Wisconsin Department of Natural Resources.

base. This element would analyze collated data to determine if any additional data collection was necessary; would identify the scope and extent of such data collection efforts; and would collect the necessary additional data. This element would also refine the identification of the location and extent of the geographic areas containing significantly polluted sediments, and the substances of concern in each of those areas. Use of the available data and such additional data as may be required to be collected through a sampling program would provide the basis for a detailed assessment of the magnitude, extent, transport and fate, degradation, bio-availability, and bio-accumulation of the problem substances. The third element would include the identification and quantification of the sources of the toxic substances of concern. This element would also examine the benefits that would be realized with abatement of important sources of toxic substances. The fourth and final element of the study would develop and evaluate alternative measures for abating the toxic substance problems in the sediments, and present a recommended abatement plan. These elements are further described below.

Establishment of Standards for Toxic Materials Element

Under the first element of the proposed study, water and sediment quality standards would be collated and documented for the 126 priority pollutants listed in Appendix D. The work conducted under the Milwaukee Harbor estuary study indicated that 27 of 71 toxic substances considered, or about 38 percent of the total substances investigated, were present in the sediments at problem levels based upon preliminary standards. Thus, 44 substances, or about 62 percent of the total considered, were found not to present a problem and should not require further study. Final standards for these substances should be documented, however. The interpretation of the existing data would require the application of water quality standards developed by the U. S. Environmental Protection Agency and Wisconsin Department of Natural Resources and summarized in Chapter II of this volume; human health standards for food consumption developed by the U. S. Food and Drug Administration (FDA); and in-place sediment quality standards currently under development by the EPA.

This element of the study should include consideration of standards for acute and chronic toxicity as well as for bio-availability and bio-accumulation. The applicable types of standards will vary depending on the type of pollutant. With regard to the consideration of acute and chronic water quality impacts, standards are available from the Wisconsin Department of Natural Resources, and are set forth in Chapter III of this volume. These standards may be refined and expanded somewhat by the Department prior to the proposed study. With regard to in-place sediment quality, the methodology for identifying the existence of pollution would be described, including a determination of special coefficients for each toxic substance which would be used to calculate the fraction of the substance in the dissolved and particulate phases under particular environmental conditions, and to determine the concentration of the substance in the sediment interstitial water. These coefficients can be used to estimate which substances will concentrate in the sediment and which will concentrate in the biota. Such coefficients would be provided for the range of organic carbon, pH conditions, and other sediment variables described in Chapter VII of Volume One and Chapter V of this volume. Preliminary standards and procedures are available for 62 organic toxic substances and are described in Chapter V. These procedures and standards are presently undergoing further development by the U. S. EPA.

With regard to bio-availability and bio-accumulation, the test procedures to be considered for each pollutant or group of pollutants would be documented. The standards considered for each level of aquatic life would be described, with the standards for fish that are normally consumed by humans being established by the U. S. Food and Drug Administration. It is recognized that the standards for the various levels of aquatic life may require consideration of the test results described under the second element of the proposed study. In that case, it would be necessary to document the procedures to be used to establish the standards. The results of the Milwaukee Harbor estuary study indicate that at least 14 toxic pollutants, as shown in Table 61, will have to be considered in this regard.

It is recognized that standards for certain pollutants may not be fully available in time to conduct the needed toxic substances management study. In that case, it may be necessary to conduct bio-toxicity tests which can empirically determine problem conditions for groups of pollutants. Procedures for this evaluation would also be documented under the first element of the toxic substances management study.

Verify and Update Current Information Element

This element is intended to complete the characterization of the toxic substance problems and identify and quantify the toxic substances of concern. Additional data would be collected to supplement the existing data base developed under the Milwaukee Harbor estuary study. The characterization of the toxic substance problems would involve the following work efforts:

1. Additional sediment samples from potential problem locations identified from the existing data base would be collected and screened against the full list of 126 priority pollutants. The sampling locations would be developed by reviewing and mapping the full range of available data and by considering available standards for acute and/or chronic toxicity. An example of such mapping for PCB's based upon data collected under this study is shown on Map 94 of Volume One. This screening would determine which priority pollutants are present in the estuary sediments—but not the concentration. No further analysis would be required for those pollutants not identified in the screening process as present in significant quantities.

2. The toxicity, bio-availability, and bio-accumulation of substances in the bottom sediments would be examined at locations identified by review of the available data and by the toxics screening described under item 1 above. Analyses for toxicity would be conducted at locations indicated by the data review and priority pollutant scan to have the potential for severe problems. Analyses conducted under the estuary study indicate that potential problems may be found with respect to about 60 pollutants. Testing for acute toxicity may involve the bacterial luminescence bioassay (Microtox), the Algal Fractionation Bioassay, tests with fathead minnows (Pimephales promelas), and the Ceriodaphnia bioassay. As noted above, some Ceriodaphnia bioassays were conducted under the Milwaukee Harbor estuary study. Chronic toxicity may be determined by evaluating effects on growth, reproduction, emergence, and egg viability for Chir-

onomus tentans, a benthic invertebrate. Chironomus organisms, or dipteran midges, which are widely distributed in the Great Lakes, spend nearly their entire life cycle in a shallow tunnel in the sediments, account for a significant portion of the benthic biomass in the Great Lakes, and are important in the cycling of contaminants from sediments. The bioassays with benthic organisms would utilize pore water extracts from the bottom sediments because pore waters are in equilibrium with contaminants adsorbed onto sediment particles, and because benthic organisms are exposed to pore water.

The bio-availability and bio-accumulation of toxic substances should be assessed to determine if sediments are a source of toxic substances to the biota. For those contaminants identified as present in the estuary system, tissue analysis would be conducted on indigenous fauna, particularly benthic invertebrates and fish. The Chironomus bioassay described above would also provide information on the bio-availability of the toxic substances in the sediments. Fish deserve special consideration because of their important position in the food chain, including consumption by humans. Important fish to evaluate are adult carp, sucker, and bullhead, as well as young spottail shiner. As previously noted and as shown in Table 61, 14 toxic substances have been shown to be a potential problem in fish found in the estuary. Fish would also be examined for deformities, tumors, lesions, and cancer indicators, which may indicate chemical stress.

3. Biological impact and sediment deposition areas where the data developed under this element do not meet the standards or criteria documented under the first element would be mapped and characterized. Data would be utilized to delineate the extent and depth of the sediments in those areas where toxic substances may be having adverse biological impacts. Some additional bottom sampling may be required to determine sediment accumulation rates, deposition areas, and the degree of sediment resuspension and transport.

   Sediment cores and grab samples would be collected from these impact and/or deposition areas and analyzed for those priority pollutants which the screening analysis indicated are present within the Milwaukee Harbor estuary. The sediment quality and water quality standards would be applied to help relate the observed biological impacts to the measured concentrations of toxic substances in the sediments. Additional bioassays may be required to help identify the toxic impacts of particular sites or individual substances.

4. The final product of this element of the toxics study would be two sets of maps delineating the problem areas. The first set of maps would show the areas in which the standards are violated. This set of maps would be directed toward defining the pollutant problems, and the groupings would be based upon how the pollutants affect aquatic life, i.e., pollutants which act synergistically to be acutely toxic to aquatic life may be grouped together. The second set of maps would be made to assist in defining and quantifying the sources of the pollutants. Accordingly, pollutants that may be attributed to a selected source may be grouped on one map.

Identification and Quantification of Sources of Toxic Substances Element

The third element of the study would evaluate the historical and existing sources of those toxic substances which are of concern. These sources may include combined and separate sewer overflows, industrial point sources, urban and rural land runoff, atmospheric loadings, groundwater inflow, leaking storage facilities, and in-place pollutants. Some toxic substances are discharged directly to the estuary, while others may be transported to the estuary via the Milwaukee, Menomonee, and Kinnickinnic Rivers. Thus, under an initial evaluation, the sources will be segregated into those contributed from: 1) upstream sources, 2) estuary direct tributary area sources, and 3) in-place sediment sources. The magnitude and importance of the various sources would be determined through the review of available discharge and spill records and permit requirements; the review of the problem locations and severity as developed under the previous elements; the compilation and review of previous studies which have evaluated sources of toxic substances; and the conduct of additional sampling and analysis for toxic substances. In this regard, analyses conducted under the Milwaukee Harbor estuary study indicate that under existing conditions, groundwater from within the estuary direct drainage area and permitted industial discharges are not significant sources of toxic substance pollution. Historic industrial discharges or accidental spills may have been a pollutant source. In developing a preliminary cost estimate for this element, it was assumed that there would not be a need to conduct sampling of industrial discharges or groundwater impacts. Bioassays to determine bio-accumulation and acute or chronic toxicity of source discharges may be required in conjunction with the chemical analyses. Loadings of toxic substances from each significant source would be estimated on an annual basis, as well as during summer storm, spring runoff, and low-flow conditions.

To help evaluate the fate and transport of toxic substances within the estuary, and thereby relate the source information to the observed toxic conditions and biological impacts, a mathematical model capable of simulating sediment-water and biological interactions may be developed and applied. Some additional sampling of toxic substance concentrations and special laboratory testing and studies may be required to develop the model parameters and to properly calibrate the model. Coefficients relating sediment concentrations to sediment interstitial water concentrations may have to be measured, along with the dissolved and particulate concentrations of the toxic substances. Special field sediment trap studies may also be required.

The model would be used to determine whether the existing toxic substances in the surface water are in equilibrium with the sediments. The model would also be used to assess whether the sediments are a source of contaminants to the water column and to the biota. A mass-balance analysis would be conducted for important toxic substances of concern. The effect of combined sewer overflows on the concentrations of toxic substances in the water column would be determined. The model would also help determine the combined sewer overflow contribution of toxic substances to the bottom sediments. These modeling results would help in estimating the reduction in levels of toxic substances that could be expected following abatement of various identified sources of pollutants.

Development and Evaluation of Alternative and Recommended Toxic Substance Abatement Measures Element

Alternative methods of abating the toxic substance problems to protect desired aquatic life and human health, and to allow the achievement of the recommended water use objectives, would be developed and evaluated. These abatement measures may include:

1. No action other than measures recommended in this study;
2. Abatement of identified sources of toxic substances;
3. Various dredging and spoils disposal methods;
4. Impervious screening, accelerated deposition, and sediment ploughing;
5. Physical isolation or chemical stabilization of local problem areas;
6. Enhancement of the natural bio-degradation process to increase the stabilization of the sediments; and
7. The use of management measures such as navigational restrictions to reduce sediment resuspension, restrictions on the human consumption of fish, and fish barriers to prevent migration.

Each of these alternatives—plus any others identified during the study—would be evaluated for technical effectiveness, cost, implementability, compatibility with other recommended management measures for the Milwaukee Harbor estuary, and environmental and human health impacts. A toxic substance abatement plan would be recommended, and the plan would be incorporated into the recommended water resources plan for the Milwaukee Harbor estuary set forth in this chapter.

COST ANALYSIS

In order to assist public officials in evaluating the recommended water resources management plan for the Milwaukee Harbor Estuary, a preliminary capital improvement program with attendant operation and maintenance costs was prepared which, if followed, would result in full plan implementation by the year 2000. The capital and operation and maintenance costs of the recommended plan elements are summarized in Table 63. The schedule of capital and operation and maintenance costs for the recommended plan is set forth in Table 64.

Table 63

ESTIMATED COST OF THE RECOMMENDED PLAN FOR THE MILWAUKEE HARBOR ESTUARY: 1987-2000

Plan Element	Capital: 1987-2000[a]		Average Annual Operation and Maintenance Upon Full Implementation[a]	
	Cost (millions)	Percent of Total	Cost	Percent of Total
Water Quality Management Element				
Point Source Pollution Abatement Subelement				
1. Abatement of Combined Sewer Overflows at a 0.7-Year Level of Protection	$204.0[b]	53.5	$ 617,000[b]	19.5
2. Elimination of Separate Sanitary Sewer Flow Relief Devices[c]	134.4[b]	35.2	923,000[b]	29.1
Subtotal	$338.4[b]	88.7	$1,540,000[b]	48.6
Nonpoint Source Pollution Abatement Subelement	$ 25.8[b]	6.8	$ 750,000[b]	23.7
Instream Water Quality Measures Subelement				
1. Operation of Existing Flushing Tunnels in Milwaukee and Kinnickinnic River Estuaries	$ 0.3	0.1	$ 130,000	4.1
2. Instream Aeration of the Menomonee River Estuary	0.3	0.1	20,000	0.6
Subtotal	$ 0.6	0.2	$ 150,000	4.7
Auxiliary Plan Subelement				
1. *Material Storage Site Control*	$ 0.6	0.2	$ --	--
2. Water Quality Monitoring Program	0.2	< 0.1	114,000	3.6
Subtotal	$ 0.8	0.2	$ 114,000	3.6
Total Water Quality Management Element	$365.6	95.9	$2,554,000	80.6
Dredging and Dredged Material Disposal Plan Element				
Dredged Material, Processing, Transportation, and Disposal Subelement				
1. Use of Existing Confined Disposal Facility: 1987 through 1992	$ 2.9[b]	0.8	$ 690,000[b]	21.7
2. New Confined Disposal Facility: 1993 through 2000	9.0[b]	2.3	550,000[b]	17.3
Total Dredging and Dredged Material Disposal Element	$ 11.9[b]	3.1	$ 600,000[b]	19.0
Shoreline Storm Damage and Flood Protection Element				
Outer Harbor Anchorage Area and Shoreline Facilities Wind Storm Protection Subelement	$ --[d]	--	$ --[d]	--
Ice Control Subelement	0.3	0.1	15,000	0.4
Inner Harbor High Water and Flood Protection Subelement	0.3	0.1	--	--
Total Shoreline Storm Damage and Flood Protection Element	$ 0.6	0.2	$ 15,000	0.4
Toxic Substances Management Plan Element	$ 3.2	0.9	$ --	--
Total Recommended Plan Cost	$381.3	100.0	$3,169,000	100.0
Total Cost of Plan Elements Previously Committed Under Other Planning Programs	$376.1	98.6	$2,890,000	91.2
Net Additional Cost of Recommended Plan Over and Above Committed Measures	$ 5.2	1.4	$ 279,000	8.8

[a] *All costs are expressed in 1986 dollars. Cost estimates are based upon data included in the Milwaukee Metropolitan Sewerage District facility planning documents dated February 1982 and December 1983, updated to 1986. It should be noted that the cost of these facilities is being continually revised and refined as implementation of the District program proceeds.*

[b] *Previously committed cost.*

[c] *Costs do not include costs for major relief sewers in the Milwaukee Metropolitan Sewerage District service area since these sewers were largely constructed prior to 1987.*

[d] *This subelement is considered in the proposed second level study recommended under the inner harbor high-water and flood protection subelement.*

Source: SEWRPC.

Table 64

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED PLAN FOR THE MILWAUKEE HARBOR ESTUARY: 1987-2000

Calendar Year	Project Year	Water Quality Management Plan Element										
		Point Source Subelement		Nonpoint Source Subelement		Instream Measures Subelement		Auxiliary Plan Subelement		Subtotal		
		Capital[a]	Operation and Maintenance	Capital	Operation and Maintenance	Capital	Operation and Maintenance	Capital	Operation and Maintenance	Capital	Operation and Maintenance	Total
1987	1	$ 80,000,000[b]	$ --	$ 700,000	$ 100,000	$ --	$ 50,000	$ --	$ --	$ 80,700,000	$ 150,000	$ 80,850,000
1988	2	50,000,000	--	700,000	100,000	--	130,000	100,000	70,000	50,800,000	300,000	51,100,000
1989	3	65,000,000	--	700,000	100,000	150,000	130,000	100,000	70,000	65,950,000	300,000	66,250,000
1990	4	70,000,000	100,000	3,300,000	250,000	150,000	140,000	100,000	300,000	73,550,000	790,000	74,340,000
1991	5	58,000,000	200,000	3,300,000	350,000	--	150,000	100,000	70,000	61,400,000	770,000	62,170,000
1992	6	10,000,000	300,000	3,300,000	450,000	--	150,000	100,000	70,000	13,400,000	970,000	14,370,000
1993	7	5,400,000	1,540,000	3,300,000	550,000	--	150,000	100,000	70,000	18,400,000	2,310,000	11,110,000
1994	8	--	1,540,000	3,300,000	650,000	150,000	150,000	100,000	70,000	3,550,000	2,410,000	5,960,000
1995	9	--	1,540,000	3,300,000	750,000	--	150,000	100,000	300,000	3,400,000	2,740,000	6,140,000
1996	10	--	1,540,000	700,000	750,000	--	150,000	--	70,000	700,000	2,510,000	3,210,000
1997	11	--	1,540,000	800,000	750,000	--	150,000	--	70,000	800,000	2,510,000	3,310,000
1998	12	--	1,540,000	800,000	750,000	--	150,000	--	70,000	800,000	2,510,000	3,310,000
1999	13	--	1,540,000	800,000	750,000	--	150,000	--	70,000	800,000	2,510,000	3,310,000
2000	14	--	1,540,000	800,000	750,000	150,000	150,000	--	300,000	950,000	2,740,000	3,690,000
Total		$338,400,000	$12,920,000	$25,800,000	$7,050,000	$600,000	$1,950,000	$800,000	$1,600,000	$365,600,000	$23,520,000	$389,120,000
Annual Average		$ 24,171,429	$ 922,857	$ 1,842,857	$ 503,571	$ 42,857	$ 139,286	$ 57,143	$ 114,286	$ 26,114,286	$ 1,680,000	$ 27,794,286

Calendar Year	Project Year	Dredging and Dredged Material Element							Shoreline Storm Damage and Flood Protection Element						
		Existing Confined Disposal Dredging and Dredged Material Disposal Subelement		New Control Disposal Facility Dredging and Dredged Material Disposal Subelement		Subtotal			Ice Control Subelement		Anchorage Area and Shoreline Facilities High Water Level and Flood Protection Subelement		Subtotal		
		Capital	Operation and Maintenance	Capital	Operation and Maintenance	Capital	Operation and Maintenance	Total	Capital	Operation and Maintenance	Capital	Operation and Maintenence	Capital	Operation and Maintenance	Total
1987	1	$2,900,000	$ 690,000	$ --	$ --	$ 2,900,000	$ 690,000	$ 3,590,000	$ --	$ --	$ --	$ --	$ --	$ --	$ --
1988	2	--	690,000	--	--	--	690,000	690,000	10,000	2,000	100,000	--	110,000	2,000	112,000
1989	3	--	690,000	--	--	--	690,000	690,000	10,000	2,000	150,000	--	160,000	2,000	162,000
1990	4	--	690,000	--	--	--	690,000	690,000	120,000	2,000	50,000	--	170,000	2,000	172,000
1991	5	--	690,000	4,500,000	--	4,500,000	690,000	5,190,000	120,000	15,000	--	--	120,000	15,000	135,000
1992	6	--	690,000	4,500,000	--	4,500,000	690,000	5,190,000	40,000	15,000	--	--	40,000	15,000	55,000
1993	7	--	--	--	690,000	--	690,000	690,000	--	15,000	--	--	--	15,000	15,000
1994	8	--	--	--	690,000	--	690,000	690,000	--	15,000	--	--	--	15,000	15,000
1995	9	--	--	--	690,000	--	690,000	690,000	--	15,000	--	--	--	15,000	15,000
1996	10	--	--	--	550,000	--	550,000	550,000	--	15,000	--	--	--	15,000	15,000
1997	11	--	--	--	390,000	--	390,000	390,000	--	15,000	--	--	--	15,000	15,000
1998	12	--	--	--	390,000	--	390,000	390,000	--	15,000	--	--	--	15,000	15,000
1999	13	--	--	--	390,000	--	390,000	390,000	--	15,000	--	--	--	15,000	15,000
2000	14	--	--	--	390,000	--	390,000	390,000	--	15,000	--	--	--	15,000	15,000
Total		$2,900,000	$4,140,000	$9,000,000	$4,180,000	$11,900,000	$8,320,000	$20,220,000	$300,000	$156,000	$300,000	$ --	$600,000	$156,000	$756,000
Annual Average		$ 207,143	$ 295,714	$ 642,857	$ 298,571	$ 850,000	$ 594,285	$ 1,444,286	$ 21,428	$ 11,143	$ 21,429	$ --	$ 42,857	$ 11,143	$ 54,000

Table 64 (continued

Calendar Year	Project Year	Toxic Substances Management Plan Element					Total Recommended Plan		
		Toxic Substances Management Study		Subtotal					
		Capital	Operation and Maintenance	Capital	Operation and Maintenance	Total	Capital	Operation and Maintenance	Total
1987	1	$ --	$ --	$ --	$ --	$ --	$ 83,600,000	$ 840,000	$ 84,440,000
1988	2	20,000	--	20,000	--	20,000	50,930,000	992,000	51,922,000
1989	3	900,000	--	900,000	--	900,000	67,010,000	992,000	68,002,000
1990	4	900,000	--	900,000	--	900,000	74,620,000	1,482,000	76,102,000
1991	5	800,000	--	800,000	--	800,000	66,820,000	1,475,000	68,295,000
1992	6	580,000	--	580,000	--	580,000	18,520,000	1,675,000	20,195,000
1993	7	--	--	--	--	--	8,800,000	3,015,000	11,815,000
1994	8	--	--	--	--	--	3,550,000	3,115,000	6,665,000
1995	9	--	--	--	--	--	3,400,000	3,445,000	6,845,000
1996	10	--	--	--	--	--	700,000	3,075,000	3,775,000
1997	11	--	--	--	--	--	800,000	2,915,000	3,715,000
1998	12	--	--	--	--	--	800,000	2,915,000	3,715,000
1999	13	--	--	--	--	--	800,000	2,915,000	3,715,000
2000	14	--	--	--	--	--	950,000	3,145,000	4,095,000
Total		$3,200,000	$ --	$3,200,000	$ --	$3,200,000	$381,300,000	$31,996,000	$413,296,000
Annual Average		$ 228,571	$ --	$ 228,571	$ --	$ 228,571	$ 27,235,714	$ 2,285,429	$ 29,521,143

NOTE: All costs are estimated in 1986 dollars.

[a] *Cost estimates are based upon data included in the Milwaukee Metropolitan Sewerage District facility planning documents dated February 1982 and December 1983, updated to 1986. It should be noted that the cost of these facilities is being continually revised and refined as implementation of the District program proceeds. Schedule reflects December 28, 1987, annual schedule establishment which provides for all projects to be underway by 1990.*

[b] *Includes estimate of costs expended prior to 1987.*

Source: SEWRPC.

The schedule assumes a 14-year plan implementation period beginning in 1987 and extending through the year 2000. The capital cost of implementing the entire Milwaukee Harbor estuary plan is estimated at $381.3 million, representing an average annual capital expenditure over the 14-year period of nearly $27.2 million. It is important to note that $376.1 million, or nearly 99 percent of the total capital cost of the plan, is for plan elements that have been committed under other planning efforts. These costs were committed in order to meet the objectives of the previously developed areawide water quality management plan and Milwaukee Metropolitan Sewerage District water pollution abatement program, and in response to the need to continue dredging for navigational purposes. The capital costs for the previouly committed measures include about $338.4 million, or 88.7 percent of the total capital cost, for abatement of combined and separate sewer overflows; about $25.8 million, or about 6.8 percent of the total capital cost, for nonpoint source control; and about $11.9 million, or about 3.1 percent of the total capital, cost for dredging and dredged material disposal. Thus, the total net additional capital cost of the plan over and above the previously committed measures is $5.2 million.

Of the total plan capital cost, about $365.6 million, or about 96 percent, representing an average annual expenditure of $26.1 million, is required to implement the water quality management element of the plan, including the construction and operation of deep tunnel separate and combined sewer overflow abatement facilities; about $11.9 million, or about 3 percent of the total representing an average annual expenditure of $850,000, is required to implement the dredging and dredged material disposal element of the plan; about $600,000, or less than 1 percent of the total, representing an average annual expenditure of about $40,000, is required to implement the shoreline storm damage and flood protection element of the plan; and $3,200,000, or about 1 percent, representing an average annual expenditure of about $230,000, is required to implement the toxic substances management element of the plan.

Of the total plan costs, nearly all would be expended by public agencies, the exception being about $14.4 million, or about 4 percent of the total plan capital cost. This cost, which would be allocated to the private sector, is for nonpoint source pollution controls. This cost is attributable to construction site erosion control and to a portion of the agricultural nonpoint source controls, with a small cost for dredging adjacent to private port facilities.

The total capital investment and operation and maintenance cost required for plan implementation may be expected to total $29.3 million on an average annual basis, or about $17 per capita per year over the 14-year plan implementation period. This per capita cost is based on a current resident tributary watershed population of 1,765,000 persons. The average annual costs of implementation of the water quality management element, the dredging and dredged material disposal element, the shoreline storm damage and flood protection element, and the toxic substances management element are estimated at, respectively, $27.6 million, or about 94 percent; $1.4 million, or about 5 percent; $48,000, or less than 1 percent; and $230,000, or about 1 percent. It should be noted that of the total annual cost of $29.2 million, about $28.6 million, or about 98 percent, is for previously committed measures.

THE ABILITY OF THE RECOMMENDED WATER RESOURCES MANAGEMENT PLAN FOR THE MILWAUKEE HARBOR ESTUARY TO MEET ADOPTED OBJECTIVES AND STANDARDS

Water resources management-related objectives and supporting standards were formulated early in the Milwaukee Harbor estuary study as the second step in a seven-step planning process. The objectives and standards set forth in Chapter II of this volume include those adopted under related areawide water quality management, land use, and park and open space planning programs, supplemented with objectives and standards developed under the Milwaukee Harbor estuary study. The objectives address abatement of both point and nonpoint sources of water pollution; floodland management; shoreline protection; protection of navigation, waterborne commerce, and anchorage; and provision of suitable recreation and access opportunities on lakes and streams. The adopted objectives and supporting standards provided the basis for plan preparation, test, and evaluation. Accordingly, it is appropriate to determine how well the recommended plan meets these adopted objectives and standards. An evaluation of the plan was therefore made on the basis of its ability to meet the objectives and standards. The results of that evaluation are summarized in Table 65. The table indicates that all of the objectives and supporting standards either would explicitly be met by the plan, or could be met, depending upon the results of local planning efforts and studies. In this regard, it

Table 65

ABILITY OF THE RECOMMENDED WATER RESOURCES MANAGEMENT PLAN FOR THE MILWAUKEE HARBOR ESTUARY TO MEET ADOPTED OBJECTIVES AND STANDARDS

Objective		Standard	Degree to Which Standard is Met
Number	Description		
SANITARY SEWERAGE SYSTEM AND WATER QUALITY MANAGEMENT OBJECTIVES			
1	The development of land management and water quality control practices and facilities which will effectively serve the existing regional urban development pattern and promote implementation of the regional land use plan, meeting the anticipated need for sanitary and industrial wastewater disposal and the need for stormwater runoff control generated by the existing and proposed land uses	Sanitary sewer service to medium- and high-density urban development	Met
		Sanitary sewer service to low-density urban development	Met
		Sanitary sewer service in poor soil areas	Met
		Sanitary sewer service not provided to undeveloped primary environmental corridor lands	Met
		Sanitary sewer service not provided to floodlands	Met
		Sanitary sewer service restricted in areas of soils with very severe limitations for urban development	Met
		Orderly extension of sanitary sewerage facilities	Could be met
		Sizing of sewerage facility components in accordance with the land use plan	Met
		Treatment and disposal of industrial wastes	Met
		Provision of stormwater management facilities to existing proposed urban areas	Met
		Priority to prime agricultural lands for land management practices	Could be met
2	The development of land management and water quality control practices and facilities, inclusive of instream measures, so as to meet the recommended water use objectives and supporting water quality standards as set forth on Map 2 and in Table 5	Level of treatment at sewage treatment plant	Met
		Type and extent of stormwater treatment and land management practices	Could be met
		Stream fencing and feedlot runoff control	Met
		No sewage treatment plant discharge directly to inland lakes	Met
		Standards for sewage treatment plants	Met
		Existing sewage treatment plants scheduled to be abandoned	Met
		Interim sewage treatment plants to be constructed	Could be met
		Prohibition of sewage bypasses to storm sewers and waterways	Met
		Elimination of combined and sanitary sewer overflows	Met
		Adequate design of sewage treatment plants—provide emergency bypass facility	Met
		Best available treatment of industrial sewage	Could be met
		Best practicable treatment of sanitary sewage	Could be met
		No nonconforming pollutant discharge	Could be met
		Orderly transition of rural lands to urban uses	Could be met
		Pollution control measures—point sources, nonpoint sources, combined sewer overflows, and instream sources	Met
		Extent of dredging of the Milwaukee Harbor Estuary	Met
		Safe storage and disposal of potential groundwater contaminants	Could be met
		Water quality not to be degraded beyond existing levels	Met
3	The development of land management and water quality control practices and facilities that are properly related to and will enhance the overall quality of the natural and man-made environments	Location of new and replacement sewage treatment plants outside the 100-year recurrence interval floodplain	Met
		Floodproofing of existing sewage treatment plants in the 100-year recurrence interval floodplain	Could be met
		Location of new and replacement sewage treatment plant and stormwater treatment and storage facilities for compatibility with existing and proposed development	Could be met
		Provision of aesthetically compatible new and replacement sewage treatment plants with buffer zones between existing and proposed development	Could be met
		Disposal of sewage treatment plant sludge	Met
		Proper location of pollutant storage facilities in relation to the 100-year recurrence interval floodplain	Could be met

Table 65(continued

Objective Number	Objective Description	Standard	Degree to Which Standard is Met
SANITARY SEWERAGE SYSTEM AND WATER QUALITY MANAGEMENT OBJECTIVES (continued)			
4	The development of land management and water quality control practices and facilities that are economical and efficient, meeting all other objectives at the lowest possible cost	Minimize investment and operating costs of sanitary sewer systems	Met
		Minimize investment and operating costs of stormwater control facilities and related land management practices	Met
		Minimize number of sanitary sewerage system and sewage treatment facilities	Met
		Maximize feasible use of sanitary sewerage facilities	Met
		Use of new and improved materials and management practices	Met
		Staged or incremental construction of sanitary sewerage facilities	Could be met
		Minimize land acquisition costs for new sewer construction	Could be met
		Minimize excessive clearwater inflows and infiltration into sanitary sewerage system	Could be met
		Integrated design of sanitary and storm sewer systems	Could be met
5	The development of water quality management institutions--inclusive of the governmental units and their responsibilities, authorities, policies, procedures, resources, and supporting revenue-raising mechanisms which are effective and locally acceptable, and which will provide a sound basis for plan implementation, including the planning, design, construction, operation, maintenance, repair, and replacement of water quality control practices and facilities, inclusive of sanitary sewerage systems, and land management practices	Develop and establish system of user charges and industrial cost recovery for program support	Could be met
		Maximum utilization of existing institutional structures	Met
		Water pollution control by local entities	Met
		Provide management groups with necessary resources	Could be met
WATER CONTROL OBJECTIVES			
1	An integrated system of drainage and flood control facilities and floodland management programs which will effectively reduce flood damage under the existing land use pattern of the watershed and promote the implementation of the the anticipated runoff loadings generated by the existing and proposed land uses	New and replacement bridges and culverts designed to pass the 10-year recurrence interval flood for minor streets; designed to pass the 50-year recurrence interval flood for arterial streets and highways; designed to pass the 100-year recurrence interval flood for freeways and expressways; and designed to pass the 100-year recurrence interval flood for railroads	Met
		New or replacement bridges and culverts designed to pass the 100-year recurrence interval flood without raising the peak stage more than 0.1 foot	
		Structure designed to maximize passage of ice floe and debris	Met
		Certain new and replacement bridges and culverts designed to pass the 100-year recurrence interval flood with two feet of freeboard	Met
		Existing bridges and culverts to meet standards 1, 3, and 4 above	
		Channel improvements, dikes, and floodwalls restricted to the absolute minimum necessary	Met
		The height of dikes and floodwalls designed to pass the 100-year recurrence interval flood with two feet of freeboard	Met
		The construction of channel modifications, dikes, or floodwalls to change limits of regulatory floodlands	Could be met
		Upon completion of the construction of reservoirs and diversions, regulatory floodland limits will be changed	Could be met
		All other water control facilities such as dams or diversion channels designed to accommodate the 100-year recurrence interval floods	Met
		Public land acquisitions intended to eliminate the need for water control facilities shall encompass the entire 100-year recurrence interval floodplain	Met
		Regulatory floodways designed to accommodate existing committed and planned floodplain land uses	Could be met
		Floodway stage increase limited to 0.1 foot based on equal degree of encroachment	Could be met

Table 65 (continued)

Objective		Standard	Degree to Which Standard is Met
Number	Description		
WATER CONTROL OBJECTIVES (continued)			
2	The development of structural and nonstructural shoreline protection measures to abate shoreline damages caused by flooding, fluctuating water levels, strong currents, ice activity, and wave action	All shoreline protection structures sized for waves expected for a 100-year recurrence interval Lake Michigan high water level	Could be met
		All shoreline protection structures designed to protect the base of the structure, the landward side of the structure, and the flanks of the structure, and to prevent undercutting of the structure	Met
		All shoreline areas not protected by a structure graded to a slope not steeper than one on two and one-half, and provided with vegetative cover	Met
		Nonstructural shoreline protection measures based on 100-year period of expected shoreline erosion and damage	Met
		All shoreline protection measures properly related to existing urban development	Met
3	The effective and efficient maintenance of deep water commercial navigation, waterborne commerce, anchorage protection, and associated waterborne transportation	Adequate port facilities provided to service ocean-going vessels, tanker vessels, carferries, barges, and large Great Lakes cargo freighters, and to facilitate loading of bulk, heavy, liquid, and general cargo	Met
		Provide at established Lake Michigan low water datum, the depths indicated on Map 17 in Chapter V at the Milwaukee outer harbor and the interconnected river channels that form the Port of Milwaukee	Met
		Instream pollution abatement measures designed, constructed, and operated so as not to interfere with existing or proposed navigation, waterborne commerce, and water-based transportation	Met
PARK AND OPEN SPACE OBJECTIVES			
1	The provision of opportunities for participation by the resident population of the Region in extensive water-based outdoor recreation activities on the major inland lakes and rivers and on Lake Michigan, consistent with safe and enjoyable lake use and maintenance of good water quality	Maximum number of public access points provided on major inland lakes	Could be met
		Maximum number of public access points provided on major rivers	Could be met
		Sufficient number of boat launch ramps provided along the Lake Michigan shoreline within harbors of refuge	Could be met
		Sufficient number of boat slips provided at marinas within harbors of refuge along the Lake Michigan shoreline	Could be met

Source: SEWRPC.

should be noted that the objectives listed in Table 65 include the final water use objectives which were selected following plan evaluation. Those objectives provide for limited recreational use and the maintenance of a warmwater fishery within the inner harbor; and full recreational use and the maintenance of a warmwater fishery in the outer harbor. These final water use objectives represent two changes to the initially selected objectives. First, the limited recreational use objective for the Milwaukee River portion of the estuary is a lower objective than that initially selected which provided for full recreational use in the reaches of the inner harbor concerned. Second, the final objective providing for the maintenance of a warmwater fishery in the Menomonee River and Kinnickinnic River represents a higher use objective than that initially selected which provided for the maintenance of a limited fishery in the reaches of the inner harbor concerned. The final use objectives were selected following evaluation of alternative water quality management plans which indicated that the achievement of full recreational use in the Milwaukee River portion of the estuary was not practical.

Of particular concern is the achievement of the water use objectives and supporting water quality standards herein recommended within the Milwaukee Harbor estuary. Table 66 presents quantitative data on the extent to which the recommended water quality standards which support the final water use objectives may be expected to be met under the recommended plan. These recommended standards vary in some instances from, and are more stringent than, the existing DNR standards. The final recommended water use objectives are limited recreational use and maintenance of a warmwater fishery within the inner harbor; and

Table 66

ACHIEVEMENT OF THE FINAL RECOMMENDED WATER USE OBJECTIVES AND SUPPORTING WATER QUALITY STANDARDS UNDER THE RECOMMENDED PLAN FOR THE MILWAUKEE HARBOR ESTUARY

Water Quality Standard	Inner Harbor			Outer Harbor
	Milwaukee River Estuary	Menomonee River Estuary	Kinnickinnic River Estuary	
Temperature	Met	Met	Met	Met
pH	Met	Met	Met	Met
Dissolved Oxygen	Met	Met	Met	Met
Fecal Coliform	Partially met	Not met	Partially met	Met
Total Residual Chlorine	Met	Met	Met	Met
Un-ionized Ammonia Nitrogen	Met	Met	Met	Partially met
Total Phosphorus	N/A	N/A	N/A	Met
Toxic Metals and Organic Substances	--[a]	--[a]	--[a]	--[a]

NOTE: N/A = not applicable. The phosphorus standard supports full recreational use, and the inner harbor is recommended for limited recreational use.

[a] *A further study of toxic substances contained in the bottom sediments of the Milwaukee Harbor estuary is recommended to determine the release of these substances to the water column and to aquatic biota.*

Source: SEWRPC.

full recreational use and maintenance of a warmwater fishery within the outer harbor. The achievement of the individual standards recommended herein for dissolved oxygen, fecal coliform, ammonia nitrogen, and lead are considered in greater detail below.

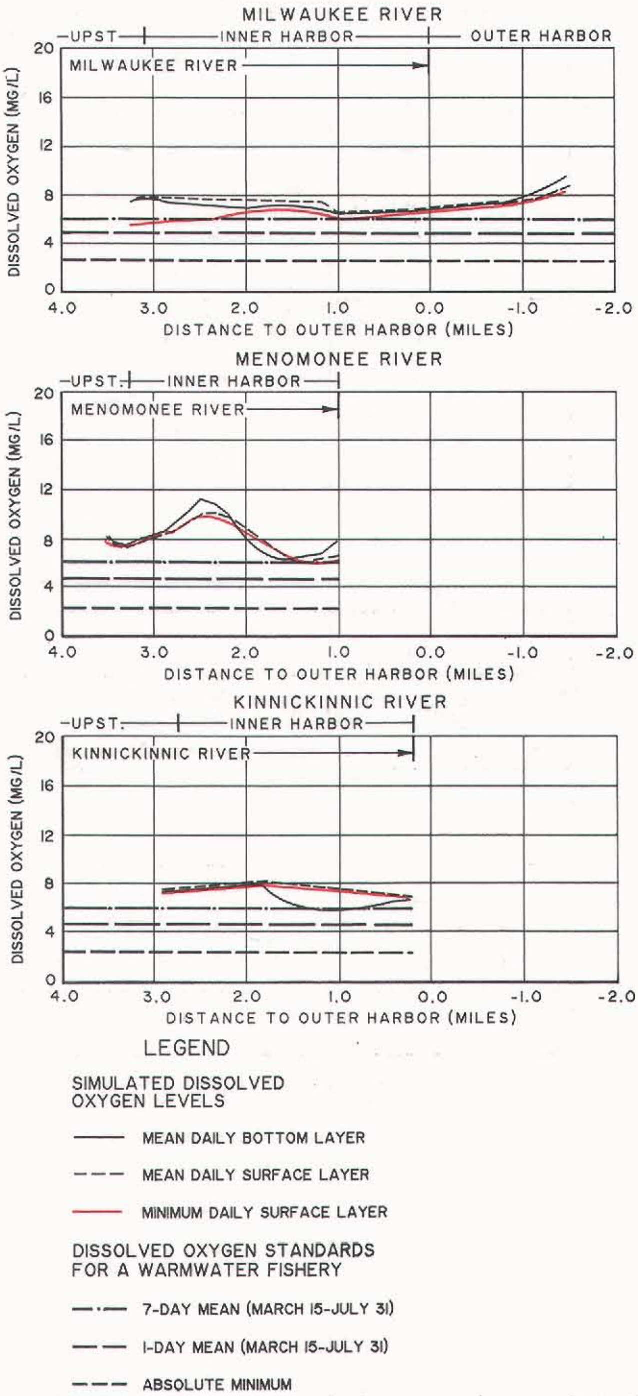
The recommended absolute minimum and 30-day mean dissolved oxygen standards may be expected to be met at all times throughout the estuary under the recommended plan. The 1-day mean standard of 5.0 mg/l may be expected to be met at least 95 percent of the time. The 7-day mean standard of 6.0 mg/l may be expected to be met at least 90 percent of the time.

The effect of the recommended plan on the critical dissolved oxygen conditions expected during low-flow and high-temperature periods was evaluated with a low-flow, steady-state simulation analysis. The simulation results, which estimate dissolved oxygen levels under 7-day, 10-year recurrence interval low-flow conditions at high temperature levels, are shown in Figure 109, and indicate that the recommended dissolved oxygen standards may be expected to be met during these critical conditions. The daily mean dissolved oxygen levels may, therefore, be expected to meet the 7-day mean and 1-day mean standards, while the daily minimum levels may be expected to meet the absolute minimum standard.

The distribution of running 30-day mean dissolved oxygen levels is shown for representative stations in Figure 110, as determined by simulation modeling. The figure demonstrates that the 30-day mean standard of 5.5 mg/l recommended to support a warmwater fishery should be readily met within the estuary.

Figure 109

ACHIEVEMENT OF DISSOLVED OXYGEN STANDARDS UNDER LOW-FLOW, STEADY-STATE CONDITIONS WITH THE RECOMMENDED PLAN



Source: HydroQual Inc., and SEWRPC.

Dissolved oxygen levels expected to occur during the period March 15 through July 31 are shown in Figure 111 and compared to the 7-day mean standard of 6.0 mg/l and the 1-day mean standard of 5.0 mg/l, which apply during this period. The applicable 7-day and 1-day mean standards would be met except in portions of the Kinnickinnic and Menomonee River estuaries, where very minor violations may occur.

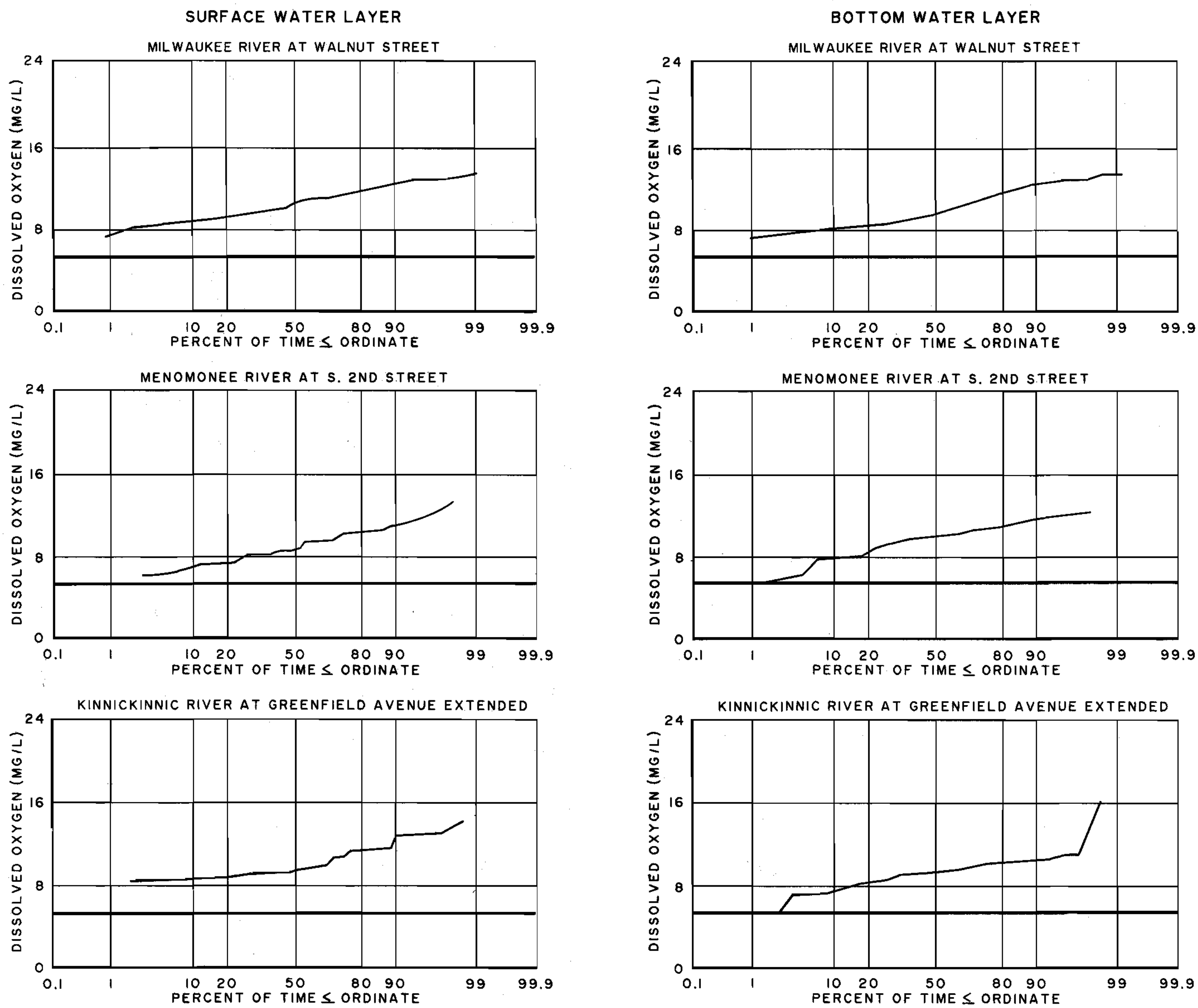
Dissolved oxygen levels expected to occur during the period August 1 through March 14 are shown in Figure 112 and compared to the 1-day mean standard of 4.0 mg/l, which applies during this period. A 7-day mean standard does not apply from August 1 through March 14. As shown in the figure, the applicable 1-day mean standard should be readily met throughout the estuary.

The estimated distribution of fecal coliform levels under the recommended plan is presented in Figure 113. The distribution plots are compared to the fecal coliform standards supporting limited recreational use of 2,000 most probable number per 100 milliliters (MPN/100 ml), which should not be exceeded more than 10 percent of the time, and 10,000 MPN/100 ml, which should not be exceeded more than 2 percent of the time. For the outer harbor, recommended for full recreational use, the fecal coliform levels should not exceed 400 MPN/100 ml more than 10 percent of the time. The figure indicates that the standards may be slightly exceeded in the upper Milwaukee and Kinnickinnic River estuaries, and significantly exceeded throughout all but the lower reaches of the Menomonee River estuary. The standard supporting full recreational use would be met within the outer harbor.

Figure 114 shows the distribution of the monthly geometric means of groups of five fecal coliform samples under the recommended plan. This figure illustrates the achievement of the geometric mean standards of 1,000 MPN/100 ml for limited recreational use in the inner harbor, which should not be exceeded more than 5 percent of the time, and 200 MPN/100 ml for full recreational use in the outer harbor, which should never be exceeded. The figure shows that the monthly geometric mean standards would be essentially met within the Milwaukee and Kinnickinnic River estuaries and the outer harbor, but violated substantially within the Menomonee River estuary. Although the recommended fecal coliform standards would be violated within the Menomonee River estuary, the fecal coliform levels that may be expected to be achieved

Figure 110

ACHIEVEMENT OF THE 30-DAY MEAN DISSOLVED OXYGEN STANDARD UNDER THE RECOMMENDED PLAN



LEGEND

—— DISTRIBUTION OF RUNNING 30-DAY MEAN DISSOLVED OXYGEN LEVELS

DISSOLVED OXYGEN STANDARD FOR WARMWATER FISHERY

—— 30-DAY MEAN STANDARD

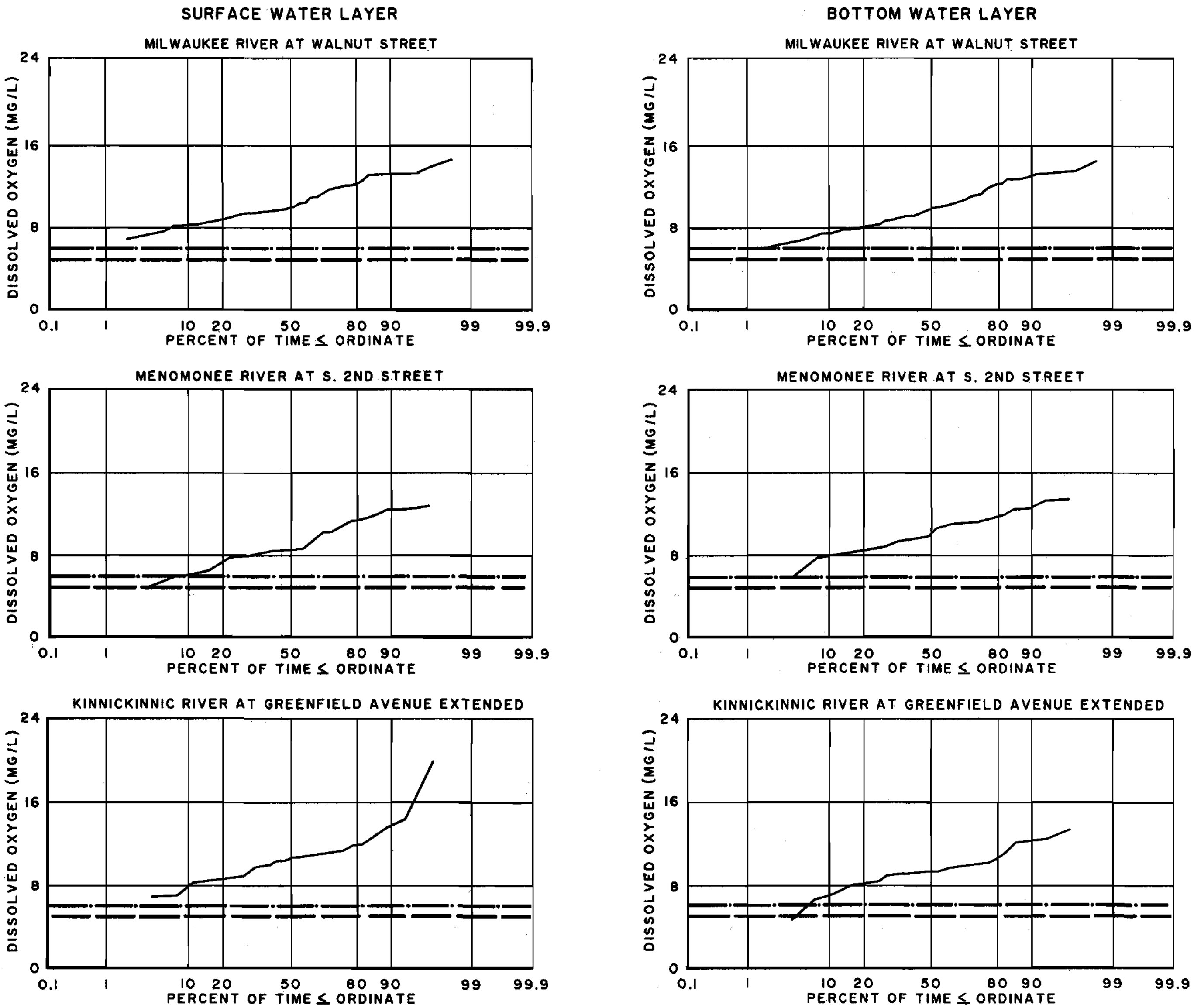
Source: HydroQual Inc., and SEWRPC.

under the recommended plan would represent a 90 percent reduction from the existing levels. Under the recommended plan, the estuary should not pose a risk to human health because participation in even partial-body contact water resource recreational activities is expected to be minimal.

Simulated ammonia nitrogen concentrations under low-flow, steady-state conditions following implementation of the recommended plan are shown in Figure 115. The ammonia nitrogen levels would be relatively low, except in the surface layer of the outer harbor. The calculation of un-ionized ammo-

Figure 111

ACHIEVEMENT OF THE 7-DAY AND 1-DAY MEAN DISSOLVED OXYGEN STANDARDS UNDER THE RECOMMENDED PLAN: MARCH 15-JULY 31



LEGEND

DISTRIBUTION OF MEAN DISSOLVED OXYGEN LEVELS (MARCH 15-JULY 31)

DISSOLVED OXYGEN STANDARD FOR WARMWATER FISHERY

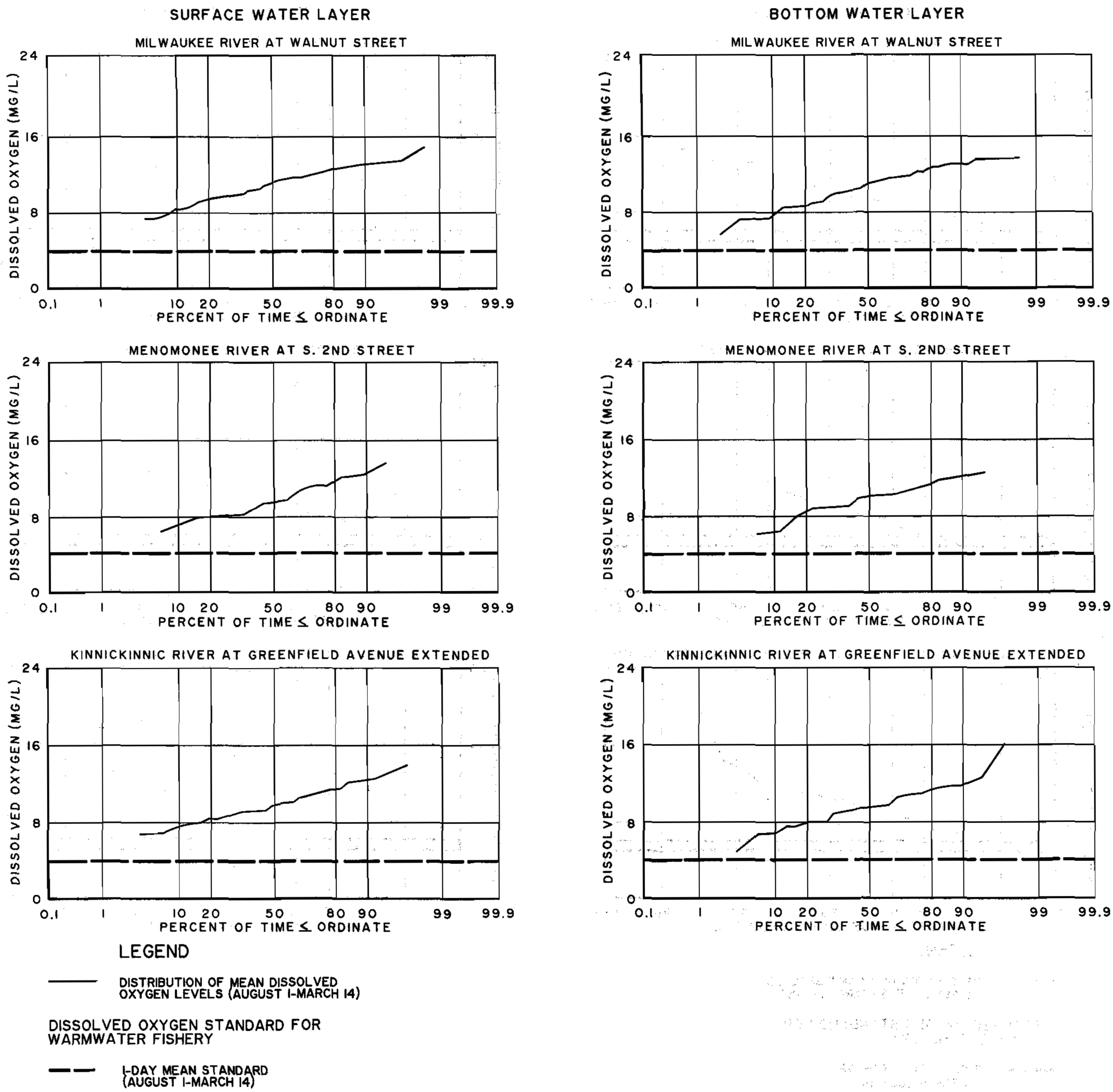
7-DAY MEAN STANDARD (MARCH 15-JULY 31)

1-DAY MEAN STANDARD (MARCH 15-JULY 31)

Source: HydroQual Inc., and SEWRPC.

Figure 112

ACHIEVEMENT OF THE 1-DAY MEAN DISSOLVED OXYGEN STANDARD UNDER THE RECOMMENDED PLAN: AUGUST 1-MARCH 14



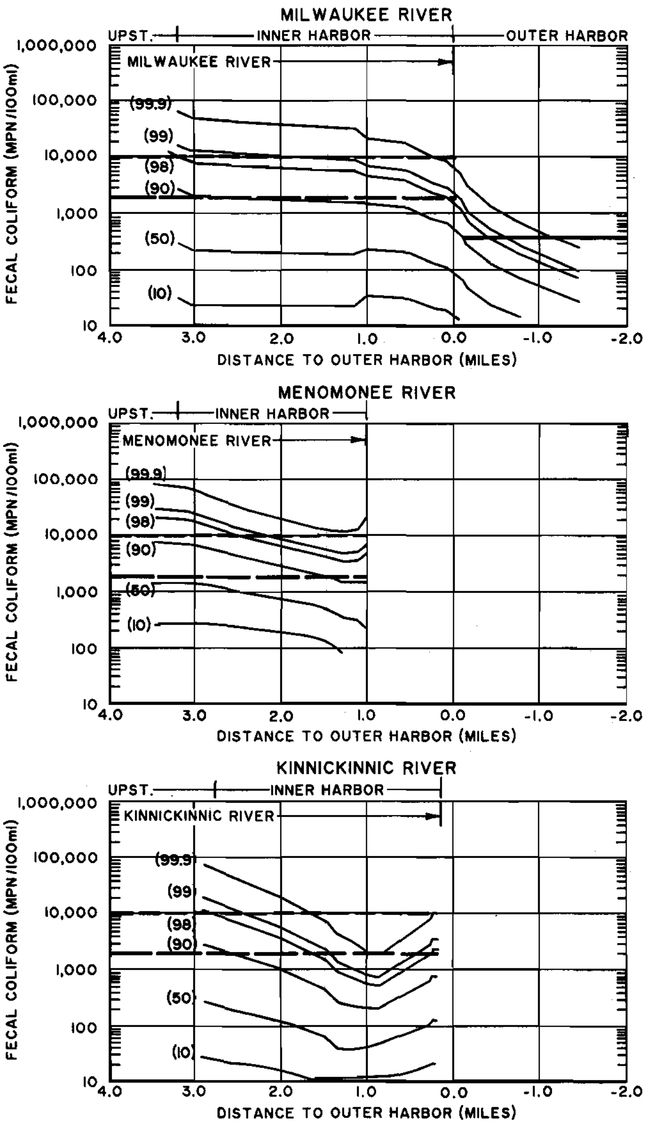
Source: HydroQual Inc., and SEWRPC.

nia nitrogen concentrations expected under the recommended plan is set forth in Table 67, along with a comparison of acute and chronic toxicity standards. The un-ionized ammonia nitrogen concentrations and acute and chronic toxicity standards were calculated in accordance with the procedures described in Chapter IV.

Upon implementation of the recommended plan and under low-flow, steady-state conditions, the estimated un-ionized ammonia nitrogen concentration may be expected to range from 0.009 to 0.022 mg/l at the upstream river stations, from 0.001 to 0.011 mg/l at the inner harbor stations, and from 0.002 to 0.009 mg/l at the outer harbor

Figure 113

ACHIEVEMENT OF THE FECAL COLIFORM STANDARDS UNDER THE RECOMMENDED PLAN



LEGEND

(99.9) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE:
OUTER HARBOR

——— LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 10 PERCENT OF THE TIME (400 MPN/100 ml)

LIMITED RECREATIONAL USE:
INNER HARBOR

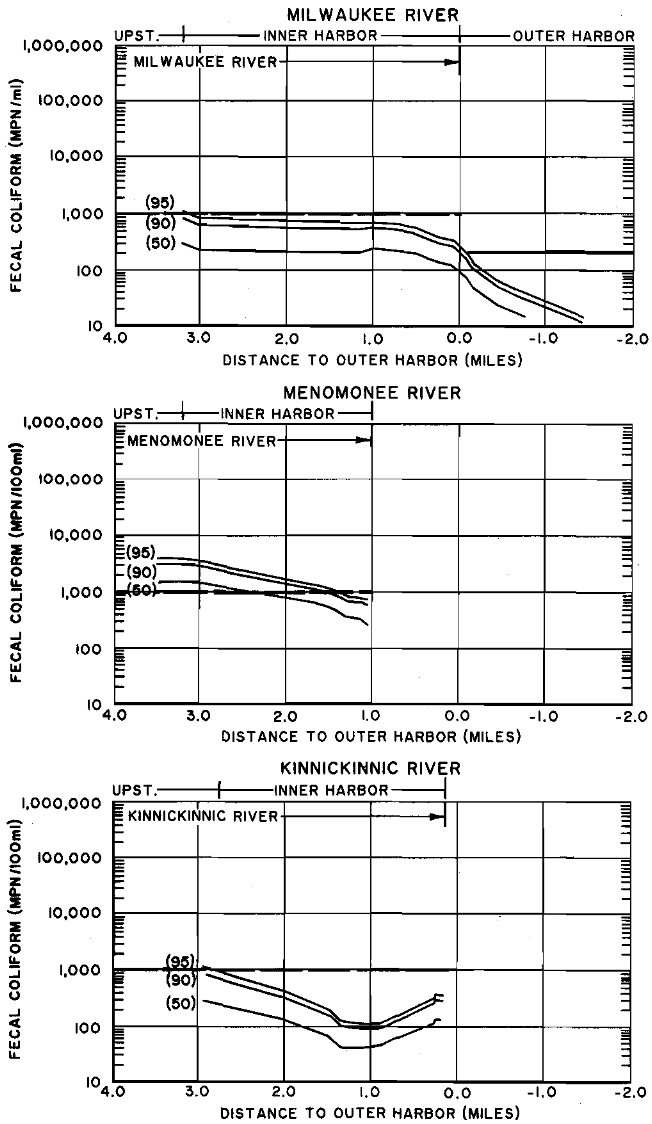
– – – LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 10 PERCENT OF THE TIME (2,000 MPN/100 ml)

—— LEVEL WHICH SHOULD NOT BE EXCEEDED MORE THAN 2 PERCENT OF THE TIME (10,000 MPN/100 ml)

Source: HydroQual Inc., and SEWRPC.

Figure 114

ACHIEVEMENT OF THE GEOMETRIC MEAN FECAL COLIFORM STANDARDS UNDER THE RECOMMENDED PLAN



LEGEND

(95) PERCENT OF TIME FECAL COLIFORM LEVELS WOULD BE LESS THAN INDICATED LEVEL

FULL RECREATIONAL USE::
OUTER HARBOR

——— LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH (200 MPN/100ML)

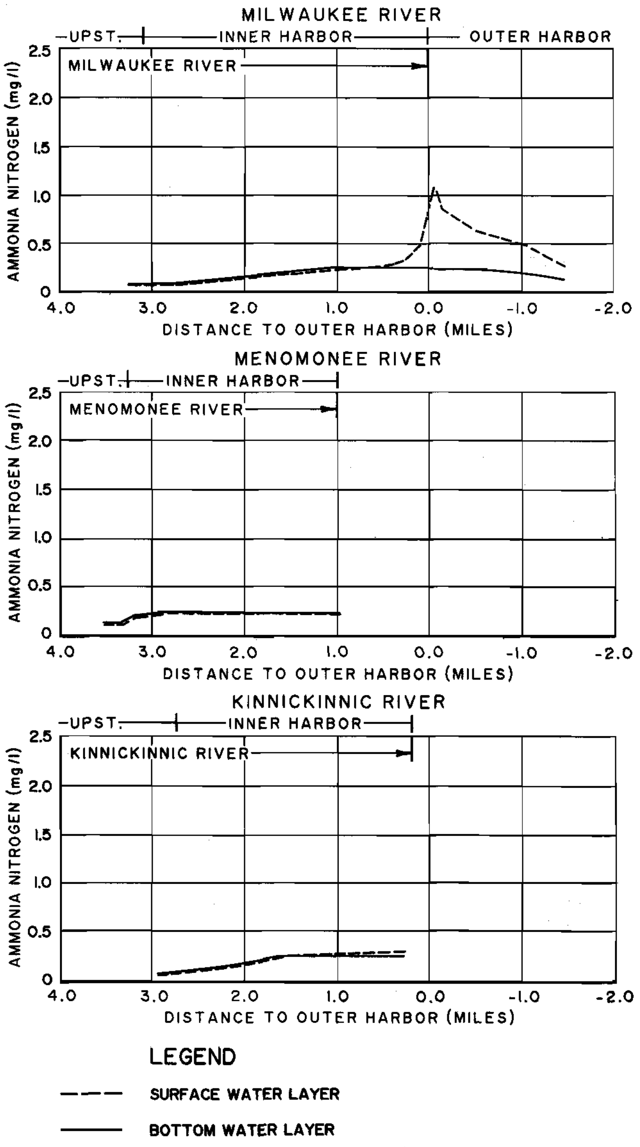
LIMITED RECREATIONAL USE:
INNER HARBOR

— — LEVEL WHICH SHOULD NOT BE EXCEEDED BY THE GEOMETRIC MEAN OF 5 SAMPLES PER MONTH MORE THAN 5 PERCENT OF THE TIME (1,000 MPN/100 ML)

Source: HydroQual Inc., and SEWRPC.

Figure 115

ESTIMATED AMMONIA NITROGEN LEVELS UNDER THE RECOMMENDED PLAN



Source: HydroQual Inc., and SEWRPC.

stations. The chronic and acute toxicity standards for un-ionized ammonia nitrogen would not be violated at any station. Although Table 67 indicates that standard violations would probably not occur within the outer harbor, occasional small violations of the chronic toxicity standards could occur within portions of the outer harbor during periods of higher pH levels.

The estimated distribution of lead concentrations in the surface and bottom water layers of the estuary under the recommended plan is presented in Figure 116. The median total lead levels, plus and minus one standard deviation of the logarithms of the data, are compared to chronic and acute toxicity standards for acid-soluble lead. The figure indicates that lead concentrations should not violate the toxicity standards at any station under the recommended plan.

As noted above, it is not possible at this time to determine whether implementation of the recommended plan would fully resolve the problem of contamination of the bottom sediments and biota with toxic substances other than lead. These toxic substances include selected metals and organic substances as described earlier in this chapter. As previously mentioned, a further study of toxic substances within the bottom sediments and the release of those substances to the overlying water column and to biota is recommended.

CONSEQUENCES OF NOT IMPLEMENTING THE RECOMMENDED COMPREHENSIVE PLAN FOR THE MILWAUKEE HARBOR ESTUARY

Within the framework of the overriding goals of the Milwaukee Harbor estuary water resources planning program—that is, the adopted objectives and standards—the recommended comprehensive plan for the estuary approaches the best combination of measures for: 1) resolving the existing problems of water pollution, flooding, sedimentation, shoreline and anchorage storm and flooding damage, and diminishing quality of the natural resource base; and 2) preventing the aggravation of existing or development of new water resource problems within the estuary. The recommended comprehensive plan for the Milwaukee Harbor estuary is based upon the most exhaustive inventories ever conducted of the water and sediments of the estuary; the application of state-of-the-art analytic tools to the inventory findings; careful examination of alternative plan elements and subelements; careful evaluation of the technical, economic, and environmental impacts of each alternative plan; and the preparation of a plan implementation strategy and of related capital and operating and maintenance costs, all of this work being subject to the scrutiny of the Technical Advisory Committee for the Milwaukee Harbor Estuary Comprehensive Water Resources Plan, a committee comprised of knowledgeable and concerned citizens and public officials.

In the absence of a sound, comprehensive plan, courses of action may be followed that will lead to the aggravation of existing water resource problems

Table 67

COMPARISON OF ESTIMATED UN-IONIZED AMMONIA NITROGEN CONCENTRATIONS TO THE RECOMMENDED ACUTE AND CHRONIC TOXICITY STANDARDS UNDER THE RECOMMENDED PLAN

Water Body	Baseline Sampling Station	Water Layer[a]	Total Ammonia Nitrogen[b] (mg/l)	pH[c] (standard units)	Temperature (°F)[c]	Un-ionized Ammonia Nitrogen[d] (mg/l)	Un-ionized Ammonia Nitrogen Toxicity Standards		Violation of Un-ionized Ammonia Nitrogen Toxicity Standards	
							Acute[e]	Chronic[e]	Acute	Chronic
Upstream										
Milwaukee River	North Avenue Dam (RIV-5)	DI	0.05	8.5	81	0.009	0.117	0.025	--	--
Menomonee River	S. 37th Street (RIV-10)	DI	0.15	8.5	75	0.022	0.116	0.025	--	--
Kinnickinnic River	S. 9th Place (RIV-13)	DI	0.05	8.9	84	0.019	0.121	0.025	--	--
Inner Harbor										
Milwaukee River	Walnut Street (RIV-6)	S	0.05	8.5	81	0.009	0.116	0.025	--	--
		B	0.05	8.4	81	0.008	0.115	0.025	--	--
	Wells Street (RIV-7)	S	0.05	8.0	79	0.003	0.102	0.025	--	--
		B	0.05	8.1	75	0.004	0.108	0.025	--	--
	Water Street (RIV-8)	S	0.06	7.9	79	0.003	0.098	0.025	--	--
		B	0.10	7.9	66	0.003	0.099	0.025	--	--
	C&NW Railway (RIV-15)	S	0.10	7.5	77	0.002	0.073	0.025	--	--
		B	0.15	8.1	64	0.007	0.105	0.025	--	--
Menomonee River	Muskego Avenue (RIV-11)	S	0.30	7.7	81	0.011	0.088	0.025	--	--
		B	0.30	7.5	72	0.004	0.077	0.025	--	--
	S. 2nd Street (RIV-17)	S	0.25	7.7	79	0.009	0.088	0.025	--	--
		B	0.25	7.7	72	0.007	0.090	0.025	--	--
Kinnickinnic River	S. 1st Street (RIV-14)	S	0.05	7.6	72	0.001	0.081	0.025	--	--
		B	0.05	7.6	72	0.001	0.081	0.025	--	--
	Greenfield Avenue Extended (RIV-18)	S	0.05	7.6	73	0.001	0.081	0.025	--	--
		B	0.10	7.6	64	0.002	0.081	0.025	--	--
	Jones Island (RIV-19)	S	0.10	7.6	73	0.002	0.083	0.025	--	--
		B	0.15	7.9	63	0.004	0.097	0.025	--	--
Outer Harbor	South OH (OH-11)	S	0.45	7.6	72	0.009	0.079	0.025	--	--
		B	0.20	7.6	57	0.002	0.083	0.025	--	--
	JI STP Plume (OH-2)	S	0.70	7.4	70	0.008	0.065	0.025	--	--
		B	0.20	7.9	61	0.005	0.097	0.025	--	--

NOTE: The existing Wisconsin Department of Natural Resources standard for un-ionized ammonia nitrogen specifies a maximum level of 0.04 mg/l for the full warmwater fishery and aquatic life water use objective. The Department has issued no standard for the limited fishery and aquatic life objective. The standard for the warmwater fishery and aquatic life objective is applied by the Department as a maximum not to be exceeded at any flow equal to or greater than the 7-day, 10-year minimum flow.

[a] *DI-Depth Integrated; S-Surface; B-Bottom.*

[b] *As estimated in Figure 115.*

[c] *Arithmetic mean pH and temperature levels measured during Survey Period 1, July 25 through August 8, 1983, under the baseline sampling program.*

[d] *The un-ionized ammonia nitrogen concentrations were calculated using the estimated total ammonia nitrogen, pH, and temperature levels.*

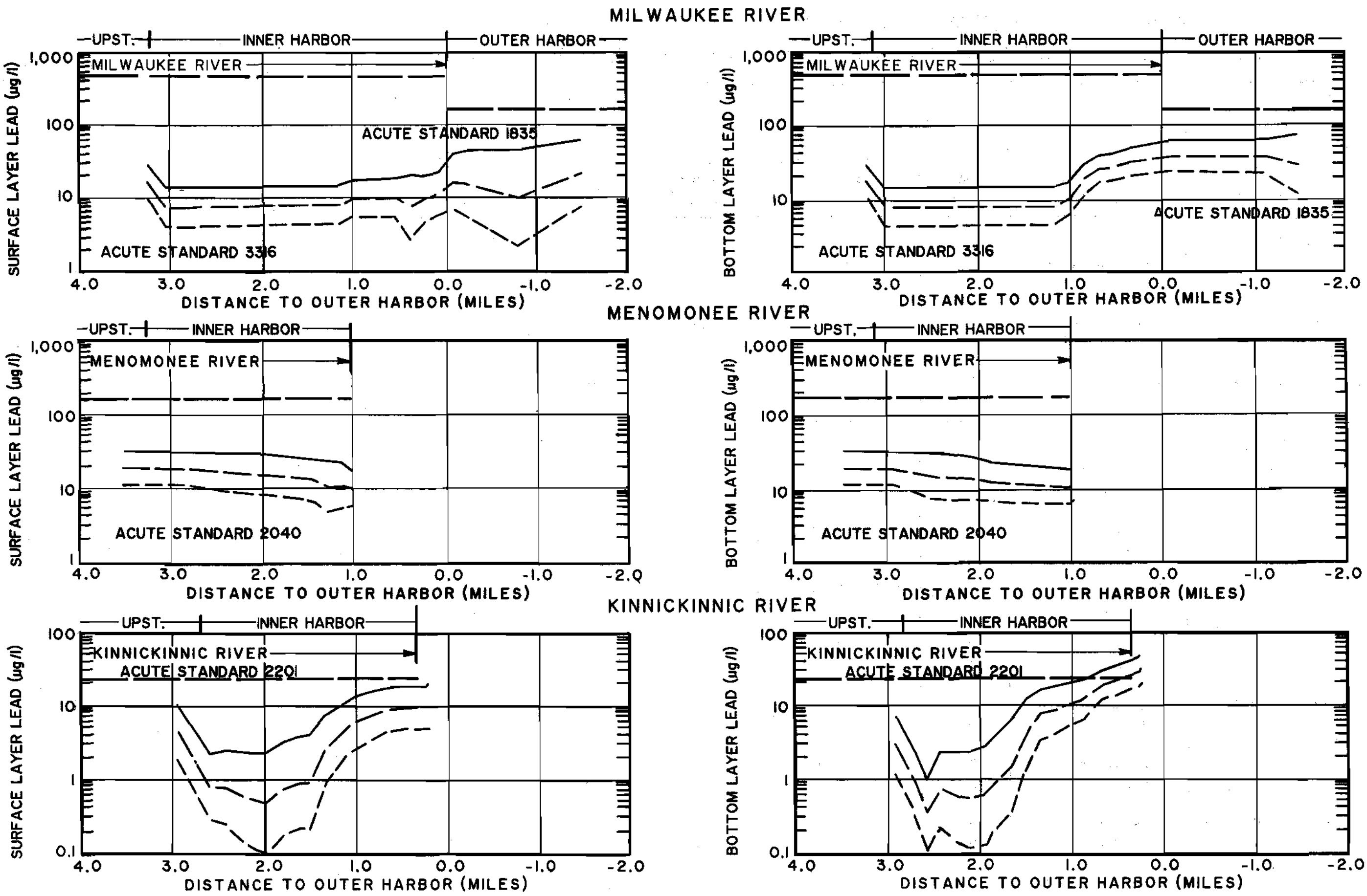
[e] *The acute and chronic toxicity standards, which vary in response to the pH and temperature of the water, were calculated in accordance with the procedures set forth in Chapter II of this volume.*

Source: SEWRPC.

and the development of new problems. Because the comprehensive plan for the Milwaukee Harbor estuary seeks to identify those courses of action most likely to provide lasting, cost-effective solutions to the water resource problems of the estuary and the prevention of future problems, it is appropriate to identify, and to the extent feasible quantify, the consequences of not adopting and implementing the recommendations of the comprehensive plan.

Figure 116

ACHIEVEMENT OF THE LEAD STANDARD FOR A WARMWATER FISHERY UNDER THE RECOMMENDED PLAN



LEGEND

STANDARDS

——— ACUTE MAXIMUM STANDARD

— — CHRONIC 30 DAY MEAN MAXIMUM STANDARD

LEAD PLOTS

——— MEDIAN PLUS ONE STANDARD DEVIATION OF THE LOGS (84TH PERCENTILE)

— — MEDIAN (50TH PERCENTILE)

- - - MEDIAN MINUS ONE STANDARD DEVIATION OF THE LOGS (16TH PERCENTILE)

NOTE: THE ACUTE AND CHRONIC STANDARDS APPLY TO ACID-SOLUBLE LEAD CONCENTRATIONS, WHEREAS THE PLOTS REPRESENT TOTAL LEAD CONCENTRATIONS. THUS, VIOLATION OF THE STANDARD DOES NOT NECESSARILY INDICATE THAT TOXIC CONDITIONS WOULD EXIST. THE ACUTE AND CHRONIC STANDARDS, WHICH ARE A FUNCTION OF THE HARDNESS OF THE WATER, WERE CALCULATED USING THE BASELINE HARDNESS LEVELS MEASURED FROM 1981 THROUGH 1983 AT THE REPRESENTATIVE SAMPLING STATIONS PRESENTED IN CHAPTER VI OF VOLUME ONE OF THIS REPORT.

Source: HydroQual Inc., and SEWRPC.

The analysis of the likely consequences of not implementing the recommended comprehensive plan for the Milwaukee Harbor estuary is based on further analyses of the data collected under the Milwaukee Harbor estuary planning program, and on empirical judgments based upon observation of the water resource problems that already exist within the seven-county Planning Region and which have been the subject of other Commission planning programs. The likely consequences of not implementing the recommended comprehensive plan for the Milwaukee Harbor estuary are summarized in Table 68. Within the overall framework of the four basic plan elements—the water quality management plan element, the dredging and dredged material disposal plan element, the shore-

Table 68

PROBABLE CONSEQUENCES OF NOT IMPLEMENTING THE RECOMMENDED COMPREHENSIVE WATER RESOURCES PLAN FOR THE MILWAUKEE HARBOR ESTUARY

Plan Element	Plan Subelement	Probable Consequences of Failure to Implement Plan Recommendations
Water Quality Management	Abatement of combined sewer overflows at a 0.7-year level of protection and abatement of sanitary sewer overflows	• Continued surface water pollution problems in the estuary • Continued high sedimentation rates and dredging costs • Continued aesthetic water quality problems in the estuary
	Nonpoint source pollution control measures	• Continued watershedwide surface water quality degradation during and immediately after runoff events, as well as during low-flow periods
	Operation of existing flushing tunnels	• Continued periodic water quality problems, including substandard dissolved oxygen levels in the Milwaukee and Kinnickinnic River estuaries • Continued surface water aesthetic problems in the Kinnickinnic and Milwaukee River estuaries
	Instream aeration of the Menomonee River estuary	• Continued periodic water quality problems with regard to dissolved oxygen levels in the Menomonee River estuary
	Salt and scrap metal storage area modification	• Continued concentrated discharge of stormwater with high concentrations of chloride and metals
	Water quality monitoring program	• Lack of data for use in documenting the impact of watershed development on water quality, and the benefits of the water quality management measures implemented
Dredging and Dredged Material Storage	New confined disposal facility	• Potential dredging limitations due to lack of available dredged material disposal sites
Shoreline Storm Damage and Flood Protection	Anchorage areas and shoreline high-water and flood protection planning	• Continued flooding and high-water damage risk potential if Lake Michigan levels are in a long-term rising trend
	Ice control system	• Continued damage to piers in McKinley anchorage area • No available in-water winter storage
Toxic Substances Management	Toxic substances management study	• Continued but reduced toxic conditions and accumulation of certain metals and organic substances in aquatic life

Source: SEWRPC.

Table 69

COMPARISON OF WATER QUALITY CONDITIONS UNDER NO ACTION, COMMITTED ACTION, AND RECOMMENDED PLAN IMPLEMENTATION CONDITIONS

Water Quality Indicator	Estuary Water Body	No Action	Committed Action		Recommended Plan	
		Concentration	Concentration	Percent Improvement Over No Action	Concentration	Percent Improvement Over No Action
Minimum Dissolved Oxygen Under Low-Flow, Steady-State Conditions (mg/l)	Milwaukee River	1.0	1.5	50	6.0	500
	Menomonee River	1.0	2.5	250	6.0	600
	Kinnickinnic River	1.0	4.5	450	6.0	600
	Outer Harbor	4.0	7.0	75	7.0	75
Mean Fecal Coliform at the Upper End of Estuary (MPN/100 ml)	Milwaukee River	1,070	460	57	300	72
	Menomonee River	5,020	2,350	53	1,600	68
	Kinnickinnic River	1,240	700	44	300	76
Mean Fecal Coliform Within Estuary (MPN/100 ml)	Milwaukee River	12,000	500	96	200	98
	Menomonee River	23,000	2,000	91	1,000	96
	Kinnickinnic River	25,000	500	98	150	99
	Outer Harbor	5,600	100	98	100	98
Mean Ammonia Nitrogen Under Low-Flow, Steady-State Conditions (mg/l)	Upper Milwaukee River	0.25	0.15	40	0.05	80
	Lower Milwaukee River	1.0	0.25	75	0.10	90
	Upper Menomonee River	0.5	0.25	50	0.25	50
	Lower Menomonee River	1.7	0.30	82	0.30	82
	Upper Kinnickinnic River	0.5	0.25	50	0.05	90
	Lower Kinnickinnic River	1.4	0.30	79	0.10	93
	Outer Harbor	0.60	0.60	0	0.60	0
Approximate Lead Concentration in the Bottom Sediments (mg/kg dry weight)	Inner Harbor	550	240	56	200	64

NOTE: Only a single set of values has been provided for dissolved oxygen, fecal coliforms, and lead because the concentrations and percent improvement are relatively constant for each river system. Ammonia nitrogen data are provided for two locations in each of the three river systems since the concentrations and percent improvement vary significantly from the upper to the lower reaches of the estuary portion of the rivers.

Source: SEWRPC.

line storm damage and flood protection plan element, and the toxic substances management plan element—Table 68 identifies each plan subelement and some likely consequences of failure to implement those subelements.

The water quality conditions expected under the recommended plan are compared to the conditions expected under the committed action alternative and under a no action alternative in Table 69. The table helps quantify the consequences of implementing only previously committed measures, as well as the consequences of taking no action whatsoever to abate water pollution. The no action alternative would result essentially in a continuation of existing water quality conditions. The effects on levels of dissolved oxygen, fecal coliform, ammonia nitrogen, and lead are presented in the table. Under the no action and committed action alternatives, the estimated dissolved oxygen levels and fecal coliform levels would violate existing and proposed standards, while under the recommended plan, only minor violations of the fecal coliform standards would still occur. Compared to the no action alternative, the recommended plan would result in a 75 to 600 percent improvement in dissolved oxygen levels; a 68 to 99 percent reduction in fecal coliform levels; a 50 to 93 percent reduction in ammonia nitrogen levels within the inner harbor; and a reduction of about 64 percent in the lead levels in the bottom sediments of the inner harbor. Because of continued large discharges of ammonia nitrogen from the Jones Island sewage treatment plant to the outer harbor, all three plans would result in similar concentrations of ammonia nitrogen within the outer harbor.

Chapter VIII

PLAN IMPLEMENTATION

INTRODUCTION

The recommended comprehensive water resources plan for the Milwaukee Harbor estuary, as described in Chapter VII of this report, provides a design for the attainment of the water resources objectives formulated under the Milwaukee Harbor estuary study. The final estuary plan consists of four major elements: 1) a water quality management element composed of various point and nonpoint source and instream pollution abatement measures; 2) a dredging and dredged material disposal element; 3) a shoreline storm damage and flood protection element; and 4) a toxic substances management element.

While the recommended comprehensive water resources plan for the Milwaukee Harbor estuary is designed to attain, to the extent practicable, the agreed-upon water resources objectives, the plan is not complete in a practical sense until the steps required to implement the plan—that is, to convert the plan into action policies and programs—are specified. This chapter provides that specification and is intended for use as a guide in the implementation of the Milwaukee Harbor estuary plan. Actions which must be taken by the various levels and agencies of government concerned if the recommended comprehensive plan is to be fully carried out by the design year 2000 are outlined. Those units and agencies of government that have plan adoption and plan implementation powers relevant to implementation of the Milwaukee Harbor estuary plan are identified; necessary or desirable formal plan adoption actions are specified; and specific implementation actions are recommended for each of the units and agencies of government concerned with the four plan elements and associated subelements of the comprehensive Milwaukee Harbor estuary plan.

PRINCIPLES OF PLAN IMPLEMENTATION

The plan implementation recommendations contained in this chapter are, to the maximum extent possible, based upon and related to the existing governmental structure and 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 organizations, and tax and fiscal policies, it is not possible to declare once and for all time precisely how the process of implementing the Milwaukee Harbor estuary plan should be administered and financed. In the continuing planning and plan implementation programs involving the estuary, it will be necessary, therefore, to periodically update not only the plan elements and the data and forecasts on which these plan elements are based, but the recommendations contained herein for plan implementation.

Distinction Between the Systems Planning, Preliminary Engineering, and Final Design and Construction Phases of the Public Works Development Process

The planning process used to prepare the Milwaukee Harbor estuary plan constituted the first, or systems planning, phase of what may be regarded as a three-phase public works development process. For those plan elements requiring physical facility construction, preliminary engineering is the second phase in this sequential process, with final design being the third and last phase prior to actual construction. The public works planning and development process is an iterative one and, in fact, the Milwaukee Harbor estuary study represents a third iteration of the system planning process, dealing with the management of the water resources of the greater Milwaukee area, and particularly, the harbor estuary. The first iteration was represented by the Milwaukee, Menomonee, and Kinnickinnic River watershed studies, and the second by the areawide water quality management planning effort. Each iteration followed implementation efforts and resulted in refinements to the plans presented in the earlier iterations. To a certain extent, the successive system planning iterations also represent implementation actions growing out of preceding efforts.

Since no additional facilities were found necessary in this system for point source pollution control—the abatement of combined and separate sanitary sewer overflows—no second and third phases beyond those already completed or underway by the Milwaukee Metropolitan Sewerage District are required. The system level planning in this case represented a third iteration of the planning process which was required to determine the adequacy of facilities that had been proposed in the first iteration of the cycle. That cycle began with the Commission's Milwaukee River watershed study and was continued in the areawide water quality management planning effort. Facilities recommended in those system planning efforts were subsequently carried through the second and third phases by the Milwaukee Metropolitan Sewerage District. For many reasons, the three-phase public works development process does not always proceed in a simple, linear fashion. In some situations, the iterative process leads to a reexamination of an earlier step. Changing federal and state regulations and guidelines can also disrupt the process. This is particularly true if a significant change in those regulations and guidelines occurs subsequent to the systems planning phase and prior to or during the preliminary engineering phase, thus necessitating an iteration to the systems planning phase to reconsider measures studied during that phase or to analyze additional measures as may be necessitated by regulation and guideline changes. During the passage of time between the systems planning phase and the final engineering phase, significant changes may occur in the explicitly stated or implicitly expressed values and objectives of elected officials and concerned citizens. In an environment of changing values and objectives, a solution to an environmental problem that was originally accepted as optimal, based on systems planning techniques and an agreed-upon set of objectives, could later encounter opposition to implementation, necessitating another iteration to the systems planning phase.

PLAN IMPLEMENTATION ORGANIZATIONS

Since the recommendations contained in the Milwaukee Harbor estuary plan are advisory, implementation of the recommended plan is entirely dependent upon action by certain local, areawide, state, and federal units and agencies of government. Such units and agencies range from general-purpose local units of government, such as counties and cities, to areawide special-purpose districts, such as the Milwaukee Metropolitan Sewerage District, to state regulatory bodies, such as the Wisconsin Department of Natural Resources, and to federal agencies, such as the U. S. Army Corps of Engineers. It is, accordingly, important to identify those agencies having the legal authority and financial capability to most effectively implement the recommended plan elements. The following section identifies those agencies whose actions will have a significant effect upon the successful implementation of the recommended Milwaukee Harbor estuary plan and whose full cooperation in plan implementation will be essential:

1. Southeastern Wisconsin Regional Planning Commission

   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 Milwaukee Harbor estuary plan, and to undertake plan updating and renovation as necessitated by changing events. Although the Regional Planning Commission can perform this continuing areawide planning function for plans covering regional or subregional areas such as the watersheds tributary to the Milwaukee Harbor estuary, it cannot do so without being called upon by, and without the active participation and support of, the state and local governmental officials concerned.

2. Milwaukee Harbor Commission

   Under Chapter 30 of the Wisconsin Statutes, municipalities having navigable waters within or adjoining its boundaries may, through a board of harbor commissioners, exercise powers to make harbor improvements, repairs, or alterations, and to participate in leasing and operation of harbor facilities. The City of Milwaukee, through its Board of Harbor Commissioners, owns and operates the public harbor facilities comprising the Port of Milwaukee. The maintenance of those facilities was an important consideration in both the dredging and dredged material disposal element and the shoreline storm damage and flood protection element of the recommended plan. Thus, the Board of Harbor Commissioners has important plan implementation functions.

3. Milwaukee County

   Operating through the Milwaukee County Park, Recreation and Culture Committee of the County Board of Supervisors, the Milwaukee County Department of Parks, Recreation and Culture is responsible for the acquisition, development, operation, and maintenance of parks and parkways and of related recreational facilities. Of particular importance in this respect is the operation of the McKinley Marina within the outer harbor. Implementation of those aspects of the shoreline storm damage and flood protection element of the Milwaukee Harbor estuary plan pertaining to the McKinley Marina will, therefore, depend upon action by the Milwaukee County Board of Supervisors. In addition, the Board, operating through its Land Conservation Committee, is the agency responsible for working with the Wisconsin Department of Natural Resources in implementing nonpoint source pollution control measures.

4. Milwaukee Metropolitan Sewerage District

The Milwaukee Metropolitan Sewerage Commission, which operates pursuant to the provisions of Sections 66.88 through 66.918 of the Wisconsin Statutes, has the power to plan, design, and construct sewage treatment plants, main and intercepting sewers, and pumping stations for the collection, transmission, treatment, and disposal of domestic, industrial, and other sanitary sewage generated within the Milwaukee Metropolitan Sewerage District and adjacent contract service areas. The District consists of all of Milwaukee County except the City of South Milwaukee and portions of the Cities of Franklin and Oak Creek, and those portions of the City of Milwaukee and the Village of Bayside in Washington and Ozaukee Counties, respectively. The Milwaukee Metropolitan Sewerage Commission, furthermore, may improve any watercourse within the District by deepening, widening, or otherwise changing the watercourse where such change is deemed necessary to carry off surface or drainage waters. However, the applicability of the provisions of Section 30.20 of the Wisconsin Statutes to watercourses within the District must be resolved.

5. Wisconsin Department of Natural Resources

The Wisconsin Department of Natural Resources has broad authority and responsibility in the areas of park development, natural resources protection, water quality control, and water regulation. Pursuant to federal planning guidelines, the Secretary of the Department is responsible for certifying areawide plans for water quality management to the U. S. Environmental Protection Agency. Without such certification and subsequent acceptance, local units of government within the watersheds tributary to the Milwaukee Harbor estuary would lose their eligibility for federal grants-in-aid for the construction of sewerage facilities.

The responsibility for water pollution control in Wisconsin rests with the Wisconsin Department of Natural Resources. The water pollution control authority and responsibilities of the Department are set forth in Chapter 144 of the Wisconsin Statutes. Under this chapter, the Department is given broad authority to prepare water use objectives and supporting water quality standards; to issue general and specific orders relating to water pollution abatement; to review and approve all plans and specifications for components of sanitary sewerage systems; to conduct research and demonstration projects on sewerage and waste treatment matters; to operate an examining program for the certification of sewage treatment plant operators; to order the installation of centralized sanitary sewerage systems; to review and approve the creation of joint sewerage systems and metropolitan sewerage districts; and to administer a financial assistance program for the construction of pollution prevention and abatement facilities.

In addition, under Chapter 147 of the Wisconsin Statutes, the Department is given broad authority to establish and carry out a pollutant discharge elimination program in accordance with the policy guidelines set forth by the U. S. Congress under the Federal Water Pollution Control Act Amendments of 1972. This legislation establishes a waste discharge permit system and provides that no permit may be issued by the Department for any discharge from a point source of pollution that is in conflict with any approved areawide wastewater treatment and water quality management plan. Also, under this legislation, the Department is given rule-making authority to establish effluent limitations, water quality limitations, performance standards related to classes or categories of pollution, and toxic and pretreatment effluent standards. All permits issued by the

Department must include the conditions that water discharges must meet, as applicable, all effluent limitations, performance standards, effluent prohibitions, and pretreatment standards, and any other limitations which must be met to comply with the established water use objectives and supporting water quality standards as developed under areawide waste treatment management planning programs. As appropriate, the permits may require periodic water quality monitoring to determine compliance, and may include a timetable for appropriate action on the part of the owner or operator of any point waste discharge. This legislation, along with accompanying procedures, is the primary tool used by the Department to achieve the water use objectives and supporting water quality standards.

The Department has responsibility for establishing standards for floodplain, wetland, and shoreland zoning and the authority to adopt, in the absence of satisfactory local action, shoreland, wetland, and floodplain zoning ordinances. The Department also has the authority to regulate water diversions, shoreland grading, dredging, encroachments, and deposits in navigable waters; the construction of neighboring ponds, lagoons, waterways, stream improvements, and pierhead and bulkhead lines; the construction, maintenance, and abandonment of dams; and water levels of navigable lakes and streams and lake and stream improvements, including the removal of certain lakebed materials. The Department also exercises regulatory and management authorities regarding wetlands, particularly the joint state-county-local zoning of wetlands in shoreland areas. The latter responsibilities require the Department to evaluate wetland impacts associated with sanitary sewer extensions, dredging and filling, the construction of dams and bridges, and stream course alteration. In addition, land acquisition programs should emphasize acquisition of high-value wetlands; enforcement activities regarding unlawfully altered wetlands should, to the extent practicable, require restoration; and the avoidance of use or minimal use of wetlands should be advocated in liaison activities with federal, state, and local units and agencies of government. The Department also has authority to require the abatement of water pollution; to administer state financial aid programs for water resource protection; to assign priority for federal aid applications for sewerage facilities; to review and approve water supply and sewerage systems; and to license well-drillers and issue permits for high-capacity wells.

State level regulatory authorities for all types of solid waste generated in the State lies with the Department. Chapter 144 of the State Statutes authorizes the Department to establish minimum standards for solid waste management functions in its disposal of hazardous waste, and provides for the identification of hazardous waste, for an analysis of the hazardous waste situation in the State, and for regulation of the transportation, storage, treatment, and disposal of hazardous waste. Waste types which are regulated by the Department include garbage, refuse, demolition material, sludges, and fly ash. The Department has also established procedures and requirements for dredging activities and dredged material disposal.

The Department of Natural Resources thus has broad authority for the protection of the natural resources of the State and the Region. The Department will be a key agency in the implementation of all of the major elements of the Milwaukee Harbor estuary plan.

6. Wisconsin Department of Transportation

The Department of Transportation has responsibility for establishing standards for the storage of highway deicing salt for the purpose of protecting the waters of the State from contamination by dissolved chlorides. The standards address various types of salt storage facilities, the quantities of highway salt used, and the times during the year when salt is used. Among the requirements are that the salt be stored on an impermeable base to minimize groundwater contamination, that stormwater runoff be diverted away from the storage facilities, that the salt be covered or placed in a building, and that the salt not be stored within 50 feet of a lake or stream. As an alternative to the placement in a building, the salt can be covered by an impermeable, water-resistent covering such as a tarp or plastic sheeting. The Department has the authority to enforce these standards.

7. U. S. Environmental Protection Agency

The U. S. Environmental Protection Agency (EPA) administers water quality management planning grants and sanitary sewerage facility construction grants. The latter are particularly important to implementation of the water quality management element of the Milwaukee Harbor estuary plan. In addition, the EPA is responsible for the ultimate achievement and enforcement of water quality standards for all interstate waters, should the states not adequately enforce such standards. In this respect, the EPA has delegated responsibility for the administration of the National Pollutant Discharge Elimination System permit issuance process in Wisconsin to the Wisconsin Department of Natural Resources. Under guidelines promulgated by the U. S. Environmental Protection Agency, areawide water quality management and sanitary sewerage facility plans must be prepared as prerequisites to the receipt of federal capital grants in support of sewerage works construction.

8. Federal Emergency Management Agency

The Federal Emergency Management Agency is the primary federal agency responsible for managing emergencies, including flooding emergencies. The agency provides technical assistance programs to state and local governments to reduce or eliminate flood risks, and administers programs to assist individuals and businesses in obtaining insurance protection against floods. In order to ensure that its residents are eligible for the purchase of flood insurance, local communities must ensure that the local floodland zoning regulations meet the minimum standards set forth in rules published by the Federal Emergency Management Agency.

9. U. S. Army Corps of Engineers

The U. S. Army Corps of Engineers is the principal federal water resources regulatory and development agency. Within the Great Lakes basin, the Corps plans, designs, and constructs flood control projects, navigation channels, harbors, and protective works for the prevention of beach and shore erosion. The Corps is also responsible for the operation and maintenance of numerous navigation channels and harbors. Because of its long history and expertise, the Corps of Engineers frequently is assigned responsibilities for the conduct of technical studies. As such, the Corps is an important planning and management agency in the Great Lakes basin. The Corps of Engineers provides monthly bulletins of lake levels and a six-month forecast of lake levels.

The U. S. Army Corps of Engineers can conduct planning studies and construct flood control facilities as authorized by the U. S. Congress. The Corps also administers a regulatory program relating to the discharge of dredge and fill materials into the waters of the United States and adjacent wetlands. This program is administered pursuant to Section 404 of the Federal Water Pollution Control Act as amended in 1972. The Corps of Engineers also maintains the federal channels in the Milwaukee Harbor estuary at established project depths and constructs dredge material disposal facilities. In view of this broad range of responsibilities on Lake Michigan, the Corps of Engineers is an important agency in the implementation of the dredging and dredged material disposal element and the shoreline storm damage and flood protection element of the Milwaukee Harbor estuary plan.

PLAN ADOPTION AND INTEGRATION

Upon adoption of the Milwaukee Harbor estuary plan by 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 plan, together with the plan itself, to the federal, state, areawide, and local units and agencies of government that have potential plan implementation functions. Adoption, endorsement, or formal acknowledgement of the comprehensive plan by the units and agencies of government concerned is highly desirable to assure a common understanding among the several governmental levels, and to enable their staffs to program the necessary implementation work. In this respect, it should be noted that adoption of the recommended Milwaukee Harbor estuary plan by any unit or agency of government pertains only to the statutory duties and functions of the adopting agencies, and 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.

Upon adoption or endorsement of the Milwaukee Harbor estuary 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 plan, and propose to the policy-making body for its consideration and approval the actions required to implement the adopted plan.

Local Level Agencies

1. It is recommended that the Milwaukee County Board of Supervisors formally adopt the Milwaukee Harbor estuary plan by resolution, pursuant to Section 66.945(12) of the Wisconsin Statutes, after the issuance of a report and recommendation by the County Parks, Recreation and Culture Committee and the County Land Conservation Committee.

2. It is recommended that the Common Council of the City of Milwaukee adopt the Milwaukee Harbor estuary plan by resolution, pursuant to Section 66.945(12) of the Wisconsin Statutes, after the issuance of a report and recommendation by the Public Improvements Committee, the City Plan Commission, and the Harbor Commission.

Areawide Agencies

It is recommended that the Milwaukee Metropolitan Sewerage Commission adopt the recommended Milwaukee Harbor estuary plan as the plan affects the work of that Commission.

State Level Agencies

It is recommended that the Wisconsin Natural Resources Board adopt the comprehensive Milwaukee Harbor estuary plan as an amendment to the previously adopted areawide water quality management plan, certify the plan to the U. S. Environmental Protection Agency through the Governor as an amendment to the areawide water quality management plan, and direct the staff of the Wisconsin Department of Natural Resources to integrate the recommended Milwaukee Harbor estuary plan into its broad range of agency responsibilities, as well as to promote plan implementation. In particular, it is recommended that the Board, through its staff, coordinate the recommended Milwaukee Harbor estuary plan with those activities relating to water regulation and control; floodland, shoreland, and wetland zoning; and water quality management planning and water pollution abatement activities.

Federal Level Agencies

1. It is recommended that the U. S. Environmental Protection Agency formally accept and endorse the Milwaukee Harbor estuary plan as an amendment to the areawide water quality management plan upon certification as such by the State of Wisconsin.

2. It is recommended that the Federal Emergency Management Agency formally acknowledge the Milwaukee Harbor estuary plan, and use the floodland data in that plan as a basis for reviewing and updating its series of federal flood insurance studies for the City of Milwaukee.

3. It is recommended that the U. S. Army Corps of Engineers formally acknowledge the Milwaukee Harbor estuary plan. It is further recommended that the Corps cooperate with any local or state units and agencies of government requesting assistance in the review, design, and construction of the dredging and dredged material disposal element and the shoreline storm damage and flood protection element of the recommended Milwaukee Harbor estuary plan.

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 for an areawide plan, such as the comprehensive water resources management plan for the Milwaukee Harbor estuary, to be viable and of use to local, state, and federal units and agencies of government, the plan must be adjusted from time to time through formal amendments, extensions, additions, and refinements to reflect changing conditions. Amendments, extensions, and additions to the Milwaukee Harbor estuary plan may be forthcoming not only from the Regional Planning Commission under various 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, 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 plan.

All these adjustments and refinements will require the cooperation of the local, areawide, state, and federal agencies of government, as well as coordination by the Southeastern Wisconsin Regional Planning Commission. To achieve this coordination between local, state, and federal programs most effectively and efficiently, and therefore to assure timely adjustments of the plan, it is recommended that all the federal, state, areawide, and local agencies concerned transmit all subsequent planning studies and plan proposals and amendments to the Regional Planning Commission for consideration and comment.

The Technical Advisory Committee for the Milwaukee Harbor Estuary Comprehensive Water Resources Management Plan—or more likely a successor committee—should be reconvened to consider any significant proposed amendments to the adopted plan. The Committee should determine whether a public hearing is needed for such changes, and advise the Commission, and through the Commission advise the concerned levels, units, and agencies of government, on the acceptability of the proposed amendments.

WATER QUALITY MANAGEMENT PLAN ELEMENT IMPLEMENTATION

The major water quality management recommendations of the Milwaukee Harbor estuary plan relate to the abatement of pollution from sanitary and combined sewer overflows, the abatement of pollution from nonpoint sources, the use of instream water quality management measures, and the conduct of a monitoring program covering water quality, sediment quality, and biological conditions. The recommended implementation actions discussed under this plan element are summarized in Table 70. The capital and operation and maintenance costs of this plan element are set forth in Table 71 by implementing agency.

Point Source Pollution Abatement Subelement

The point source pollution abatement plan subelement provides for the abatement of pollution from sanitary and combined sewer overflows. It is recommended that the Milwaukee Metropolitan Sewerage Commission continue to carry out the water pollution abatement program presently being implemented for the Milwaukee Metropolitan Sewerage District and its contract sewer service areas. That pollution abatement program presently envisions the construction, operation, and maintenance of a deep tunnel, online storage and conveyance system which will provide the primary means of abatement of pollution from combined and sanitary sewer overflows at a 0.7-year level of protection, and the abatement—virtual elimination—of pollutant discharges from all separate sanitary sewer flow relief devices within the tributary watersheds. The implementation of this subelement would provide for the abatement of combined sewer overflows by the measures recommended in the Regional Planning Commission's Milwaukee River watershed plan, adopted in 1972, and areawide water quality management plan, adopted in 1979, as those recommendations were subsequently refined and detailed in the facility planning efforts conducted by the Milwaukee Metropolitan Sewerage District.

In order to abate pollutant discharges from the sanitary and combined sewer overflows, each local unit of government in the Milwaukee Metropolitan Sewerage District service area will need to continue to work cooperatively with the Milwaukee Metropolitan Sewerage District to identify and eliminate the discharges from all existing points of flow relief. This will, in some cases, require the construction of local relief sewers as recommended in the areawide water quality management plan.

Nonpoint Source Pollution Abatement Subelement

As noted in Chapter VII, the nonpoint source pollution abatement plan subelement provides for no additional recommendations over and above those called for in the areawide water quality management plan as needed to achieve water quality objectives in the reaches of the Kinnickinnic, Menomonee, and Milwaukee Rivers upstream of the Milwaukee Harbor estuary. This subelement of the plan recommends provision for implementation measures in both the rural and urban areas of the tributary watershed areas. With regard to rural nonpoint source pollution abatement measures, a level approximating 50 percent of the maximum achievable level is recommended. Such a program would include application of measures to control both livestock waste and agricultural land runoff. With regard to nonpoint source pollution control in urban areas, it was concluded that only construction erosion control measures should be included in the recommended plan because of the modest costs entailed and the potential effectiveness in improving water quality within the Milwaukee Harbor estuary.

Since this subelement of the plan does not include any new recommendations, no additional implementing agencies have been identified. The non-

Table 70

SUMMARY OF MILWAUKEE HARBOR ESTUARY PLAN ELEMENTS AND PRIMARY IMPLEMENTING ORGANIZATIONS

Action or Plan Element	Responsible Unit of Government										
	Milwaukee Metropolitan Sewerage District	Wisconsin Department of Natural Resources	Wisconsin Department of Transportation	U. S. Army Corps of Engineers	Cities and Villages in Milwaukee Metropolitan Sewerage District and Its Contract Service Areas	City of Milwaukee	Private Riparian Owners Requiring Maintenance Dredging Adjacent to Docks or New Construction	Milwaukee County	Milwaukee Yacht Club	Identified in Ongoing Study Design	U. S. EPA and FEMA
Plan Adoption/Endorsement	X	X	X	X	--	X	--	X	--	--	X
Water Quality Management Element											
Abatement of Combined Sewer Overflows	X[a]	--	--	--	--	--	--	--	--	--	--
Elimination of Pollutant Discharge from Separate Sanitary Sewer Flow Relief Devices	X[a]	--	--	--	X[a]	--	--	--	--	--	--
Nonpoint Source Pollution Abatement	--	X[b]	--	--	--	--	--	--	--	--	--
Instream Water Quality Measures											
1. Existing Flushing Tunnel Operations	X	--	--	--	--	--	--	--	--	--	--
2. Menomonee River Aeration System	X	--	--	X	--	--	--	--	--	--	--
Auxiliary Plan Elements											
1. Water Quality, Sediment Quality, and Biological Conditions Monitoring	X	X	--	--	--	--	--	--	--	--	--
2. Salt and Material Storage Area Runoff Control	--	X[c]	X	--	--	--	--	--	--	--	--
Dredging and Dredged Material Disposal Element											
Dredging for Navigation and New Construction	--	--	--	X[d]	--	X	X	--	--	--	--
New Dredged Material Disposal											
1. Existing Confined Disposal Facility	--	--	--	X[d]	--	--	--	--	--	--	--
2. New Confined Disposal Facility	--	--	--	X	--	--	--	--	--	--	--
Shoreline Storm Damage and Flood Protection Element											
Ice Control in McKinley Anchorage Area	--	--	--	X	--	--	--	X	X	--	--
Inner Harbor High Water and Flood Protection	--	--	--	--	--	--	--	--	--	X	--
Toxic Substances Management Plan Element	X	X	--	--	--	--	--	--	--	--	--

[a]Previously committed measure ongoing as part of the Milwaukee Metropolitan Sewerage District pollution abatement program.

[b]Includes detailed second level planning partially committed as part of ongoing Milwaukee and Menomonee River Priority Watersheds Program.

[c]Recommended to be included as part of the Wisconsin Department of Natural Resources Nonpoint Source Priority Watersheds Program.

[d]Includes maintenance dredging for navigation previously committed as part of ongoing commercial shipping system.

Source: SEWRPC.

point source programs would be carried out by the county land conservation committees and the local units of government within the tributary watersheds, as recommended in the areawide water quality management plan. The implementation would entail participation in the Wisconsin Nonpoint Source Water Pollution Abatement Program administered by the Wisconsin Department of Natural Resources. Under the program, a detailed nonpoint source abatement plan is prepared for priority watersheds designated by the Department. Following preparation of that plan, municipalities and landowners within the priority watershed are eligible for state funding for 50 to 70 percent of the capital cost of designated nonpoint source control measures. Both the Menomonee River and the Milwaukee River watersheds are designated as priority watersheds. It is recommended that the City of Milwaukee and Milwaukee County continue to work cooperatively with the Department toward designation of the Kinnickinnic River watershed as a priority watershed. It is also recommended that the nonpoint source abatement plan be coordinated with stormwater management planning within the tributary watersheds. There are areas of urban development within the watershed which currently suffer from inadequate stormwater drainage. These drainage problems need to be addressed in detailed subwatershed stormwater system management plans.

The plan recommends the elimination of contaminated stormwater runoff and seepage from salt and other material storage sites located on docks and other areas within the drainage area directly tributary to the estuary. As discussed in Chapter VII, this will require either the removal of the stored material, the provision of measures to avoid contact with rainfall and stormwater runoff, the provision of stormwater treatment, or the connection of the stormwater drainage system to the combined sewers. In some cases, the dependence of the operations on the shipping canals and the type of equipment used will limit the alternatives considered viable. Such measures should be refined in the second level nonpoint source planning conducted as part of the priority watershed nonpoint source program administered by the Wisconsin Department of Natural Resources. Such second level planning should be conducted in close cooperation with affected landowners and facility operators. That planning is underway for the Menomonee and Milwaukee River watersheds, and it is recommended that the plans include a determination of the most cost-effective measures to resolve the salt and scrap metal runoff problems in the tributary area. As noted above, it is recommended that the Kinnickinnic River watershed be designated as a priority watershed under the Wisconsin Department of Natural Resources nonpoint source abatement program.

The abatement of pollution from the salt pile and scrap metal yards presents a special problem in plan implementation. As a practical matter, either full state funding or a regulatory program based on new legislation likely will be required to achieve compliance with the plan recommendations. The present guidelines for funding of nonpoint source control measures do not include provision for funding of such sites. Thus, Chapter NR 120.10 of the Wisconsin Administrative Code would need to be revised to allow state cost-sharing to control stormwater runoff from salt, scrap metal, and other material storage sites.

Instream Water Quality Measures Subelement

The instream water quality measures subelement includes provisions for continued operation of the existing flushing tunnels that discharge to the Milwaukee and Kinnickinnic River portions of the estuary, and the installation and operation of an aeration system in the Menomonee River portion of the estuary. These systems would be operated whenever the instream dissolved oxygen levels approached standards for a warmwater fishery and the standards would be otherwise violated. This will require the operation to be closely linked with the water quality monitoring plan subelement. It is recommended that the Milwaukee Metropolitan Sewerage District continue to operate and maintain the existing flushing tunnels. It is further recommended that the District, as part of its water pollution abatement program, expand its facility planning to provide for the construction and operation and maintenance of the Menomonee River aeration system. This will allow for a coordinated responsibility for the instream measures and the water quality monitoring programs. It is recognized that this action would require a change in the existing policy of the Sewerage District.

Water Quality, Sediment Quality, and Biological Monitoring and Reporting

It is recommended that the Milwaukee Metropolitan Sewerage District continue to carry out its baseline water quality monitoring program which would provide for routine monitoring of 17 sites at weekly or monthly intervals, depending on the season. In addition, it is recommended that the Milwaukee Metropolitan Sewerage District conduct a more intensive monitoring program for water and sediment quality at five-year intervals. It is recommended that, in coordination with the District water and sediment quality monitoring program, the Wisconsin Department of Natural Resources carry out a biological conditions monitoring program at five-year intervals, with that program including fish and aquatic life surveys and habitat inventories to be conducted similar to the inventory work completed for the Milwaukee Harbor estuary study. It is recommended that the agencies responsible for the monitoring programs provide annual monitoring reports setting forth the findings of the programs.

DREDGING AND DREDGED MATERIAL DISPOSAL PLAN ELEMENT IMPLEMENTATION

The major dredging and dredged material disposal plan element recommendations of the Milwaukee Harbor estuary plan provide for continued dredging of bottom sediment for navigation and new construction purposes, and the disposal of dredged materials in the existing confined disposal facility and a new such facility. The implementation recommendations of each of these elements are summarized in Table 70, and capital and operation and maintenance costs of this plan element are set forth in Table 71.

Table 71

ESTIMATED COST OF THE RECOMMENDED WATER RESOURCES PLAN FOR THE MILWAUKEE HARBOR ESTUARY BY IMPLEMENTING AGENCY

Implementing Agency	Plan Element	Capital: 1987-2000[a] Cost (millions)	Capital: 1987-2000[a] Percent of Total	Average Annual Operation and Maintenance 1987-2000[a] Cost	Average Annual Operation and Maintenance 1987-2000[a] Percent of Total
Milwaukee Metropolitan Sewerage District	Water Quality Management Element				
	Point Source Pollution Abatement Subelement				
	1. Abatement of Combined Sewer Overflows at a 0.7-Year Level of Protection	$204.0[b]	53.5	$ 370,000[b]	16.2
	2. Elimination of Separate Sanitary Sewer Flow Relief Devices[c]	134.4[b]	35.2	553,000[b]	24.3
	Instream Water Quality Measures Subelement				
	1. Operation of Existing Flushing Tunnels in Milwaukee and Kinnickinnic River Estuaries	0.3	0.1	125,000	5.5
	2. Instream Aeration of the Menomonee River Estuary	0.3	0.1	15,000	0.7
	Auxiliary Plan Subelement				
	1. Water and Sediment Quality Monitoring Program	0.2	< 0.1	99,000	4.3
Subtotal—Recommended Plan Element		$339.2	88.9	$1,162,000	51.0
(Subtotal—previously committed subelements)		$338.4	88.7	$ 923,000	40.5
Subtotal—Net Additional Cost of Plan Subelements		$ 0.8	0.2	$ 239,000	10.5
Wisconsin Department of Natural Resources	Water Quality Management Element				
	Nonpoint Source Pollution Abatement Subelement	$ 11.4[b]	3.0	$ 270,000[b]	11.8
	Auxiliary Plan Subelement				
	1. Biological Conditions Monitoring	--	--	15,000	0.7
	2. Salt and Scrap Metal Storage	0.6	0.2	--	--
	Toxic Substances Management Plan Element	3.2	0.8	--	--
Subtotal—Recommended Plan Element		$ 15.2	4.0	$ 285,000	12.5
(Subtotal—previously committed subelements)		$ 11.4	3.0	$ 270,000	11.8
Subtotal—Net Additional Cost of Plan Subelements		$ 3.8	1.0	$ 15,000	0.7
U. S. Army Corps of Engineers	Dredging and Dredged Material Disposal Plan Element				
	1. Use of Existing Confined Disposal Facility: 1987 through 1992	$ 2.2[b]	0.6	$ 220,000[b]	9.6
	2. New Confined Disposal Facility: 1993 through 2000	6.8[b]	1.8	220,000[b]	9.6
Subtotal—Recommended Plan Element		$ 9.0	2.4	$ 440,000[b]	19.2
(Subtotal—previously committed subelements)		$ 9.0	2.4	$ 440,000	19.2
Subtotal—Net Additional Cost of Plan Subelements		$ --	--	$ --	--

Table 71 (continued)

Implementing Agency	Plan Element	Capital: 1987-2000[a] Cost (millions)	Capital: 1987-2000[a] Percent of Total	Average Annual Operation and Maintenance 1987-2000[a] Cost	Average Annual Operation and Maintenance 1987-2000[a] Percent of Total
City of Milwaukee	Dredging and Dredged Material Disposal Element				
	1. Use of Existing Confined Disposal Facility: 1987 through 1992	$ 0.7[b]	0.2	$ 75,000[b]	3.3
	2. New Confined Disposal Facility: 1993 through 2000	2.2[b]	0.6	78,000[b]	3.4
Subtotal—Recommended Plan Element		$ 2.9	0.8	$ 153,000	6.7
(Subtotal—previously committed subelements)		$ 2.9	0.8	$ 153,000	6.7
Subtotal—Net Additional Cost of Plan Subelements		$ --	--	$ --	--
Milwaukee County	Shoreline Storm Damage and Flood Protection Element				
	Ice Control Subelement	$ 0.3	0.1	$ 11,000	0.5
Subtotal—Recommended Plan Element		$ 0.3	0.1	$ 11,000	0.5
(Subtotal—previously committed subelements)		$ --	--	$ --	--
Subtotal—Net Additional Cost of Plan Subelements		$ 0.3	0.1	$ 11,000	0.5
Private Property Owners	Water Quality Management Plan Element				
	Nonpoint Source Pollution Abatement Subelement.	$ 14.4[b]	3.7	$ 234,000[b]	10.1
Subtotal—Recommended Plan Element		$ 14.4	3.7	$ 234,000	10.1
(Subtotal—previously committed subelements)		$ 14.4	3.7	$ 234,000	10.1
Subtotal—Net Additional Cost of Plan Subelements		$ --	--	$ --	--
Cost to be Allocated Based Upon Study Design	Shoreline Storm Damage and Flood Protection Element				
	Lake Michigan High Lake Level Flooding and Groundwater Second Level Plan	$ 0.3	0.1	$ --	--
Subtotal—Recommended Plan Element		$ 0.3	0.1	$ --	--
(Subtotal—previously committed subelements)		$ --	--	$ --	--
Subtotal—Net Additional Cost of Plan Subelements		$ 0.3	0.1	$ --	--
Total Comprehensive Plan Cost		$381.3	100.0	$2,285,000	100.0
Total Cost of Plan Element Previously Committed Under Other Planning Programs		$376.1	98.6	$2,020,000	88.3
Net Additional Cost of Recommended Plan Over and Above Committed Measures		$ 5.2	1.4	$ 265,000	11.7

[a] *All costs are expressed in 1986 dollars.*

[b] *Previously committed cost.*

[c] *Costs do not include costs for major relief sewers in the Milwaukee Metropolitan Sewerage District service area since these sewers were largely constructed prior to 1987.*

Source: SEWRPC.

Dredging Subelement

It is recommended that dredging activities continue to be undertaken by the U. S. Army Corps of Engineers, the City of Milwaukee Harbor Commission, and riparian property owners for the maintenance of commercial navigation and for new port facility construction. The U. S. Army Corps of Engineers would maintain the federal channels at project depths ranging between 21 and 30 feet below established low water datum. The City of Milwaukee, through the Board of Harbor Commissioners, would conduct maintenance dredging as required between the federal project water limits and terminal facilities and in berthing areas within the Port of Milwaukee. Maintenance activities conducted from the shoreline to the federal project water limits would be the responsibility of private facility operators.

Dredged Material Disposal Subelement

The dredged material disposal subelement provides for the continued filling of the existing confined disposal facility located along the shoreline in the southern portion of the outer harbor until its capacity is filled, in about 1993. In addition, it is recommended that a new facility with a capacity of 1.4 million cubic yards be constructed just north of the existing facility. It is recommended that the U. S. Army Corps of Engineers be the lead agency in the construction and operation of these two confined disposal facilities.

SHORELINE STORM DAMAGE AND FLOOD PROTECTION PLAN ELEMENT IMPLEMENTATION

The shoreline storm damage and flood protection plan element includes the provision of an ice control system in the McKinley anchorage area and the conduct of a second level, more detailed plan dealing with the impact of high Lake Michigan levels on flooding and high groundwater problems. The implementation recommendations of each of these elements are summarized in Table 70, and the capital and operation and maintenance costs of this plan element are set forth in Table 71.

Ice Control Subelement

The recommended ice control system for the McKinley anchorage area provides for the installation of a diffused compressed air protection system. As a first step in implementing this alternative, it is recommended that a pilot application of the diffused air system be constructed and operated over a few winters. The results of such a test would provide information for detailed design and construction. It is recommended that Milwaukee County, through its Department of Parks, Recreation and Culture, assume implementation responsibilities for the ice control system in the McKinley Marina, and that the Milwaukee Yacht Club undertake the pilot studies and subsequent detailed design for the Club's boat slip area.

High Lake Level Flooding and Groundwater Study

At the request of the Milwaukee County Board of Supervisors, made on November 6, 1986, the Regional Planning Commission has prepared a prospectus for a study of the impacts of Lake Michigan high water levels on flooding and high groundwater problems in the downtown Milwaukee area; and for the preparation of contingency plans to abate these problems should the lake be in a long-term rising trend. The preparation of this prospectus was guided by a technical advisory committee consisting of knowledgeable elected and appointed officials, technicians, educators, and citizens. The prospectus was completed at the end of 1987. The agencies responsible for implementation of the recommended study are identified in that prospectus.

TOXIC SUBSTANCES MANAGEMENT PLAN ELEMENT IMPLEMENTATION

The toxic substances management plan element includes a recommendation that a further, more detailed study be undertaken of the pollution of the bottom sediments by toxic substances and of the attendant problems. Such study should address in-place sediment and water quality standards relating to toxic substances; the presence of and the release of toxic substances in the sediments to the water column and biota; the sources of the toxic substances present in the sediments; and necessary corrective measures. The implementation actions for this element are set forth in Table 70, and the capital and operation and maintenance costs of this plan element are set forth in Table 71. Because of the responsibilities of the Wisconsin Department of Natural Resources under agreements with the U. S. Environmental Protection Agency, it is recommended that the Department assume the responsibility for implementation of this plan element. The conduct of the study should be coordinated with the water quality monitoring program and other programs of the Milwaukee Metropolitan Sewerage District.

Chapter IX

SUMMARY

INTRODUCTION

Water resources constitute one of the most important elements affecting the overall quality of the environment, as well as the growth and development of an area. Water resources not only condition, but are conditioned by, local growth and development. Any meaningful comprehensive planning effort must therefore recognize water resources as an important element of a limited natural resource base to which both rural and urban development must be adjusted if serious developmental and environmental problems are to be avoided. This is particularly true in the highly urbanized Milwaukee Harbor estuary, an area richly endowed with water resources. Properly managed, these resources can constitute a renewable resource that can serve the area for all time. Misused and mismanaged, however, these resources will become the focus of serious and costly developmental and environmental problems, and be a severe constraint on the sound social and economic development of the area. Water pollution is one manifestation of the misuse of water resources, and the public has become increasingly aware of, and concerned over, such pollution, which has seriously interfered with desired water uses. In recognition of the serious water pollution problems existing within the Milwaukee Harbor estuary, the Common Council of the City of Milwaukee, in July 1973, formally requested the Southeastern Wisconsin Regional Planning Commission, upon completion of comprehensive studies of the tributary Milwaukee, Menomonee, and Kinnickinnic River watersheds, to undertake a comprehensive study of the estuary. A comprehensive plan for the Milwaukee River watershed was completed in 1972, for the Menomonee River watershed in 1977, and for the Kinnickinnic River watershed in 1979. Accordingly, the Commission prepared a design for a study of the Milwaukee Harbor estuary in 1981. The study was subsequently funded and initiated in 1982. The findings and recommendations of that study are presented in a two-volume planning report.

The first volume of the report sets forth the basic principles and concepts underlying the program, and summarizes the findings of the extensive inventories and analyses conducted under the program. More specifically, the first volume describes the man-made and natural resource base of the drainage area tributary to the Milwaukee Harbor estuary; describes the hydrologic and hydraulic characteristics of the estuary; presents definitive data on the existing water quality, sediment quality, and biological conditions in the estuary; and describes the mathematical simulation models and other analytical techniques used in the complex planning effort.

The second volume of the report sets forth recommended water use objectives and supporting water quality standards for the estuary; describes the anticipated growth and change in the tributary drainage areas; and describes and evaluates alternative water quality management plans, alternative dredging and spoils disposal plans, and alternative storm damage protection and flood control plans. Importantly, the second volume of the report sets forth a recommended comprehensive water resources management plan for the Milwaukee Harbor estuary.

Together, the two-volume report is intended to present a sound basis for decision-making concerning water pollution abatement and water resource management in the Milwaukee Harbor estuary by the local, state, and federal units and agencies of government concerned. To this end, the report considered the economic and financial, as well as the technical and environmental, factors involved in such abatement and control, together with the social and political considerations involved in plan adoption and implementation.

STUDY PURPOSE AND ORGANIZATION

The primary purpose of the Milwaukee Harbor estuary study was to develop a sound and workable plan for the abatement of water pollution within the Milwaukee Harbor estuary so as to meet established water use objectives and supporting water quality standards in a cost-effective manner, and so as to further the protection and wise use of the natural resource base. More specifically, the study was intended to develop a plan to abate water pollution from combined sewer overflows, other point sources, and nonpoint sources; to provide instream measures as may be needed to help achieve water use objectives; to abate damage caused by flooding; to provide for the continued navigation of recreational as well as deep draft commercial vessels through a maintenance dredging program which ensures the environmentally safe disposal of the polluted spoils; to ameliorate damage in the harbor area caused by storm and wave action, and to prevent deterioration of the shoreline within the estuary; and to maximize the potential utilization of the estuary as a prime urban recreational area.

The technical work required was carried out by the Regional Planning Commission staff in cooperation with the staffs of participating governmental agencies, including the Milwaukee Metropolitan Sewerage District, the Wisconsin Department of Natural Resources, and the U. S. Geological Survey, and of private consultants engaged by the Commission, including HydroQual, Inc.; Aero-Metric Engineering, Inc.; and National Survey and Engineering, Inc. These organizations were selected for participation in the study because of their skills and experience in specialized phases of water resources planning, engineering, and management. The disciplines provided through such assistance included topographic mapping and related land and control surveys; stream- and groundwater flow measurement; surface water, suspended sediment, bottom sediment, and groundwater quality sampling and analyses; fisheries studies; sediment process studies; algae studies; and hydrologic-hydraulic water quality simulation modeling. In addition, special laboratory biotoxicity tests were conducted by the U. S. Environmental Protection Agency Research Laboratory—Duluth; and Ecological Analysts, Engineering, Science, and Technology, Inc.

WATER RESOURCE MANAGEMENT OBJECTIVES

Any sound planning process requires the formulation of objectives to guide alternative plan design, test, and evaluation. In order to be useful in the Milwaukee Harbor estuary planning process, the water resource management objectives concerned not only had to be logically sound and related in a demonstrable and measurable way to alternative water resource management proposals, but also had to be consistent with, and grow out of, more comprehensive areawide development objectives. The Southeastern Wisconsin Regional Planning Commission has, in its planning efforts to date, adopted a number of areawide development objectives relating to land use, housing, transportation, water quality management, flood control, and outdoor recreation and open space development. All of these objectives were adopted following careful review and recommendation by various advisory and coordinating committees, and following public hearings. As discussed below, some of these objectives and supporting standards are directly applicable or adaptable to the Milwaukee Harbor estuary planning effort, and, together with two new objectives, are hereby recommended for adoption as water quality management and related objectives for the Milwaukee Harbor estuary.

Water Quality Management Objectives

All of the following five water quality management objectives adopted by the Commission under its areawide water quality management planning effort are directly applicable to the Milwaukee Harbor estuary planning effort. These are:

1. The development of land management and water quality control practices and facilities which will effectively serve the existing regional urban development pattern and promote implementation of the regional land use plan, meeting the anticipated need for sanitary and industrial wastewate disposal and the need for stormwater runoff control generated by the existing and proposed land uses.

2. The development of land management and water quality control practices and facilities, including instream measures, which will meet—for the watercourses tributary to the Milwaukee Harbor estuary—the recommended water use objectives and supporting water quality standards as set forth in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, and—for the waters comprising the Milwaukee Harbor estuary—the water use objectives and supporting water quality standards set forth in this report.

3. The development of land management and water quality control practices and facilities that are properly related to and which will enhance the overall quality of the natural and man-made environments.

4. The development of land management and water quality control practices and facilities that are economical and efficient, meeting all other objectives at the lowest possible cost.

5. The development of water quality management systems—inclusive of governmental units and their responsibilities, authorities, policies, procedures, and resources—and supporting revenue-raising mechanisms which are effective and locally acceptable, and which will provide a sound basis for plan implementation—including the planning, design, construction, operation, maintenance, repair, and replacement of water quality control practices and facilities, inclusive of sanitary sewerage systems, stormwater management systems, land management practices, and in-place pollution control measures.

Water Control Facility Development Objectives

One of the four water control facility development objectives previously adopted by the Commission is applicable to the Milwaukee Harbor estuary planning effort: the development of an integrated system of drainage and flood control facilities and floodland management programs which will effectively reduce flood damage under the existing land use pattern of the study area and promote the implementation of the regional land use plan, properly accommodating the anticipated hydraulic runoff quantities generated by the existing and proposed land uses. In addition, the following two water control facility development objectives were adopted for the Milwaukee Harbor estuary planning program:

1. The development of structural and nonstructural shoreline protection measures to abate shoreline drainages caused by flooding, fluctuating water levels, strong currents, ice activity, and wave action.

2. The effective and efficient maintenance of deep water commercial navigation, waterborne commerce, anchorage protection, and associated waterborne transportation.

Recreation and Park and Open Space Objectives

Seven park and open space objectives have been adopted by the Commission under its regional park and open space planning program. One of these objectives—the provision of opportunities for participation by the resident population of the Region in extensive water-based outdoor recreation activities on the major inland lakes and rivers and on Lake Michigan, as consistent with safe and enjoyable water use and maintenance of good water quality—was adopted for the Milwaukee Harbor estuary planning program.

Recommended Water Use Objectives and Water Quality Standards

The recommended water use objectives for the entire Milwaukee Harbor estuary tributary drainage area are shown on Map 2 of this volume. Essentially, these objectives envision fully fishable and swimmable water quality conditions in the outer harbor; and fully fishable but limited recreational use water quality conditions in the inner harbor. These objectives represent a substantial improvement over existing state-established water use objectives for the inner harbor. Water quality standards supporting these recommended objectives for the watercourses tributary to the harbor estuary are set forth in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000; and for the harbor estuary, in Table 5 of this volume.

POPULATION AND ECONOMIC ACTIVITY

In any comprehensive planning effort, the future demand for the natural resources is usually determined primarily by the size and spatial distribution of future population and employment levels. In the study concerned, the issues involved are complicated by the influx of a large number of daily commuters and, intermittently, of participants in, and spectators of, special entertainment events held in the portion of the planning area of primary concern—the Milwaukee Harbor estuary direct drainage area. In the preparation of the Milwaukee Harbor estuary planning program, therefore, future population and economic activity levels were examined and, as necessary, converted to future demands for land and water resources in the study area.

Because of factors operating largely external to the Region, the magnitude and character of future development in the Southeastern Wisconsin Region are uncertain. Therefore, alternative future scenarios for the development of the Region were examined based upon consideration of a range of conditions which may be expected to influence such development. The principal factors considered in the development of these scenarios were energy cost and availability, technology, conservation, population lifestyles, and economic conditions. Based on a careful review of these factors, two alternative future scenarios having quite different implications for the development of the Region were devised. The scenarios were developed to represent consistent and reasonable extremes of future development conditions in the Region. One scenario, termed the moderate growth scenario, envisions moderate population and economic growth in the Region. The other scenario, termed the stable or declining growth scenario, envisions stable or slightly declining population and economic activity levels in the Region. Under each of these scenarios, two different alternative futures were developed for the Region—one based upon a centralized land use pattern and one upon a decentralized land use pattern. Following review of these four sets of potential conditions, the Advisory Committee concluded that the alternative water resource management plans for the Milwaukee Harbor estuary should be based upon the moderate growth scenario, centralized land use plan.

Resident Population

Under the moderate growth scenario, centralized land use plan, the resident population of the Milwaukee Harbor estuary direct drainage area may be expected to decline by about 16,500 persons, or nearly 7 percent—from about 255,200 persons in 1980 to about 238,700 persons by the year 2000. Population levels in the total study area, however, may be expected to increase by about 151,100 persons, or nearly 16 percent—from about 970,200 persons in 1980 to about 1,121,300 persons by the year 2000.

Housing and Employment Levels

The number of households within the study area may also be expected to increase between 1980 and the year 2000. The combined number of households within the Milwaukee Harbor estuary direct drainage area and its tributary river watersheds may be expected to increase by about 24,300 units, or about 7 percent—from about 374,500 households in 1980 to about 398,900 households by the year 2000. Average household size is forecast to decrease in the direct drainage area—from 2.33 persons per household in 1980 to 2.16 persons per household in 2000—but is expected to increase within the tributary river watersheds. Overall, average household size within the total study area may be expected to increase from 2.52 persons in 1980 to 2.73 persons in the year 2000.

Under the moderate growth scenario, centralized land use plan, employment in the study area may be expected to increase by about 97,400 jobs, or by nearly 19 percent—from about 523,000 jobs in 1980 to about 620,400 jobs in the year 2000. The Milwaukee Harbor estuary direct drainage area itself may be expected to gain almost 32,400 jobs, for an increase of about 18 percent—from about 184,700 jobs in 1980 to about 217,000 jobs in the year 2000.

Land Use

In order to accommodate the population levels and economic activity envisioned under the moderate growth, centralized land use plan, it is envisioned that approximately 27 square miles of rural land will be converted to urban uses within the study area by the year 2000. Because of the existing level of intensive urbanization in the Milwaukee Harbor estuary direct drainage area, however, very little change in land use may be expected in the planning area proper between 1980 and the year 2000.

ALTERNATIVE WATER QUALITY PLANS

In an effort to reduce pollutant loadings to the Milwaukee Harbor estuary, eight alternative water quality plans were developed and evaluated on their ability to achieve water quality standards supporting limited recreational use and the maintenance of a warmwater fishery or a limited fishery within the inner harbor, and supporting full recreational use and the maintenance of a warmwater fishery within the outer harbor. The following section provides a brief description and cost estimate of each alternative considered.

Alternative One: Committed Action

This alternative incorporates previously committed water quality management measures, including abatement of combined sewer overflows at a 0.7-year level of protection; elimination of separate sanitary sewer flow relief devices; and continued dredging of the estuary to maintain conditions conducive to navigation. Although pollutant loadings from combined sewer overflows would be reduced by about 97 percent, water quality conditions within the Milwaukee Harbor estuary would not be suitable for either limited recreational use or the maintenance of a warmwater or limited fishery. This alternative is also a functional component of all other alternatives considered; therefore, its $25.3 million equivalent annual cost estimate would be included with all other alternative plans. However, this cost is separated from the costs of each of the following alternatives in order to allow comparison of Alternatives Two through Eight.

Alternative Two: Elimination of Combined Sewer Overflows

This alternative provides for additional storage to virtually eliminate discharges from combined sewer overflows during high-flow conditions. The water quality conditions within the inner harbor will be slightly better under this alternative than under the committed action alternative. This alternative has an equivalent annual cost of about $16.3 million.

Alternative Three: Existing Flushing Tunnels

This alternative requires the continued operation of the flushing tunnels that discharge directly to the Milwaukee and Kinnickinnic River estuaries. Under this alternative, water quality standards for limited recreational use and the maintenance of a warmwater fishery are expected to be achieved in the Milwaukee and Kinnickinnic River estuaries, but violated in the Menomonee River estuary. The equivalent annual cost of this alternative is approximately $100,000.

Alternative Four: Menomonee River New Flushing Tunnel

This alternative provides for the continued operation of the existing flushing tunnels in addition to the construction of a new flushing tunnel which would discharge directly to the Menomonee River estuary near N. 25th Street. Under this alternative, all water quality standards supporting limited recreational use and the maintenance of a warmwater fishery are expected to be met throughout the inner harbor. The equivalent annual cost of this option is about $280,000.

Alternative Five: Menomonee River Instream Aeration

This alternative requires the continued operation of the existing flushing tunnels with the installation of four mechanical aerators to increase dissolved oxygen levels in the Menomonee River estuary. Under this alternative, water quality standards would be met in the Milwaukee and Kinnickinnic River estuaries. The fecal coliform standards supporting limited recreational use would, however, continue to be violated in the Menomonee River estuary because of high fecal coliform loadings contributed by sources discharging upstream of the estuary, and because the dilution effect of the flushing tunnels would be absent in the Menomonee River portion of the estuary. The equivalent annual cost of this alternative is approximately $140,000.

Alternative Six: Abatement of Nonpoint Sources of Pollution

This alternative provides for the implementation of nonpoint source pollution control measures to achieve the maximum level of control practicable. Under this alternative, the water quality conditions are expected to be suitable for limited recreational use, but the standards for the maintenance of a warmwater or limited fishery are expected to be violated throughout the inner harbor. The equivalent annual cost of this alternative is about $11.8 million.

Alternative Seven: Reduction in Point Source Phosphorus Loadings

This alternative provides for a 90 percent reduction in phosphorus loadings discharged from the public sewage treatment plants to the surface waters in the Milwaukee River watershed. Under this alternative, the water quality standards for limited recreational use and the maintenance of a warmwater or a limited fishery are expected to be violated throughout the inner harbor. The equivalent annual cost of this alternative is approximately $2.9 million.

Alternative Eight: Modification/Relocation of the WEPCo Valley Power Plant Outfalls

This alternative consists of three separate subalternatives—cooling tower, outfall diversion, and deep tunnel discharge—each designed to eliminate the discharge of heated condenser cooling water into the South Menomonee Canal.

The existing flushing tunnels would also continue to discharge into the Milwaukee and Kinnickinnic River estuaries. Under this alternative, water quality standards for the maintenance of a warmwater fishery would be met in the Milwaukee and Kinnickinnic River estuaries. Some standards, however, would continue to be violated in the Menomonee River estuary—particularly those relating to dissolved oxygen and fecal coliform organisms—with the water quality of the South Menomonee Canal declining owing to reduced circulation of Lake Michigan water. The equivalent annual cost of this alternative ranges from about $520,000 to $1.02 million, depending upon which of three options would be selected.

Following careful review of the findings of the alternative plan evaluations, a recommended plan was selected by the Advisory Committee for the study. That plan is the Menomonee River instream aeration alternative, the alternative plan considered to most fully meet the water quality standards. Selection of the plan was also based on considerations of technical feasibility and cost.

ALTERNATIVE DREDGING AND SPOILS DISPOSAL MEASURES

Historically, dredge spoils removed from the Milwaukee Harbor were loaded into scows, transported to the deep water portion of Lake Michigan, and discarded. However, in the early 1970's, the Wisconsin Department of Natural Resources adopted regulations prohibiting the open lake disposal of dredge spoils—whether polluted or nonpolluted—into state waters, citing the need for further evaluation of the environmental impacts of dredging and the disposal of dredged material on navigation, fish, and other aquatic life, water quality, and the general public interest. In response to this prohibition, the U. S. Army Corps of Engineers constructed a confined disposal facility in the southern portion of the outer harbor in 1975.

Since this confined disposal facility provides only a short-term solution to the problem of disposing of dredged material removed from the Milwaukee Harbor, the development of a plan for the disposal of such spoils was made a part of the Milwaukee Harbor estuary planning program.

Dredging Activities

Maintenance dredging in the Milwaukee Harbor is carried out by the federal government, the City of Milwaukee, and private riparian property owners. The federal government, through the U. S. Army Corps of Engineers, maintains the federal channels at project depths ranging from 21 to 30 feet below established low water datum. The City of Milwaukee, through the Board of Harbor Commissioners, conducts maintenance dredging between the federal project water limits and terminal facilities and in berthing areas within the Port of Milwaukee. Maintenance activities conducted from the shoreline to the federal project water limits are the responsibility of both private facility operators and the City of Milwaukee.

Estimated Quantity of Dredged Materials

From 1961 through 1970, approximately 4.7 million cubic yards of dredge spoil were removed from the existing federal project areas within the Milwaukee Harbor estuary, consisting of the 0.7 mile of the Milwaukee River downstream of E. Buffalo Street; the 1.7 miles of the Menomonee River downstream of N. 25th Street; the 1.4 miles of the Kinnickinnic River downstream of S. Kinnickinnic Avenue; the 1.4 miles of the Burnham and South Menomonee Canals; and the outer harbor. Of the total volume, approximately 0.8 million cubic yards, or 17 percent, were dredged for harbor maintenance; while approximately 3.9 million cubic yards, or 83 percent, were dredged for harbor expansion or improvement. Of the total maintenance dredging quantity, about 418,000 cubic yards of material, or about 55 percent, were dredged by the U. S. Army Corps of Engineers, and about 348,000 cubic yards, or about 45 percent, were dredged by private riparian owners and the Port of Milwaukee.

The most recent federal dredging projects were conducted by the Corps of Engineers in the Milwaukee Harbor from 1975 through 1981. During this period, approximately 919,000 cubic yards of material was dredged. An annual average of 131,000 cubic yards of dredge spoils was removed from within the federal project areas and placed in the confined disposal facility from 1975 to 1981, compared to an annual average of 77,000 cubic yards of bottom material removed from 1961 through 1970.

Dredging activities performed under City of Milwaukee contracts from 1980 through 1984 resulted in the removal of approximately 231,600 cubic yards of bottom sediments from the Kinnickinnic River, the Municipal Mooring Basins, and the outer slips of piers. The dredged materials resulting from these maintenance activities were also deposited in the Corps of Engineers' confined disposal facility. Only minimal dredging activities have been performed by private riparian facility owners since 1980.

Over the period 1975 through 1984, an average of 115,000 cubic yards of dredge spoils per year was removed from the Milwaukee Harbor and placed in the confined disposal facility. Following abatement of the combined sewer overflows, the volume of spoils generated by dredging for maintenance of navigation will be reduced to approximately 65,000 cubic yards per year.

Dredge Spoils Disposal Alternatives

As of 1986, the existing confined disposal facility had a remaining capacity for approximately 800,000 cubic yards of dredge spoils. Assuming an average annual dredge spoil quantity of 115,000 cubic yards, the existing facility will be filled by the year 1992. The following dredge spoil disposal methods were considered for the period 1993 through 2000, the end of the planning period, during which approximately 650,000 cubic yards of spoils will need to be disposed of. To estimate the capital cost of new confined or upland disposal facilities, however, it was assumed that these facilities would have a 20-year design life—from 1993 through the year 2013—and would have a capacity of about 1.4 million cubic yards.

In a preliminary screening, six of 11 dredge spoils disposal alternatives were eliminated from further consideration because they were found to be technically or economically impractical, or because of legal constraints. Evaluations of five of the remaining alternatives were conducted, and the findings of these evaluations are summarized below. A cost estimate, including the cost of dredging, which is expected to be approximately $460,000 on an average annual basis, is provided for each alternative disposal method for 1993 through the year 2000.

Alternative One: Open Water Disposal: This alternative provides for transport of dredge spoils by barge several miles into Lake Michigan, and then injection of the spoils into deep water for disposal. As already noted, open water disposal was used for Milwaukee Harbor sediments until the late 1900's. The open water disposal of dredge spoils requires site identification surveys, special environmental impact studies, and specialized equipment for the near-bottom injection of spoils. Because of water quality concerns, the Wisconsin Department of Natural Resources currently prohibits the open water disposal of dredge spoils. Open water disposal, including dredging and transport of dredge spoils by barge, would have an estimated capital cost of $200,000 and an annual operation and maintenance cost of $510,000.

Alternative Two: Increase Capacity of the Existing Confined Disposal Facility: This alternative requires modifying the dike of the existing confined disposal facility in order to increase its capacity to dispose of approximately 650,000 cubic yards of dredge spoils through the year 2000. Dredge spoils would continue to be transported to the confined disposal facility by barge. This alternative would have an estimated capital cost of $3.25 million and an annual operation and maintenance cost of $530,000.

Alternative Three: New Harbor Area Confined Disposal Facility: This alternative provides for the construction of a new confined disposal facility similar to the existing facility within the outer harbor or adjacent land area. The containment dikes would be designed and constructed—with clay liners if necessary—to effectively and safely filter contaminants, and thereby prevent contaminated leachate from being discharged to the outer harbor. Four new confined disposal facility sites within the harbor were considered, the most feasible of which is located immediately north of the existing confined disposal facility. This alternative would have an estimated capital cost of $9 million and an annual operation and maintenance cost of $550,000.

Alternative Four: New Confined Disposal Facility in Burnham Canal Upstream of S. 11th Street: This alternative consists of filling in the Burnham Street Canal upstream of S. 11th Street—presently not dredged for navigational purposes—with dredge spoils, and the filled land made available for additional development in the area. The portion of the canal that would be filled with dredge spoils has a surface area of about 3.5 acres, and, at an assumed spoil storage depth of about 10 feet, would have a capacity of about 60,000 cubic yards of dredge spoils, or for far less than one year of dredged materials. Filling in this portion of the Burnham Canal would eliminate the need for a two-span, fixed bridge at S. 11th Street as planned by the City of Milwaukee. It would, however, require extension of the storm sewer outfalls that discharge to the canal to new outfall locations. This alternative would have a capital cost of about $700,000 and an operation and maintenance cost of about $390,000 for the one-year filling project.

Alternative Five: Upland Disposal: This alternative provides for the placement of dredge spoils in various types of upland disposal sites, including the disposal of dredge spoils in a new upland landfill specifically designed and used for dredge materials; disposal in an existing or new general refuse sanitary landfill; use as a soil conditioner for agricultural land; or use as fill material for industrial, commercial, or recreational development areas. Each of these methods would require a spoils storage and dewatering system, a transportation system most likely using trucks, and a filling or application system at the upland sites. A combination of upland disposal methods could also be used.

The capital costs for upland disposal of dredge spoils would range from $2 million for the application of dredge spoils to agricultural lands to approximately $12 million for disposal in a new landfill or lagoon. The annual operation and maintenance costs, however, would range from $680,000 for disposal as fill, to $1.2 million for application of dredge spoils on agricultural land. These estimates are based on the assumption that the dredge spoils will not be classified as hazardous wastes.

Summary of Costs and Economic Analysis: From 1987 through 1992, the existing confined disposal facility will be filled at an estimated capital cost of $2.9 million, with an annual operation and maintenance cost of $740,000. However, from 1993 through the year 2000, the capital cost of dredging and nonhazardous spoils disposal will range from $200,000 for open water disposal to $11 million for the construction of a new landfill or lagoon. Furthermore, the average annual operation and maintenance costs are expected to range from $510,000 for open water disposal to $1.2 million for the use of spoils as an agricultural soil conditioner. Finally, the disposal of dredge spoils in the Burnham Canal upstream of S. 11th Street, which would provide capacity for only about 60,000 cubic yards of spoils, would have a capital cost of $700,000, with an annual operation and maintenance cost of $390,000.

ALTERNATIVE ANCHORAGE, DOCKAGE, AND FLOOD PROTECTION MEASURES

The recreational and commercial watercraft facilities presently in use in the Milwaukee Harbor have been developed since 1929. These facilities include the City Harbor Commission north piers; the Port of Milwaukee piers and terminals; the Municipal Mooring Basin; the city heavy lift dock; the McKinley Park peninsula and anchorage area; and the harbor breakwater. These facilities provide relatively safe anchorage for both smallcraft and larger vessels during ordinary Lake Michigan storm events. More severe storms can produce wave action in the outer harbor, including the McKinley Park anchorage area, resulting in damage to both smallcraft and larger commercial vessels berthed at municipal piers. Protection of the shoreline as well as the riparian facilities located behind the breakwater has become increasingly important as the number of facilities has increased and as the water level of Lake Michigan at Milwaukee has risen to and above previous records for the 20th century.

The principal problems related to anchorage, dockage, and shoreline facilities in the Milwaukee Harbor are associated with the waves produced by high winds over Lake Michigan and by ice formation and breakup within the McKinley Park anchorage area. The methods commonly employed for protecting anchorage areas, piers, and shorelines exposed to wave and ice action include breakwater construction, ice breaking, ice booms, deicing techniques, and air screens. A brief description of these methods is presented below.

Protection from Storm Waves

Protection of harbor anchorage areas and port facilities along an exposed coastline from storm-generated waves is most effectively provided by installation of an adequate breakwater which may be either shore-connected or detached from shore. Most breakwaters extend from the sea or lake bottom to some elevation above the water level. Generally, the higher the breakwater, the less wave overtopping will occur, and the safer the anchorage area protected by the structure. However, the cost of a breakwater generally increases substantially with height. Breakwaters on exposed shorelines must be constructed to withstand the wave regime of the lake. The 10- and 100-year recurrence interval deep water wave heights offshore from Milwaukee, as determined by the U. S. Army Corps of Engineers, are 16 and 24 feet, respectively. A number of breakwater designs were considered, as discussed in Chapter VI. However, the alternatives developed focused on two options—extension of the existing breakwater system forming the outer harbor and the construction of a new replacement rubblemound breakwater. Consideration was also given to the regulation of Great Lakes levels as a method of alleviating high water level problems.

Protection from Ice Damage

Ice control in port and marina settings can be achieved by either controlling the ice after formation or melting the ice before it can form a thick layer. Methods of controlling ice covers include ice breaking, ice booms, artificial islands, and removable gravity structures.

Ice Breaking: Ice breaking in the Milwaukee Harbor has been performed by the vessel Harbor Seagull, operated by the Port of Milwaukee. The Harbor Seagull is capable of breaking ice covers up to about eight inches thick. Ice thickness in the outer harbor seldom exceeds eight inches south of the McKinley Park anchorage area.

Ice Booms: Ice booms are flexible floating structures used to retard the movement of ice and/or to cause early formation of stable ice cover. Ice booms are more frequently used in rivers than in harbors, marinas, or lakes.

Deicing by Thermal Destratification Using Water Pumps: Artificial circulation has been utilized to eliminate winter thermal stratification in lakes and marinas in order to inhibit or prevent formation of ice cover at desired locations. Circulators pump warmer, denser water lying near the bottom to the surface to melt ice or prevent its formation.

Deicing by Thermal Destratification Using Compressed Air: Compressed air bubbling systems have been used to destratify lakes and inhibit ice cover formation for dissolved oxygen enhancement, to melt ice in marinas, to mitigate ice damage to structures left in the water during the winter, and to provide winter wet storage areas for boats. Two types of air bubbler systems are in general use—the point source bubbler which releases compressed air bubbles from a single orifice, and the diffused source bubbler which releases compressed air bubbles from a perforated conduit.

Deicing by Thermal Effluents: Ice cover in rivers is commonly suppressed downstream from reservoirs and power plant thermal effluent discharges. Ice suppression in an estuary or harbor by water warmer than 32.2°F is governed by natural phenomenon similar to what occurs in rivers, with the exception of the more complex hydrodynamic mixing.

Ice Retention by Air Screens: An air screen is a wall of bubbles released from a submerged diffuser designed to block the movement of ice or other floating debris. High-flow and -velocity air screens can remove ice pushed by ships entering locks by creating a localized increase in water level, resulting in the development of a strong current which pushes floating ice and debris away from the bubble barrier. Air screens are also useful in the open water season for reducing wave energy in leeward mooring areas.

Protection of Harbor and Shoreline Facilities by Higher Breakwater

The outer harbor of Milwaukee is formed by a 3.9-mile-long, shore-connected breakwater that provides a less than desirable level of protection to the anchorage and shoreline areas. The design height of the breakwater was set by the U. S. Army Corps of Engineers at a time when lake levels were relatively low and when little long-term water level data were available for the determination of a design lake level. Consequently, the existing breakwater height is inadequate, and may become even more so if Lake Michigan continues to rise to above the present levels. Therefore, analyses were made of the benefits and costs of modifying the breakwater under existing lake level conditions and under a scenario whereby the lake levels would continue to rise.

The first alternative considered assumed a design lake level that is based upon historical conditions over the past 85 years. Under these present-day lake levels, it was concluded that the damages to piers and port facilities on Jones Island were not extensive enough to justify provision of further protective measures since it is less expensive to repair the damages as they occur than to construct a higher breakwater at an estimated cost of $22 million. Damages are estimated at $600,000 for a 100-year recurrence interval storm event, with an average annual storm damage estimate of $50,000. In contrast, the average annual cost of increasing the existing breakwater height by about 8.0 feet, which would significantly reduce damages, would be $1.9 million during the planning period. A second option considered was the construction of a new, higher rubblemound breakwater on the outside of the existing breakwater. That option had an average annual cost of $4.1 million.

The analyses conducted confirm the observations of the Harbor Commission staff that under present-day lake levels, the damages to piers and port facilities on Jones Island are not extensive enough to justify provision of further protection measures, it being less costly to repair the damages.

The second alternative considered was based upon a long-term rising lake level scenario. That alternative was based upon a lake level which would be 4.0 feet higher than 1985 levels and about 3.5 feet higher than 1986 levels. Under this alternative, damages to the piers and port facilities may be expected to increase to an average annual total of $900,000. In order to minimize wave-related damages, it is necessary to construct a new breakwater system that is about 16 feet higher than the existing breakwater—at an estimated cost of $150 million, or $9.5 million on an average annual basis during the planning period. Indirect benefits of raising the height of the breakwater include the provision of a safe harbor of refuge for both small-craft and ships, and facilitation of waterborne commerce by the Port of Milwaukee.

If the breakwater elevation is not increased under this long-term rising lake level scenario, standing wave heights in the municipal slips may increase by up to four feet, and would be oscillating on a four-foot higher lake level. Thus, the crests would be about eight feet higher than under present conditions. Pre-storm freeboard at the municipal piers in the outer harbor would be only about three feet. Thus, not only would the municipal slips become unsafe for mooring, but the piers and related facilities would be subject to serious damage by wave attack. It is probable under these conditions that the use of port facilities in the outer harbor would be impractical—except during fair weather—and the use of the inner harbor would have to be increased. Flooding of Jones Island from storm wave runup would become both more frequent and more extensive, requiring implementation of flood control measures to maintain the viability of port facilities as well as of the Jones Island sewage treatment plant.

In view of the above, no new major breakwater construction was recommended at this time. However, because of the indirect benefits and potential loss of a viable port facility, it is recommended that continued surveillance of this situation be carried out and that contingency planning for storm damage and flood conditions be undertaken by the involved units of government, as well as planning for related high groundwater level problems in the downtown Milwaukee area which could result from this long-term rising lake level.

The potential for regulation of Lake Michigan levels was also considered. In August 1986, the governments of the United States and Canada requested that the International Joint Commission undertake a comprehensive study of methods of alleviating the adverse impacts of changing water levels, ranging from very high to very low levels, on the Great Lakes/St. Lawrence River Basin. The study involves two phases. The first phase of the study is to consider short-term alternatives—not involving major structural improvements—to minimize the adverse impacts of fluctuating water levels. The second phase, which is scheduled to be completed in 1989, will include a comprehensive evaluation of potential solutions, including structural improvements, land use planning, and other management activities.

Because the results of these studies are not known at this time and because the recommendations to provide for further controls will likely take many years to implement, other, shorter-term solutions were recommended to be pursued.

<u>McKinley Park Anchorage Area Ice Control</u>

Management of the ice problems in the McKinley Park anchorage area was evaluated to determine if cost-effective means could be identified to minimize the problem. Three alternative strategies for ice control were developed and tested for technical and economic feasibility, namely: 1) melting of ice in the entire McKinley anchorage area using diffused compressed air; 2) melting of ice in the municipal pier area by the same method with retention of ice floes in the remaining area by an ice boom; and 3) melting of ice in the municipal pier area with retention of ice floes with an air screen. These alternatives are briefly discussed with their attendant costs in the following paragraphs.

<u>Alternative 1: Ice Control by Diffused Compressed Air:</u> This alternative provides for the deicing of the entire McKinley Park anchorage area using a diffused air system. The air diffusing system includes diffuser lines 150 feet apart and lying in parallel on the bottom, six air blowers positioned at McKinley Marina with operating rates of 140 cubic feet per minute (cfm) to 520 cfm, and one blower located at the Milwaukee Yacht Club with a normal operating rate of 120 cfm. The total length of the diffuser lines, made of 1-1/2-inch PCV pipe, is 28,500 feet. The average annual cost of this system is estimated to be $32,000.

<u>Alternative 2: Ice Control by Diffused Air and Ice Booms:</u> This alternative requires the installation of a diffused compressed air system to deice the slips in the McKinley Park anchorage area, and an ice boom positioned offshore from the municipal piers for stabilization of ice cover. A significant benefit of this approach is that winter mooring conditions in the slips would be much calmer owing to the wave-dampening effects of the stabilized ice cover. The proposed ice boom would be 2,800 feet long and secured by boom anchors to maintain the boom position in open water at both the beginning and end of the season. The proposed air diffusion deicing system would have four blowers housed at different locations, with operating rates ranging from 150 cfm to 350 cfm and a total of 13,000 feet of 1-1/2-inch PCV diffuser line. The total cost of the combined ice boom/deicing system is estimated at $640,000, with an average annual cost of $93,000.

<u>Alternative 3: Ice Control by Diffused Compressed Air and Air Screens:</u> This alternative provides for the installation of a diffused air system to deice the slips of the McKinley Park anchorage area and an air screen to stop the movement of ice floes into the pier area. The proposed air screen would be 2,800 feet long and driven by eleven 187-horsepower air blowers with normal discharge capacities of 2,500 cfm. The air supply lines and diffuser lines would remain in place permanently, but the blowers could be brought in and connected to the system in late winter to await breakup. The air diffusion deicing system to be installed for use

with the air screen is the same as that described under Alternative 2. The total cost of the combined air screen-deicing system is estimated at $320,000.

Based upon review and evaluation of the three alternatives, it was recommended that the alternative providing for ice control by the use of diffused air be considered further by constructing and operating a pilot application. This pilot application could involve modifying the existing air diffuser system in the North Marina. Concurrently, it is recommended that a pilot system be operated in the central anchorage area.

Flood Protection

Flood control studies for the Kinnickinnic, Menomonee, and Milwaukee River estuaries were made, and the findings and recommendations published by the Regional Planning Commission in 1978, 1976, and 1971, respectively. Since the completion of these reports, Lake Michigan water levels have risen to or near the 100-year recurrence interval values utilized in these studies. In October 1986, the lake reached a recorded instantaneous high level of 584.1 feet National Geodetic Vertical Datum (NGVD). Geological evidence is believed by some to indicate that within the last 1,000 years, lake levels have exceeded recorded levels by about four feet. The interpretation and application of this evidence is complicated, however, by differential crustal movement within the Great Lakes Basin, and by man-made changes in the level of Lakes Michigan-Huron. Moreover, there is some archeological evidence to indicate that the level of Lakes Michigan-Huron have not changed appreciably since at least 1645. Never-the-less, it was concluded that a reevaluation of the flood protection elevations for the three river estuaries was warranted.

The 100-year recurrence interval flood stages for Lake Michigan and the three river estuaries were revised following analyses of additional stage data collected for Lake Michigan at Milwaukee since completion of the earlier watershed studies. A summary of the revised flood stage data is provided in Table 72. The revised 100-year recurrence interval instantaneous maximum stage for Lake Michigan of 584.5 feet NGVD, or 583.2 feet International Great Lakes Datum (IGLD), is 0.7 foot higher than the 100-year stage published earlier by the Commission. This stage was extended from Lake Michigan upstream in each of the rivers until it intersected the flood profile for the 100-year recurrence interval peak flood discharge for the river, and new 100-year recurrence interval flood profiles and flood hazard area maps were prepared. These profiles and flood hazard area maps are presented in Chapter VI.

Table 72

100-YEAR RECURRENCE INTERVAL REGULATORY FLOOD STAGE AND FLOOD STAGES AT THE MILWAUKEE HARBOR ASSUMING A LONG-TERM RISING LAKE LEVEL TREND

Actual Lake Levels	
Mean Lake Level: 1900-1986.	579.6 feet NGVD
Annual Mean Lake Level: 1985	582.0 feet NGVD
Annual Mean Lake Level: 1986	582.5 feet NGVD
Instantaneous Maximum: 1985	583.7 feet NGVD
Instantaneous Maximum: 1986	584.1 feet NGVD
Recommended Regulatory 100-Year Recurrence Interval Instantaneous Maximum Stage	584.5 feet NGVD
Flood Stages, Assuming that Lake Michigan is in a Long-Term Rising Trend[a]	
Instantaneous Maximum Level, Assuming a 2.0-Foot Increase in the Mean Lake Level over 1985[b].	585.9 feet NGVD
Instantaneous Maximum Level, Assuming a 4.0-Foot Increase in the Mean Lake Level over 1985[b]	587.9 feet NGVD

[a] *The stages attendant to a long-term rising lake level trend scenario are intended to be advisory to engineers and architects involved in project design, and are not intended to be used for regulatory purposes.*

[b] *These stages are derived by adding the 2.0- or 4.0-foot rise to the annual mean levels for 1985, and then adding 1.9 feet to account for the difference between the annual mean level and the instantaneous maximum level. The 1.9 feet reflects the effects of seiche, wind setup, and seasonal variations.*

Source: National Ocean Service and SEWRPC.

Flood stages, river profiles, and potential areas of inundation were also developed for the Milwaukee Harbor estuary to show the range of potential flood levels and areas of inundation if Lake Michigan is in a long-term rising trend as described earlier. Data are provided in Chapter IV for a range of conditions resulting from a 2.0-foot and a 4.0-foot rise in Lake Michigan over 1985 levels. The resulting average annual levels of 584.0 feet NGVD and 586.0 feet NGVD, respectively, were determined to have a 50 percent and 10 percent chance of occurring in 50 years if the lake is in a long-term rising trend. Resulting instantaneous maximum levels of 585.9 feet NGVD and 587.9 feet NGVD were also estimated to have a 50 percent and 10 percent chance of occurring in 50 years under this long-term rising lake level scenario. These lake level elevations and associated inundation areas are intended to be advisory to engineers and architects involved in project design, and are not intended to be used for regulatory purposes. This range of advisory levels was developed assuming that the lake is in a long-term rising trend, as some have indicated may be possible. Consequently, the advisory levels are higher than the recommended regulatory level indicated above, which is based upon a statistical analysis of the lake level data systematically collected at Milwaukee. Each individual designer can utilize the data developed and presented in Chapter VI to determine what lake levels should be used in the design of the particular project concerned.

RECOMMENDED WATER RESOURCES MANAGEMENT PLAN

A comprehensive water resources management plan was synthesized from the alternative plan proposals set forth in Chapters IV, V, and VI of this volume. The plan consists of a water quality management plan element, a dredging and dredged material disposal plan element, a shoreline storm damage and flood protection plan element, and a toxic substances management plan element. The comprehensive plan, which is recommended for adoption as a guide for the management of the Milwaukee Harbor estuary, contains the following salient proposals.

Water Quality Management Plan Element

The recommended water quality management plan element consists of a point source pollution abatement subelement, a nonpoint source pollution abatement subelement, an instream water quality measures subelement, and an auxiliary water quality management subelement. The recommended water quality management measures are closely related to, and help refine, recommendations set forth in the areawide water quality management plan for southeastern Wisconsin and the Milwaukee Metropolitan Sewerage District's water pollution abatement program. This recommended plan element proposes the following measures:

1. The provision of facilities to abate combined sewer overflows at a 0.7-year level of protection, and the virtual elimination of pollutant discharges from all separate sanitary sewer flow relief devices within the tributary watersheds. Under this plan recommendation, approximately 97 percent of the combined sewer pollutant loadings would be captured and treated at the District's sewage treatment facilities. About 1,140 acre-feet of storage would be provided for combined sewer overflows and excessive flows from separately sewered areas. Elimination of flow relief devices would be accomplished by expansion of wastewater treatment plants, the construction of deep storage tunnels and new trunk sewers, and other sewerage system improvements.

2. The number and location of, and effluent limitations for, sewage treatment plants and industrial wastewater discharges as set forth in the areawide water quality management plan. In addition, the analyses indicated that it would not be necessary to relocate the Jones Island sewage treatment plant outfall in order to meet desired water quality standards within the outer harbor.

3. Application of agricultural land management measures—such as conservation tillage, contour plowing and cropping, grassed waterways, terraces, and diversions—to about 15 percent of the rural land within the tributary watersheds, and installation of livestock waste control measures to about 30 percent of the livestock operations in the watersheds. Such measures would reduce phosphorus, sediment, and fecal coliform loadings from agricultural land runoff and livestock operations by 15 and 30 percent, respectively. This would provide approximately 50 percent of the maximum achievable level of abatement of rural nonpoint source pollution.

4. Application of construction erosion control measures in urban and developing land areas within the tributary watersheds. These measures may be expected to reduce phosphorus and sediment loadings from urban areas by about 45 percent. These measures, however, may be expected to reduce fecal coliform loadings by only 10 percent. In addition, an ongoing priority watershed program being conducted by the Wisconsin Department of Natural Resources for the Milwaukee and Menomonee River watersheds may indicate a need to implement additional urban nonpoint source control measures to achieve desired water use objectives in surface waters upstream of the estuary, or in Lake Michigan.

5. The continued operation of the existing flushing tunnels which discharge to the upstream end of the Milwaukee and Kinnickinnic River watersheds, and the installation and operation of an instream aeration system in the Menomonee River estuary. The flushing tunnels will need to be operated about 1,500 hours per year, and the aeration system about 2,000 hours per year, in order to meet the recommended water use objectives and standards. To meet the recommended water use objectives and existing Department

of Natural Resources standards, it is estimated that the flushing tunnels will need to be operated 200 additional hours per year, or a total of 1,700 hours per year; and the aeration system 200 additional hours per year, or a total of 2,200 hours per year. It was not found necessary to dredge the bottom sediments in the estuary to achieve the water use objectives and standards for conventional pollutants.

6. The implementation of measures to prevent contamination of surface water by stormwater runoff from scrap metal, salt, and other material storage sites located within the direct drainage area. Alternative methods of controlling the stormwater runoff from these areas may include providing modified stormwater drainage systems that eliminate or reduce the volume of water which contacts the storage areas; stormwater treatment by sedimentation or infiltration; removal of the stored material; covering of the operations to eliminate contact with stormwater; or connection of the drainage system serving the area to the combined sewer system. This latter option could require the installation of new stormwater drainage facilities, as well as modification of existing facilities. In some cases, the viable means for reducing stormwater pollutant discharges are limited in that certain storage operations are dependent on being located adjacent to shipping channels, thus eliminating the potential for moving the operations to remote locations. In other cases, the operations require the use of high cranes, making covering of the operations impractical. It is recommended in all cases that the best alternatives for each area determined to need modification be developed in a detailed second level plan to be conducted as part of the Wisconsin Department of Natural Resources Priority Watersheds Program in cooperation with the affected landowners and facility operators.

7. The development and continued operation of a water quality, sediment quality, and biological conditions monitoring program to document the extent to which desired water use objectives are being met over time.

Dredging and Dredged Materials Disposal Plan Element

This plan element consists of a dredging needs subelement; a dredging methods subelement; a dredged material processing and transportation subelement; and a dredged material disposal subelement. Dredging and disposal of dredged materials are presently carried out within the estuary for maintenance of adequate water depths for commercial navigation, and for limited construction of new port facilities. Dredged materials are disposed of in a confined disposal facility located in the southern portion of the outer harbor. This recommended plan element proposes the following measures:

1. The continued dredging and disposal of dredged materials within the project limits established by the U. S. Army Corps of Engineers to maintain suitable water depths for commercial navigation. It does not appear necessary to dredge for water quality improvement purposes at this time, although further analysis of the need to abate toxic substances in the bottom sediments is recommended. Also, widespread dredging to improve aquatic habitat conditions should not be needed, although some localized dredging for this purpose may be desired.

2. The use of mechanical dredges such as the dragline, dipper, and clamshell dredges, or hydraulic dredges, such as the cutterhead or hopper dredges, to carry out the dredging operations. The specific equipment used should be selected by the project sponsor and by the contractor.

3. Consideration of the use of a gravity dewatering system—such as mounding—to increase the sediment solids content and maximize the life of the confined disposal facilities.

4. The continued filling of the existing confined disposal facility with dredge spoils to about 1993, and the construction of a new confined disposal facility just north of the existing facility within the outer harbor. The facility would have a surface area of about 50 acres and a volume of about 1.4 million cubic yards, providing capacity through the year 2013.

Shoreline Storm Damage and Flood Protection Plan Element

This plan element consists of a design lake level subelement, an outer harbor facilities windstorm protection subelement, an ice control subelement, and an inner harbor high-water and flood protection subelement. The plan element is designed to prevent damages from wind-generated waves, ice, high water levels, and flooding. This recommended plan element proposes the following measures:

1. Consideration, on a project-by-project basis by the architects and engineers concerned, of a range of newly developed data on Lake Michigan and inner harbor flood levels. Designers should consider the recommended revised 100-year recurrence interval lake level of 584.5 feet National Geodetic Vertical Datum. In addition, consideration should be given to a range of future Lake Michigan instantaneous levels—from 585.9 feet NGVD to 587.9 feet NGVD—which were estimated to have a 50 percent and 10 percent chance, respectively, of occurring in 50 years under the assumption that Lake Michigan is in a long-term rising trend, as is hypothesized by some hydrologists, geologists, and climatologists.

2. The construction and repair of individual shore protection measures such as revetments, bulkheads, dockwall improvements, and floodproofing measures to protect facilities in the outer harbor. Substantial modification of the outer harbor breakwater is not recommended at this time. However, it is recommended that continued surveillance of this situation be carried out, and that contingency planning for both storm damage and flood conditions, as well as high groundwater levels, which could result from this long-term rising lake level be undertaken by the involved units of government. Such continued surveillance would entail an annual review of the lake level data provided for Milwaukee by the National Ocean Survey, with further review to be included in the contingency planning.

3. The installation of a diffused compressed air system in the McKinley anchorage area to prevent ice accumulation and associated damages. The operation of a pilot system is recommended as the first step in implementing the system. If successful, design and installation of a full-scale system could be considered further for all or parts of the anchorage areas. Ice control for the remainder of the estuary, as needed, should be performed by vessels operated by the Port of Milwaukee.

4. The use of newly developed flood stages and profiles for the inner harbor. A further second level study of flooding and high groundwater problems relating to high Lake Michigan water levels is also proposed. Floodproofing measures, to be designed on a site-specific basis, are recommended to be considered to abate damages from overland flooding until such time as further recommendations are advanced in the second level plan.

Toxic Substances Management Plan Element

The toxic substances management plan element consists of a verification of existing data subelement; an identification and quantification of sources subelement; and an alternative and recommended abatement measures subelement. This Milwaukee Harbor estuary study compiled and interpreted the available data on toxic substances and found that the water, bottom sediments, and biota were contaminated with toxic substances. Of particular concern was the bottom sediment, which may act as a residual source—as well as a sink—of toxic substances. With respect to human health, the greatest known hazard is related to the consumption of fish containing excessive levels of polychlorinated biphenyls (PCB's). This recommended plan element proposes the following measures:

1. The establishment of water quality and sediment quality standards for each of the 126 priority pollutants identified by the U. S. Environmental Protection Agency. The standards should consider acute and chronic toxicity, bio-availability, and bio-accumulations. Of these 126, 71 were examined under the study, and of these 71, only 27—occurring in the sediments, water column, or fish—were found to be present at levels approximating or exceeding available standards or generally accepted levels. This indicates that only about 60 toxic substances should be present at levels requiring further study.

2. The verification and update of available data on toxic substances in the estuary. This subelement would include additional sediment sampling and analysis; tests on the toxicity, bio-availability, and bio-accumulation of toxic substances in the estuary; the delineation and further analysis of biological impact and sediment deposition areas; a comparison of the data collected to the standards; and the mapping of toxic substance problem areas within the estuary.

3. The identification of historical and existing sources of toxic substances, including atmospheric, upstream sources, direct tributary sources, and in-place sediment sources.

4. The development and application of a mathematical model capable of simulating sediment-water and biological interactions related to toxic substances. The model would help determine whether the existing toxic substances in the water column are in equilibrium with the sediments; whether the sediments are a source of toxic substances to the water column and biota; the effect of combined sewer overflows on toxic substances levels; and the expected reduction in toxic substance levels following abatement of various identified sources of pollutants.

5. The development and evaluation of alternative toxic substance abatement plans and the selection of a recommended plan.

COST ANALYSIS

In order to assist public officials in evaluating the recommended Milwaukee Harbor estuary plan, a preliminary capital improvement program with attendant operation and maintenance costs was prepared which, if followed, would result in total watershed plan implementation by the year 2000. The schedule of capital and operation and maintenance costs for the recommended estuary plan is set forth in Table 64 in Chapter VII. This schedule assumes a 14-year plan implementation period beginning in 1987 and extending through the year 2000. The capital cost of implementing the entire Milwaukee Harbor estuary plan is estimated at $381.3 million.

Of the total plan capital cost, about $365.6 million, or about 96 percent, is required to implement the water quality management element of the plan, including the deep tunnel separate and combined sewer overflow facilities; about $11.9 million, or about 3 percent of the total, is required for implementation of the dredging and dredged material disposal element of the plan; about $600,000, or less than 0.5 percent of the total, is required for implementation of the shoreline storm damage and flood protection element of the plan; and about $3.2 million, or about 1 percent, is required for implementation of the toxic substances management element of the plan.

It is important to note that $376.1 million, or nearly 99 percent of the total capital cost of the plan, is for plan elements that have been committed under other planning efforts. These costs were committed in order to meet the objectives of the previously developed areawide water quality management plan and the Milwaukee Metropolitan Sewerage District water pollution abatement program, and in response to the need to continue dredging for commercial navigation purposes. The capital costs of the previously committed measures include about $338.4 million, or 88.7 percent of the total capital cost, for abatement of combined and separate sewer overflows; about $25.8 million, or about 6.8 percent of the total, for nonpoint source control; and about $11.9 million, or about 3.1 percent of the total, for dredging and dredged material disposal. Thus, the total net additional capital cost of the plan over and above the previously committed measures is $5.2 million.

The capital costs of the new proposed projects include about $300,000 for the instream aeration system on the Menomonee River and about $300,000 for periodic replacement work for components of the existing flushing tunnels; about $600,000 for salt, scrap metal, and other material storage site runoff controls; about $200,000 for water quality, sediment quality, and biological monitoring; about $300,000 for the second level Lake Michigan high water level and flood protection planning; about $300,000 for an ice control system in the McKinley Marina; and $3.2 million for the development of a second level toxic substances management plan.

Of the total plan costs, all but $14.4 million, or about 4 percent of the total plan capital cost, would be expended by public agencies. Nearly all of this cost, which would be allocated to the private sector, is for nonpoint source pollution controls, with a small cost for dredging adjacent to private port facilities.

The capital investment and operation and maintenance cost required for plan implementation may be expected to total $29.5 million on an average annual basis, or about $17 per capita per year over the 14-year plan implementation period. This per capita cost is based on a current resident tributary watershed population of 1,765,000 persons. The average annual costs, including both capital and operation and maintenance, of implementation of the water quality management element, the dredging and dredged material disposal element, the shoreline storm damage and flood protection element, and the toxic substances management element are estimated at, respectively, $27.8 million, or about 94 percent; $1.4 million, or about 5 percent; $54,000, or less than 1 percent; and $230,000, or about 1 percent. It should be noted that of the total annual cost of $29.5 million, about $28.9 million, or about 98 percent, is for previously committed measures.

PLAN IMPLEMENTATION

Chapter VIII of this volume identifies the various plan implementation responsibilities by level and unit of government. All the major recommendations contained in the comprehensive Milwaukee Harbor estuary plan can be undertaken by the existing federal agencies and state, county, and local units of government. At the local governmental level, plan implementation entities include Milwaukee County and the City of Milwaukee. On an areawide level, the implementation agency is the Milwaukee Metropolitan Sewerage District. The implementation entity at the state level is the Wisconsin Department of Natural Resources. At the federal level, plan implementation entities include the U. S. Environmental Protection Agency, the Federal Emergency Management Agency, and the U. S. Army Corps of Engineers. The most important recommended plan implementation actions are summarized below by agency or unit of government.

Milwaukee County

It is recommended that Milwaukee County, through its various committees and the County Board of Supervisors, act to implement the recommended estuary plan in the following manner:

1. The County Board of Supervisors should adopt the recommended Milwaukee Harbor estuary plan after the issuance of a report and recommendation by the County Parks, Recreation and Culture Committee and the County Land Conservation Committee as a guide to park facility development and water quality management in the Milwaukee Harbor estuary area.

2. The County Department of Parks, Recreation and Culture should consider further the implementation of the ice control system for the McKinley Marina area by designing and operating a pilot air diffusion system.

City of Milwaukee

It is recommended that the City of Milwaukee, through its various departments, committees, commissions, boards, and the Common Council, act to implement the recommended estuary plan in the following manner:

1. The Common Council should adopt the recommended Milwaukee Harbor estuary watershed plan after a report and recommendation by the Public Improvements Committee, the City Plan Commission, and the Harbor Commission as a guide to land use, park facility development, floodland, and water quality management in the Milwaukee Harbor estuary.

2. The City Plan Commission and the Common Council should review and revise, as necessary, the City of Milwaukee zoning ordinance to implement the recommendations regarding regulatory flood stages set forth in the floodland protection subelement of the Milwaukee Harbor estuary plan.

3. The Harbor Commission should continue to provide dredging for navigational purposes between the federal project water limits and terminal facilities and in the berthing areas of the Port of Milwaukee. The Harbor Commission should continue to work with the U. S. Army Corps of Engineers in the development of a new confined disposal facility for dredged materials in about 1990. The Corps is recommended to be the lead agency in the construction of the facility. However, it is recommended that capacity be provided for the City and private as well as federal dredging projects.

Milwaukee Metropolitan Sewerage District

It is recommended that the Milwaukee Metropolitan Sewerage Commission, acting as the agent for the Milwaukee Metropolitan Sewerage District:

1. Adopt the recommended Milwaukee Harbor estuary plan, including the shoreline storm damage and flood protection, water quality management, and toxic substances management elements.

2. Carry out the recommended separate and combined sewer overflow pollution abatement recommendations as part of its ongoing water pollution abatement program.

3. Continue to operate the flushing tunnels on the Kinnickinnic and Milwaukee River portions of the estuary in a manner designed to achieve the water quality standards for the warmwater fishery-limited recreational use objective.

4. Construct and operate the Menomonee River aeration system included in the recommended water quality management element in a manner necessary to achieve the water quality standards associated with the limited recreational use-warmwater fishery objective.

5. Continue to maintain and refine its program of water and sediment quality and stream stage monitoring in the Milwaukee Harbor estuary and the watersheds tributary to the estuary, including financially supporting the continuous stage recorder stream gages presently in place.

Wisconsin Department of Natural Resources

It is recommended that the Wisconsin Department of Natural Resources:

1. Endorse the Milwaukee Harbor estuary plan as an amendment to the previously endorsed areawide water quality management plan for the Southeastern Wisconsin Region and certify the plan as such through the Governor to the U. S. Environmental Protection Agency.

2. Direct the staff of the Department to integrate the estuary plan recommendations into its broad range of agency responsibilities and to assist in coordinating plan implementation. In particular, Department decisions regarding nonpoint source pollution control should be made in a manner fully consistent with the recommended plan.

3. Cooperate with the Southeastern Wisconsin Regional Planning Commission and the Milwaukee Metropolitan Sewerage District in designing and carrying out a continuing monitoring program for the Milwaukee Harbor estuary and its tributary watersheds, with the Department developing and conducting an intensive biological monitoring survey at about five-year intervals.

4. Undertake the development of a second level toxic substances management plan working cooperatively with the Milwaukee Metropolitan Sewerage District as recommended in the estuary plan. This may require seeking federal as well as state funding.

U. S. Environmental Protection Agency

It is recommended that the U. S. Environmental Protection Agency formally accept and endorse the Milwaukee Harbor estuary plan as an amendment to the regional water quality management plan upon certification as such by the Governor of the State of Wisconsin.

Federal Emergency Management Agency

It is recommended that the Federal Emergency Management Agency acknowledge the Milwaukee Harbor estuary plan and use the flooding-related data, including recommended regulatory flood stages, contained in the plan as a basis for reviewing and updating flood insurance studies.

U. S. Army Corps of Engineers

It is recommended that the U. S. Army Corps of Engineers:

1. Formally acknowledge the Milwaukee Harbor estuary plan.

2. Assist, upon request, any local or state units and agencies of government in the review, design, and construction of the facilities and studies which are proposed as part of the planned high lake level flooding and groundwater study recommended to be developed as part of the shoreline storm damage and flood protection element, and participate in the preparation of that second level study.

3. Continue to provide dredging for navigational purposes in federal channels of the Milwaukee Harbor estuary.

4. Continue to maintain the existing dredged material confined disposal facility until the end of its useful life, and construct a new confined disposal facility at such time as the existing facility nears complete filling. The new facility should be sized to accommodate the needs of the City of Milwaukee Harbor Commission and private riparian landowners, with an estimated capacity for 1.4 million cubic yards of dredged material.

RESOLUTION OF MAJOR ISSUES

As discussed in Chapter VIII of Volume One of this report, several important water quality issues were raised by the Milwaukee Metropolitan Sewerage District facility plan, completed in 1980,[1] by the U. S. Environmental Protection Agency and Wisconsin Department of Natural Resources environmental impact statement concerning that plan, completed in 1981,[2] and by the areawide water quality management plan.[3] Those major issues, which were intended to be addressed by this Milwaukee Harbor estuary study, included the following:

1. The desired and achievable water use objectives and supporting water quality standards for the Milwaukee Harbor estuary.

2. The level of protection for combined sewer overflow abatement required to meet those objectives.

3. The need to abate in-place sediment pollution and the recommended methods of abating such pollution.

4. The reductions in pollutant loadings from nonpoint and point sources that discharge upstream of the Milwaukee Harbor estuary required to meet the water use objectives within the estuary.

5. The presence and severity of toxic conditions which may affect the beneficial use of the Milwaukee Harbor estuary.

This study has provided the information and recommendations needed to resolve each of these issues, although in one instance further study is needed for full resolution. In that instance, the scope and content of the needed further study is defined.

Water Use Objectives and Water Quality Standards

Chapter VIII of Volume One described the inventory findings which helped define the desired and achievable water use objectives and water quality standards for the Milwaukee Harbor estuary. The following conclusions were reached in Volume One:

- The poor aquatic habitat conditions within the inner harbor are caused not only by combined sewer overflow discharges, but also by man-made physical modifications to the waterway, and by intensive urban development located immediately adjacent to the estuary;

- The inner harbor supports a relatively diverse warmwater fishery, in spite of poor water quality, sediment quality, and habitat conditions;

- The abatement of combined sewer overflows may be expected to enhance populations of benthic organisms, which would help establish healthy populations of fish;

- Control of sources of pollution that discharge upstream of the estuary will also be required to meet desired water use objectives; and

- The water quality conditions within the estuary are significantly affected by hydrologic and hydraulic conditions, and the water quality of the Milwaukee and Kinnickinnic River estuaries is substantially improved when lake water is discharged from flushing tunnels located at the upstream ends of the Milwaukee and Kinnickinnic River estuaries.

The analyses set forth in this volume have helped further define appropriate water use objectives and water quality standards for the estuary. In the initial evaluation and selection of water use objectives set forth in Chapter II of this volume, the Milwaukee River estuary and the outer harbor were recommended for full recreational use and the maintenance of a warmwater fishery, since such fully "fishable-swimmable" water quality was considered to be both publicly desired and achievable. The Menomonee and Kinnickinnic River estuaries, however, were initially recommended for limited recreational use and the maintenance of a limited fishery. Even if higher use objectives could be achieved, it was concluded in Chapter II that such objectives may not be desired because of the character of the existing and proposed land uses adjacent to these portions of the estuary, and the character of the estuary itself.

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[1] *Milwaukee Metropolitan Sewerage District, MMSD-Wastewater System Plan, 1980.*

[2] *U. S. Environmental Protection Agency and Wisconsin Department of Natural Resources, Environmental Impact Statement for the Milwaukee Water Pollution Abatement Program, 1981.*

[3] *SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, Volume Three, Recommended Plan, 1979.*

The initial water use objectives assigned to the estuary were subsequently revised based on the results of the analyses of the water quality impacts of the alternative water quality management plans set forth in Chapter IV of this volume. The final recommended water use objectives are as follows:

1. The entire inner harbor is recommended to be classified for limited recreational use and maintenance of a warmwater fishery. The water quality analyses demonstrated that the water quality standards supporting a warmwater fishery could be achieved within the inner harbor under the recommended plan. Because of high bacteria loadings from nonpoint sources, however, which the analyses indicated could be reduced only to a very limited extent by any feasible alternative, the fecal coliform standards supporting full recreational use were found to be not achievable in any part of the inner harbor. Indeed, even under the recommended plan, violations of the fecal coliform standards supporting limited recreational use—which are less stringent than those supporting full recreational use—are expected to occur, with the standards violated up to about 45 percent of the time in the Menomonee River portion of the estuary, and up to about 5 percent of the time in the Milwaukee and Kinnickinnic River portions of the estuary.

2. The outer harbor is recommended to be classified for full recreational use and maintenance of a warmwater fishery. The analyses made indicated that water quality standards supporting these objectives could be fully met within the outer harbor under the recommended plan with but one minor exception. That exception is the occasional low level violation of the un-ionized ammonia standard in the immediate vicinity of the Jones Island sewage treatment plant outfall.

The selection and interpretation of water quality standards is another important issue addressed by the estuary study. This issue was first raised in the areawide water quality management plan, where it became necessary to develop and apply standards which could be used to evaluate both dry-weather and wet-weather water quality problems, particularly with respect to nonpoint sources of pollution. In the areawide plan, a probabilistic approach to the interpretation and application of standards was utilized, whereby certain numeric standards were required to be met a specified percentage of the time. The required compliance levels were selected based on whether the pollutant concerned could affect aquatic life, and on the observed compliance levels in relatively clean waterways which supported healthy populations of aquatic life. The achievement of standards at the required compliance levels generally ensured that suitable water quality would exist during all but the most extreme wet-weather and dry-weather periods. The probabilistic standards were readily compared to the results of continuous water quality modeling conducted under the areawide planning program.

Additional research conducted since the completion of the areawide plan—primarily by the U. S. Environmental Protection Agency—has helped to better define the frequency and duration of water quality conditions which may have an impact on aquatic life. In particular, the standards for dissolved oxygen and toxic substances were refined. With respect to dissolved oxygen, standards were established for several durations—30-day mean, 7-day mean, 1-day mean, and absolute minimum—rather than for a single specific compliance level. Some of the duration standards are intended to apply to only a part of the year. These revised standards provide more specific protection against the harmful effects of low dissolved oxygen levels. With respect to toxic substances, including metals, organic substances, and un-ionized ammonia nitrogen, specific standards to protect against acute toxicity and chronic toxicity were developed. These toxic substance standards are also intended to be applied for specific durations—with the acute standards never to be exceeded, and the chronic standards not to be exceeded on a 30-day mean basis, and then for a total of not more than 96 hours during any 30-day period. These toxic substance standards can thus be related to anticipated effects—either the death of the organisms concerned, or long-term harmful effects on those organisms.

Finally, a new set of fecal coliform standards to support limited recreational use was proposed. The areawide plan did not include recommended standards for limited recreational use, and thus these new standards represent an extension of that plan.

<u>Level of Protection for Combined Sewer Overflow Abatement</u>

As of February 1986, the Milwaukee Metropolitan Sewerage District had estimated that the storage facilities designed to contain excess discharges from the separate sewered areas would also provide for combined sewer overflow abatement at a 0.7-year level of protection. In other words, the combined sewers would continue to discharge untreated sewage into the estuary an average of once every 0.7 year, or approximately once every eight months. Chapter IV of this volume documented the impacts and cost of this 0.7-year level of protection through the analysis of the committed action alternative. The analysis indicated that although a 0.7-year level of protection would substantially improve water quality conditions within the estuary, removing about 97 percent of the existing pollutant loadings from combined sewer overflows, the recommended water use objectives would occasionally be violated.

A higher level of protection for combined sewer overflow abatement could be provided by creating additional overflow storage volume. The incremental beneficial impacts and higher costs associated with virtual elimination of all combined sewer overflows was evaluated through the analysis of the elimination of combined sewer overflows alternative. That analysis demonstrated that elimination of the overflows would be very costly—with a capital cost of about $300 million and an incremental equivalent annual cost of about $16.3 million. Although the estuary, under the elimination of combined sewer overflows alternative, would not experience the negative water quality impacts during overflow events that it would under the committed action alternative, the overall water quality benefits of elimination of the overflows would be minimal. For example, under high-temperature, low-flow conditions, during which critical dissolved oxygen levels may be expected, the elimination of combined sewer overflows alternative would provide dissolved oxygen levels that are substantially higher than under the committed action alternative only about 10 percent of the time. The remaining 90 percent of the time, the dissolved oxygen levels would be essentially the same. The analysis thus indicated that it would not be cost-effective to provide additional storage volume to increase the level of protection for overflow abatement beyond that previously committed by the Milwaukee Metropolitan Sewerage District. It should be noted that under either level of protection—complete, or 0.7 year—instream measures, such as flushing tunnels and aeration systems, would have to be utilized to fully abate any anticipated dissolved oxygen problems.

Abatement of In-Place Pollution

Large amounts of decomposable organic material and toxic substances have been deposited in the bottom sediments of the estuary, and these pollutants affect the biota and contribute to the poor water quality conditions within the estuary. The evaluation of the need to abate, or remove, the bottom sediments considered three problems: 1) interference with navigation caused by insufficient water depths; 2) dissolved oxygen problems caused by the decomposition of organic sediments; and 3) the effects of toxic substances in the sediments on the water column and biota.

Historically, dredging of the bottom sediments has been conducted to maintain suitable water depths for navigation. Chapter V of this volume recommended that dredging be continued to maintain commercial navigation within the estuary. It may be expected that once the combined sewer overflows are abated, sedimentation rates, and the attendant required frequency of dredging, will be reduced by about 50 percent. To accommodate disposal of dredge spoils, it is recommended that a new confined disposal facility be constructed in the outer harbor.

With respect to dissolved oxygen problems associated with the bottom sediments, the study determined that—contrary to what was previously believed—depleted dissolved oxygen levels during wet-weather periods are not caused by sediment scour during combined sewer overflow events, such depletions resulting instead from algal respiration and inhibited photosynthesis. Undisturbed sediments were found to cause dissolved oxygen problems primarily during warm, dry-weather, low-flow periods. About 70 percent of the reactive organic sediments were estimated to be contributed by combined sewer overflows, and once the combined sewer overflows are abated to the recommended level of protection, the bottom sediments may be expected to decompose and stabilize within a period of approximately two years. Following abatement of the overflows and stabilization of the sediments, some dissolved oxygen problems may be expected to remain. However, removal of the bottom sediments would not resolve those residual problems which are caused by upstream pollution and algal respiration. Accordingly, those residual problems can be resolved only by upstream control measures and instream measures such as the operation of flushing tunnels or the provision of aerators. Thus, removal of the bottom sediments to abate dissolved oxygen problems—beyond that required to maintain navigation—was not recommended.

This study was not intended, and was not able, to definitively determine the extent, severity, and sources of toxic substance pollution problems related to the bottom sediments, or whether abatement measures are needed to resolve such problems. The bottom sediments were classified as heavily polluted based on a comparison of the metal concentrations found present to U. S. Environmental Protection Agency sediment quality guidelines. The concentrations of 11 toxic organic substances were also estimated to exceed toxicity standards in the interstitial water of the bottom sediments. Furthermore, fish tissue sample concentrations exceeded allowable levels of polychlorinated biphenyls (PCB's) for consumption. In view of these findings, and as discussed in Chapter VII of this volume, a further study of pollution by toxic substances is recommended to be conducted.

Abatement of Upstream Sources of Pollution

Chapter VIII of Volume One of this report described two primary water quality problems in the estuary that may be directly related to pollutant loadings from sources located upstream of the estuary. These problems are high fecal coliform levels, which interfere with certain recreational uses, and excessive growths of algae, which cause aesthetic problems and high diurnal fluctuations in dissolved oxygen levels.

In the areawide water quality managment plan for southeastern Wisconsin, the Milwaukee River upstream of the estuary was recommended for full recreational use, while the Menomonee and Kinnickinnic Rivers upstream of the estuary were recommended for limited recreational use. In the areawide plan, the fecal coliform standards supporting full recreational use and limited recreational use were the same, whereas this study recommends standards for limited recreational use which are less stringent than those for full recreational use.

The study results indicated that a high level of reduction in fecal coliform loadings—from 80 to 95 percent—would be needed to achieve the standards supporting full recreational use of the river reaches immediately upstream of the estuary. It was further concluded that it would not be practicable to achieve these high levels of reduction, primarily because fecal coliform loadings from certain sources, such as urban land runoff, would be difficult to control. The study concluded that bacterial levels in the reaches of the tributary rivers immediately upstream of the estuary could not be reduced enough to support full recreational uses within the inner harbor. Therefore, the inner harbor was classified for limited recreational use.

Excessive growths of algae from upstream sources were found to affect the Milwaukee River estuary. Algal levels in the Kinnickinnic and Menomonee Rivers were found to be relatively low. To reduce algal growths within the Milwaukee River, the areawide water quality management plan concluded that abatement of nonpoint sources and a high level of phosphorus removal at sewage treatment plants would be required. The benefits of the upstream nutrient removal are discussed in Chapter IV of this volume under the evaluation of the abatement of nonpoint sources of pollution alternative and of the reduction in point source phosphorus loadings alternative. The analyses indicated that abatement of nonpoint sources to the highest achievable level practicable would result in a substantial improvement in dissolved oxygen levels—up to 2 milligrams per liter (mg/l) higher than under the committed action alternative—in portions of the Milwaukee River estuary, but that the dissolved oxygen standards supporting a warmwater fishery would continue to be violated. This is due, in part, to the fact that the production of algae in the Milwaukee River upstream of the estuary may at times be nitrogen-limited, and nonpoint source controls are not effective in removing nitrogen. Very high levels of phosphorus control could result in phosphorus becoming the factor limiting algal growth. To help reduce the sediment, phosphorus, and biochemical oxygen levels in the Milwaukee River upstream of the estuary, the plan recommends that rural nonpoint sources of pollution be controlled. Control of urban nonpoint sources of pollution, which is more costly and would provide only minor benefits, was not recommended for the purpose of protecting the water quality of the estuary. The control of urban nonpoint sources of pollution may be needed in some areas, however, to protect water bodies located upstream of the estuary. With respect to a high level of phosphorus removal at sewage treatment plants, Chapter IV indicated that such control would provide only minimal water quality benefits within the Milwaukee Harbor estuary, and would entail a high cost. The recommended water use objectives in the estuary could be achieved without the implementation of such measures. However, such levels of removal may be needed to protect the water bodies upstream of the estuary.

Toxic Conditions

The estuary study included a review of toxic substances data that were collected and collated under the study. Toxic substances were found in the water and bottom sediments of the estuary, as well as in the tissue of fish residing in the estuary. The bottom sediments of the inner harbor were classified as heavily polluted based on the high concentrations of five metals and one organic substance found in the sediments. Acute or chronic toxicity standards for 11 organic substances were estimated to be violated in the interstitial water of the bottom sediments. Fourteen toxic substances, including four metals and 10 organic substances, were found at detectable levels in the tissue of fish caught in the estuary. Chronic toxicity standards were found to be violated for three substances within the water column of the estuary. The study results suggested that contaminated bottom sediments may be a source of toxic substances to the overlying water column and to aquatic organisms. With respect to human health, the greatest known hazard is related to the consumption of fish containing excessive levels of polychlorinated biphenyls (PCB's). A faunal toxicity survey conducted under the study indicated that chronic toxic conditions are present, particularly during wet-weather periods. Acute toxic effects, however, were not identified in the survey.

To further define the toxic conditions within the estuary, a toxic pollution abatement study was recommended. The study should address the adoption and application of in-place sediment quality standards, the release of toxic substances from the bottom sediments to the biota and water column, the sources of toxic substances present in the sediments, and necessary abatement measures.

PUBLIC REACTION TO THE RECOMMENDED PLAN AND SUBSEQUENT ACTION OF THE TECHNICAL ADVISORY COMMITTEE

Introduction

The recommended Milwaukee Harbor estuary plan was the subject of a formal public hearing held on December 2, 1987. The hearing was conducted on behalf of the Regional Planning Commission by the Technical Advisory Committee for the Milwaukee Harbor Estuary Comprehensive Water Resources Management Plan, with the Chairman of the Committee presiding. The purpose of the hearing was to present the findings and recommendations of the estuary study for review and comment by concerned public officials and interested citizens. The hearing was announced through news releases sent to all news media serving the greater Milwaukee area, and through publication and distribution of two Commission newsletters summarizing the preliminary findings and recommendations of the study.[4] The hearing was held at 7:00 p.m. on December 2, 1987, at the Milwaukee County Courthouse Annex. Minutes of the public hearing were published by the Commission and provided to both the Technical Advisory Committee and the Regional Planning Commission.[5]

Only 37 people attended the public hearing, and only five chose to comment. Of these five, three generally supported the plan as presented, while two expressed concerns about the plan, primarily with regard to the toxic substances management element.

Summary of Public Comment

The following summarizes the comments received at the hearing, along with the Advisory Committee response to those comments.

1. A chemical engineer employed by a Milwaukee industrial firm and a resident of the Village of Germantown was the first commentator. He expressed six concerns about the recommended plan, the first three concerns relating to toxic substances, the fourth concern relating to the water use objectives recommended for the Milwaukee River estuary, the fifth concern relating to the responsibilities assigned to the various implementing agencies, and the sixth concern relating to the categorization of the cost of the toxic substances management study as a capital cost.

   The commentator suggested that more emphasis should have been placed on toxic pollution in the study. The toxic pollution problem, he said, should be addressed concurrently with the conventional pollution problem. He expressed concerns that once the problem of deficient dissolved oxygen levels is resolved, the newly established fishery populations would then be susceptible to harm by toxic substances and would continue to be a potential source of toxic substances in the food chain. An example of a similar situation in the Green Bay-Fox River system was cited. The commentator noted that the study did not contain recommendations for the abatement of the toxic pollution problem in the estuary, but merely recommended further study of the problem.

[4] *See SEWRPC Newsletter, Vol. 27, No. 5, September-October 1987; and Vol. 27, No. 1, January-February 1987.*

[5] *See Minutes of Public Hearing, A Water Resources Management Plan for the Milwaukee Harbor Estuary, SEWRPC.*

He indicated that while it would be desirable to have established sediment quality standards for toxic substances, the conduct of a toxic substances study should not be delayed until such standards are developed by the U. S. Environmental Protection Agency.

In response to the first concern raised by the commentator, it was concluded by the Technical Advisory Committee that while it may have been preferable to fully address the toxic pollution problem in the estuary under the study, the very existence of that problem was not fully known when the study design was prepared in 1981. Indeed, the water column, sediment, and fish tissue sample surveys performed under the study helped to reveal the problem. Moreover, sediment and water quality standards, as well as sampling and analytical techniques, were, and are still, not well established for the full range of toxic substances. It was therefore deemed prudent to proceed with the estuary study as conceived in the study design to develop plans for resolving problems related to conventional pollutants.

With respect to toxic substances, the study provides an initial assessment of the existing conditions, and recommends the preparation of the toxic substances management plan. The estuary study did compile, review, and evaluate all available data on the presence of toxic substances in the estuary; and collected data on the concentrations of toxic metals present in the bottom sediments and water column, and on the concentrations of toxic metals and organic substances present in the tissue of fish. In addition, a faunal toxicity survey was conducted to evaluate acute and chronic toxicity effects of harbor water on the zooplankton Ceriodaphnia. Most importantly, implementation of the recommended plan will in any case contribute materially to the abatement of the toxic pollution problem in the estuary. The Committee further concluded that water quality and sediment quality standards will be needed to more definitively evaluate the existing and probable future toxic pollution situation in the estuary. The Committee accordingly concluded that no specific changes to the plan would be appropriate in response to the first concern raised by the commentator. The Committee, however, did recommend that in response to the second concern raised, the plan be clarified to specifically state that the recommended preparation of a toxic substances management plan, as well as implementation of any recommended actions, be placed on a schedule consistent with the point and nonpoint source pollution abatement programs also recommended. The Committee also acknowledged that the toxic substances management program should be coordinated with the remedial action plan to be prepared by the Wisconsin Department of Natural Resources in response to a request by the International Joint Commission.

The first commentator expressed the opinion that the recommendation for sediment disposal in a confined disposal facility after de-watering by mounding could result in pollutants being returned to the estuary at a rate greater than if the material were not de-watered. In response, the Advisory Committee noted that any liquid resulting from the de-watering process and leaving the confined disposal site would be filtered in the facility prior to discharge. Most toxic pollutants would likely remain attached to the solids, and be captured in the filter beds. It was further noted that the most practical and economically feasible methods of de-watering dredge spoils available at this time were recommended, and that there should be no significant adverse impacts associated with these procedures if the confined disposal facility is properly designed. Thus, no specific changes to the plan were recommended in this regard.

The fourth concern raised by the first commentator was related to the water use objective classification for the Milwaukee River upstream of Wisconsin Avenue. That portion of the inner harbor, it was suggested, should be classified for full recreational use because the shoreline is not heavily industrialized and the area contains the theater districts. In response, the Advisory Committee noted that the Milwaukee River estuary, as well as the rest of the inner harbor, was recommended for limited partial-body contact recreational use, rather than full-body contact recreational use, because very high—more than 95 percent—reductions in fecal coliform loadings would be required upstream of the estuary in order to achieve coliform levels appropriate for the suggested higher use objective. Attainment of the high level of reduction in fecal coliform loadings required was found to be technically impractical and economically unfeasible at this time. The Committee accordingly reaffirmed the water use objectives recommended in the plan.

The fifth major concern raised by the first commentator was related to the roles of the various agencies in implementing the plan. It was specifically suggested that the Wisconsin Department of Natural Resources be assigned primary responsibility for all water quality, sediment quality, and fish tissue quality monitoring activities, rather than assigning some of these responsibilities to the Milwaukee Metropolitan Sewerage District. It was also suggested that the Department should not have to bear any of the costs of abating pollutant runoff from salt and other material storage sites, but rather, that the parties responsible for such runoff should be held responsible for controlling it.

In response to this concern, the Advisory Committee noted that the Milwaukee Metropolitan Sewerage District is presently responsible for the elements of the plan involving combined and separate sewer overflow abatement and for operating instream water quality improvement facilities—flushing tunnels, and that the District has a well-established, ongoing monitoring program and has been involved in previous water quality planning programs, including the Milwaukee Harbor estuary study. The Committee noted that the functions assigned to the District in Chapter VIII are consistent with the District's previous water quality management efforts, and that the District is fully capable of effectively carrying out these duties. It will, however, be necessary for the District, the Wisconsin Department of Natural Resources, and the other implementing agencies to work cooperatively in implementing the plan. With regard to the responsibility for resolution of the problems caused by runoff from material storage sites, it was noted by the Committee that the Wisconsin Department of Natural Resources does provide for implementation through second level plans and grants to landowners for abatement of nonpoint source pollution in rural areas. In those areas, the landowners also receive pollution control benefits in the form of reduced soil loss. Thus, it was concluded that similar plan development and incentives to control nonpoint sources of pollution in urban areas should be provided. In view of the above conclusion, no specific plan revisions were deemed necessary in response to the fifth comment of the first commentator.

The final comment by the first commentator related to the cost of implementing the plan. He suggested that the cost of implementing the plan was in part misleading since the toxic substance study, which represents $3.2 million of the $5.2 million cost cited in the report, is only the amount needed to complete additional second level facility planning regarding the toxic pollution problem. An additional cost will likely be needed to carry out the findings of that plan. With regard to this comment, the Advisory Committee agreed that the cost estimate for the toxic substances management element of the plan should be footnoted in the tables and clarified in the text to indicate that the cost was only for the preparation of a toxic substances management plan, and not a capital cost for subsequent action, if needed, to implement that plan.

2. The President of the Milwaukee Chapter of the Audubon Society—who was also a member of the Technical Advisory Committee that guided the development of the estuary study—commented on the toxic substances plan element and the recommended water use objectives. This commentator reported that the Technical Advisory Committee had deliberated at length upon the recommended water use objectives. She indicated that, while several members of the Committee would have liked to have seen fully fishable-swimmable objectives recommended, it was recognized that compromises were necessary based on practicality of implementation, costs, and adjacent land uses. She noted that nothing in the study recommendations would preclude the designation of higher use objectives at some later date should that prove to be viable. This commentator also supported the continued work to resolve the toxic substances problems, and called for a cooperative effort involving the Milwaukee

Metropolitan Sewerage District and the Wisconsin Department of Natural Resources in this report. She also noted that the remedial action program to be prepared by the Wisconsin Department of Natural Resources will require legislative action for funding, and that her organization would support such action. This commentator also indicated that her organization endorsed the notion of zero toxic discharges as a means to attain the ultimate goal of not having to use fish consumption advisories. The speaker concluded her presentation by indicating that the planning process used in the estuary study was long and tedious but had resulted in a very good plan that she thought could and should be implemented and adopted by the communities and agencies involved.

These comments were welcomed by the Advisory Committee; no changes to the plan in response to these comments were deemed to be necessary.

3. The next speaker was a registered professional engineer in private practice who lives in Mequon and specializes in water resources management. The speaker indicated that she was employed by one of the largest consulting engineering firms in the County, that she had been involved in the development and review of many similar studies throughout the country, and that upon review of this particular study, she concluded that it was one of the best such studies that she has reviewed, providing practical, cost-effective, achievable solutions to the identified problems. She also indicated that additional work was required on the toxic pollution problem, and she hoped that the required toxic substances pollution abatement plan could be completed in as sound a manner as the plan which was reviewed at the public hearing.

   Again, these comments were welcomed by the Advisory Committee; no changes to the plan in response to these comments were deemed necessary.

4. The fourth commentator, the State Research Director of Citizens for a Better Environment, commended the plan as a step toward resolving the water resources problems, but raised several concerns and questions.

   The first concern raised by the commentator related to the additonal work required with respect to toxic pollution. The commentator pointed out that the Wisconsin Department of Natural Resources now had a responsibility to prepare a remedial action plan. He noted, however, that at this time, the resources to prepare that plan were not available. The Advisory Committee noted in response that the funding necessary for the study was set forth in the plan and that it was recommended that such funding be made available by the state and federal governments. No plan revisions were deemed to be necessary in response to this item.

   The commentator also noted that the $5.2 million estimate of the cost of implementing the plan was misleading since the recommended toxic pollution abatement study, which represents $3.2 million of that cost, is only a study. An additional cost will likely be incurred to carry out the findings of that study. The Advisory Committee agreed that the cost estimate for the toxic substances management element of the plan should be footnoted in the tables and a statement added to the text that the $3.2 million cost was for the conduct of a second level, more-detailed study, and not a capital cost to implement the plan.

   The fourth speaker asked why only 15 percent and 30 percent control levels were recommended for pollutants contributed by agricultural land runoff and livestock operations, respectively. With regard to this question, the Advisory Committee noted that the levels of nonpoint source control recommended represented about 50 percent of the maximum achievable levels. Higher levels were not recommended because such levels were found to be unnecessary for meeting the recommended estuary water quality standards.

   The fourth commentator also noted that the control of runoff from salt and other material storage areas was recommended, but that details of how that should be done were not included in the plan. The Advisory Committee noted with regard to runoff from salt, scrap metal, and other material storage sites that the site-specific nature of developing controls for such areas required that each site be examined in cooperation with the operators of the sites concerned to determine the most cost-effective way to abate the problem. The text of the report does include a list of potential means of achieving the desired reductions, but does not identify the most cost-effective option. Such identification requires detailed, site-specific, engineering studies which take into account the operational requirements of the land uses involved. Accordingly, it was concluded that the report was adequate in this regard.

The fourth commentator also questioned what uses were recommended to be made of the existing and proposed confined disposal area facilities once sediments are deposited in the existing and new facility. With regard to the reuse of the confined disposal facility area after the facilities are full, it was noted by the Committee that these areas are located in the areas covered by lakebed grants, and thus only certain uses, including navigation or harbor facilities, public parks, or highways, could be made of the sites. A discussion of the lakebed grant requirements is included in Chapter VI. No specific changes to the plan were deemed necessary by the Advisory Committee regarding this matter.

Finally, the fourth commentator suggested that additional comments should have been sought from the public—particularly from neighborhood groups—regarding their goals and priorities for the estuary.

With regard to the suggestion for additional public input into the planning process, the Advisory Committee noted that the Committee itself was composed of knowledgable technicians, elected and appointed local officials, and concerned citizens, including representatives of environmental groups, and that inputs from such a balanced Committee were useful in carrying out the planning process in accordance with sound objectives. Furthermore, the Committee noted, there had been extensive newspaper and radio coverage of the work as it proceeded. The Commission Newsletter describing the plan and announcing the hearing was distributed to approximately 1,800 persons. Thus, interested persons had been informed but apparently most chose not to comment.

5. The final speaker was a citizen of the Bay View area of the City of Milwaukee. His only comment relating directly to the plan indicated that he felt that the importance of toxic pollution, and particularly of polychlorinated biphenyls—PCB's—was over-stressed, and that the plan's focus on conventional pollutants was sound.

   In response to these comments, the Advisory Committee recognized that while there may be some dispute among the experts concerned regarding the health threat posed by PCB's, prudence indicated that it was sound to consider PCB's as a likely threat to human health. It was also noted that the recommended toxic substances management study would clarify this issue.

Concluding Remarks

Based upon the testimony submitted at the hearing, the Advisory Committee recommended adoption of the Milwaukee Harbor estuary plan essentially as that plan was presented at the public hearing.

CONCLUSION

Adoption and implementation of the recommended comprehensive plan for the Milwaukee Harbor estuary may be expected to result in the substantial achievement of the adopted water resources objectives and supporting standards. Consequently, the implementation of the plan may be expected to provide a safer, more healthful and more pleasant, and more orderly and efficient environment. Implementation of the recommended plan would abate the most serious and costly environmental problems of the estuary, including flooding and high groundwater problems due to high lake levels, and water pollution; would minimize the development of new problems of this kind; and would enhance the potential biological and recreational use of the waterway system, as well as its navigational use potential. Failure to implement the estuary plan may be expected to result in the further intensification of developmental and environmental problems, and, potentially, the creation of new problems that will be even more expensive to resolve. The Milwaukee Harbor estuary plan also provides for the resolution of long-standing major issues relating to water use objectives and water quality standards, and the best means for achievement of those objectives.

APPENDICES

Appendix A

HYDROLOGIC-HYDRAULIC SUMMARY FOR STRUCTURES WITHIN THE MILWAUKEE HARBOR ESTUARY: PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

Table A-1

HYDROLOGIC-HYDRAULIC SUMMARY—KINNICKINNIC RIVER ESTUARY: PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

	Structure Identification and Selected Characteristics					10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
60	Chicago & North Western Railway	0.84	1S	100	Yes	4,550	582.9	582.9	0.0	--	--	6,500	584.1	584.1	0.0	--	--	7,400	584.5	584.5	0.0	--	--
65	S. Kinnickinnic Avenue/STH 32	1.28	1S	50	Yes	4,550	582.9	582.9	0.0	--	--	6,500	584.1	584.1	0.0	--	--	7,400	584.5	584.5	0.0	--	--
70	Soo Line Railroad	1.31	1S	100	Yes	4,550	582.9	582.9	0.0	--	--	6,500	584.1	584.1	0.0	--	--	7,400	584.5	584.5	0.0	--	--
75	Chicago & North Western Railway	1.35	1S	100	Yes	4,550	582.9	582.9	0.0	--	--	6,500	584.1	584.1	0.0	--	--	7,400	584.5	584.5	0.0	--	--
80	S. 1st Street	1.43	1S	50	Yes	4,350	582.9	582.9	0.0	--	--	6,200	584.1	584.1	0.0	--	--	7,000	584.5	584.5	0.0	--	--
85	W. Becher Street	1.67	1S	50	Yes	4,350	582.9	582.9	0.0	--	--	6,200	584.1	584.1	0.0	--	--	7,000	584.5	584.5	0.0	--	--
90	W. Lincoln Avenue	1.96	1S	50	Yes	4,350	582.9	582.9	0.0	--	--	6,200	584.1	584.1	0.0	--	--	7,000	584.5	584.5	0.0	--	--
95	S. 1st Street	2.01	1S	50	Yes	4,350	582.9	582.9	0.0	--	--	6,200	584.1	584.1	0.0	--	--	7,000	584.5	584.5	0.0	--	--
100	S. Chase Avenue	2.40	1S	50	No	4,350	587.0	582.9	4.9	0.4	--	6,200	589.2	584.1	5.1	2.6	--	7,000	590.0	584.9	5.1	3.4	0.6

Source: SEWRPC.

Table A-2

HYDROLOGIC-HYDRAULIC SUMMARY—MENOMONEE RIVER ESTUARY: PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

	Structure Identification and Selected Characteristics					10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
500	Soo Line Railroad	0.02	1I	100	Yes	10,920	582.9	582.9	--	--	--	16,450	584.1	584.1	--	--	--	19,620	584.5	584.5	--	--	--
505	N. Plankinton Avenue	0.06	1I	50	Yes	10,900	582.9	582.9	--	--	--	16,450	584.1	584.1	--	--	--	19,620	584.5	584.5	--	--	--
510	N. 6th Street	0.35	1I	50	Yes	10,900	582.9	582.9	--	--	--	16,450	584.1	584.1	--	--	--	19,620	584.5	584.5	--	--	--
515	North-South Freeway/IH 94	0.58	1I	100	Yes	10,900	582.9	582.9	--	--	--	16,450	584.1	584.1	--	--	--	19,620	584.5	584.5	--	--	--
520	N. Muskego Avenue	0.92	1I	50	Yes	10,900	582.9	582.9	--	--	--	16,450	584.1	584.1	--	--	--	19,620	584.5	584.5	--	--	--
525	N. 16th Street	1.11	1I	50	Yes	10,900	582.9	582.9	--	--	--	16,450	584.1	584.1	--	--	--	19,620	584.5	584.5	--	--	--
527	N. 25th Street	1.70	1I	50	Yes	10,900	582.9	582.9	--	--	--	16,450	584.1	584.1	--	--	--	19,620	584.5	584.5	--	--	--
530	Soo Line Railroad	1.87	1S	100	No	10,900	583.9	583.8	0.1	--	--	16,450	587.1	586.3	0.8	1.4	--	19,620	587.8	587.6	0.2	2.1	--
535	Soo Line Railroad	1.91	1S	100	No	10,900	584.6	583.9	0.7	--	--	16,450	587.4	587.1	0.3	3.0	--	19,620	588.0	587.8	0.2	3.6	--
540	Soo Line Railroad	1.95	1S	100	No	10,900	585.1	584.6	0.5	--	--	16,450	587.8	587.4	0.4	1.7	--	19,620	588.0	588.0	0.0	1.9	--
542	Soo Line Railroad	1.97	1S	100	No	10,900	585.6	585.1	0.5	--	--	16,450	589.4	587.8	0.6	1.3	--	19,620	589.5	588.0	1.5	1.4	--
545	N. 27th Street	2.10	1S	50	Yes	10,900	591.6	586.4	5.2	--	--	16,450	595.2	589.8	5.4	--	--	19,620	597.2	590.2	7.0	--	--
546	Falk Dam	2.22	2S	--	--	10,900	592.2	591.8	0.4	--	--	16,450	595.7	595.4	0.3	--	--	19,620	597.7	597.4	0.3	--	--

Source: SEWRPC.

Table A-3

HYDROLOGIC-HYDRAULIC SUMMARY—MILWAUKEE RIVER ESTUARY: PLANNED LAND USE AND EXISTING CHANNEL CONDITIONS

	Structure Identification and Selected Characteristics					10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile[a]	Structure Type and Hydraulic Significance[b]	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage[d,e] (feet above NGVD)	Downstream Stage[d,e] (feet above NGVD)	Backwater[f] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)
237	Chicago & North Western Railway	0.44	1S	100	Yes	13,100	582.9	582.9	0.0	--	--	19,400	584.1	584.1	0.0	--	--	26,700	584.5	584.5	0.0	--	--
236	N. Broadway Street	0.63	1S	50	Yes	13,100	582.9	582.9	0.0	--	--	19,400	584.1	584.1	0.0	--	--	26,700	584.5	584.5	0.0	--	--
235	N. Water Street	0.78	1S	50	Yes	13,100	582.9	582.9	0.0	--	--	19,400	584.1	584.1	0.0	--	--	26,700	584.5	584.5	0.0	--	--
233	St. Paul Avenue	1.06	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.5	584.5	0.0	--	--
232	East-West Freeway/IH 94	1.12	1I	100	Yes	10,300	582.9	582.9	--	--	--	14,800	584.1	584.1	--	--	--	16,700	584.5	584.5	--	--	--
231	Clybourn Street	1.15	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.5	584.5	0.0	--	--
230	Michigan Street	1.23	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.5	584.5	0.0	--	--
229	Wisconsin Avenue	1.32	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.5	584.5	0.0	--	--
228	Wells Street	1.48	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.5	584.5	0.0	--	--
227	Kilbourn Avenue	1.55	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.5	584.5	0.0	--	--
226	State Street	1.65	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.5	584.5	0.0	--	--
225	Juneau Avenue	1.83	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.5	584.5	0.0	--	--
224A	Freeway Spur	1.89	1I	100	Yes	10,300	582.9	582.9	--	--	--	14,800	584.1	584.1	--	--	--	16,700	584.5	584.5	--	--	--
224	Cherry Street	2.06	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.7	584.6	0.0	--	--
223	Walnut Street	2.32	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	584.8	584.8	0.0	--	--
222	N. Holton Street	2.60	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	585.0	585.0	0.0	--	--
221	N. Humboldt Avenue	2.98	1S	50	Yes	10,300	582.9	582.9	0.0	--	--	14,800	584.1	584.1	0.0	--	--	16,700	585.0	585.0	0.0	--	--
220	North Avenue Dam	3.17	2S	--	--	10,300	599.2	582.9	16.3	--	--	14,800	600.4	584.1	16.3	--	--	16,700	601.0	585.4	15.6	--	--

[a] Measured in miles above mouth at Lake Michigan for Milwaukee River estuary. Measured in miles above confluence with Milwaukee River for Kinnickinnic River and Menomonee River estuaries.

[b] Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.

[c] A bridge has an adequate hydraulic capacity if it will remain open during a flood having a recurrence interval equal to or less than the recommended design frequency. A bridge is hydraulically inadequate if the approach road or bridge is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.

[d] The flood stage indicated represents the water surface elevation approximately 50 feet from the bridge.

[e] City of Milwaukee Vertical Datum = National Geodetic Vertical Datum - 580.60 feet.

[f] Backwater is defined as the change in stage from the upstream side of the hydraulic structure to the downstream side.

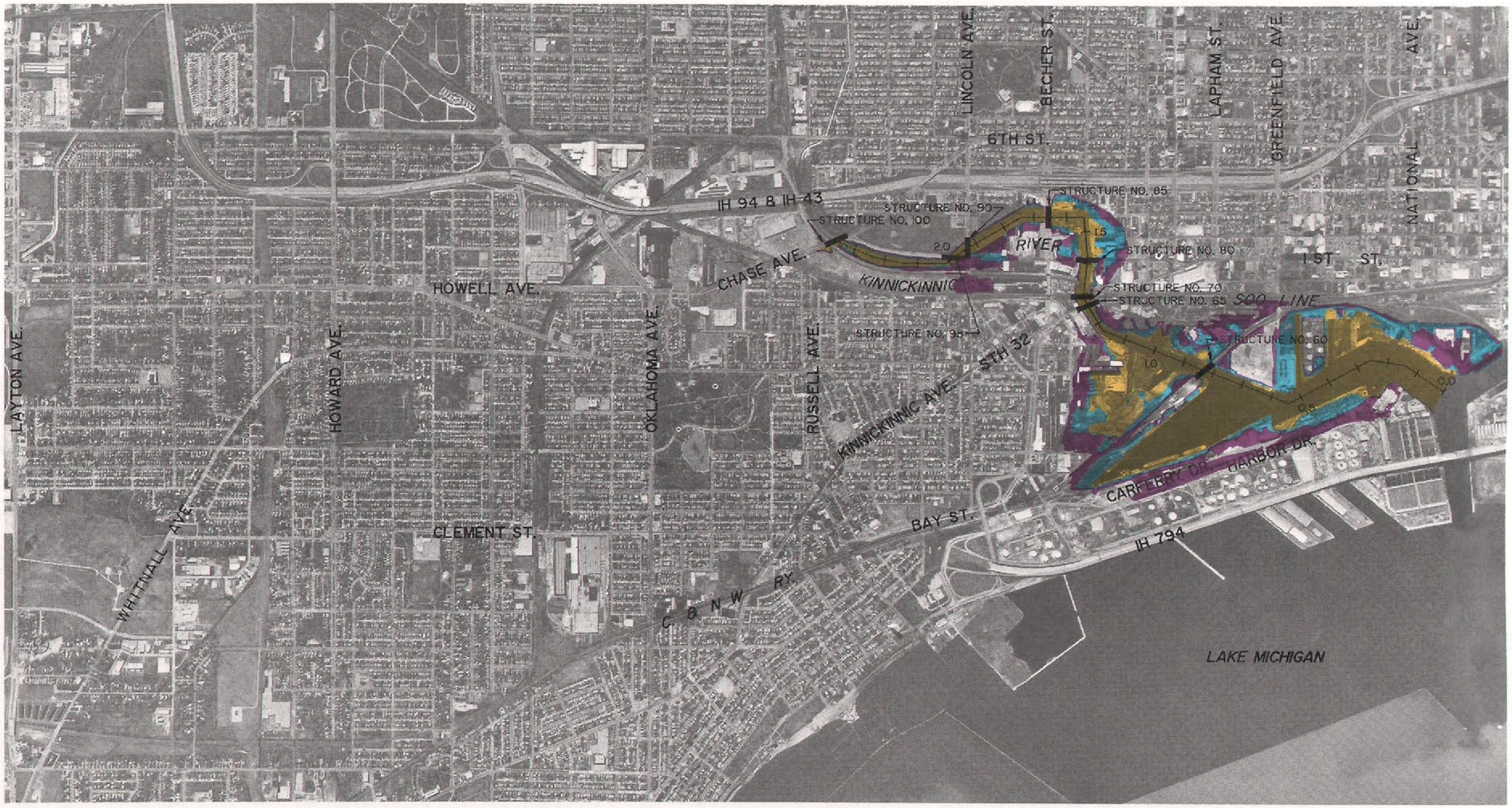
Source: SEWRPC.

Appendix B

FLOOD STAGE AND STREAMBED PROFILES AND AERIAL PHOTOGRAPHS SHOWING AREAS SUBJECT TO FLOODING

Map B-1

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG KINNICKINNIC RIVER ESTUARY



LEGEND

- RECOMMENDED REVISED REGULATORY FLOODPLAIN
- ADDITIONAL FLOODPLAIN ASSUMING A 50-YEAR RISING TREND WITH A TWO-FOOT RISE IN LAKE MICHIGAN OVER 1985 LEVEL
- ADDITIONAL FLOODPLAIN ASSUMING A 50-YEAR RISING TREND WITH A FOUR-FOOT RISE IN LAKE MICHIGAN OVER 1985 LEVEL
- 1.0 — APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATION

NOTE: THE BLUE AND PURPLE SHADED AREAS ON THIS FLOOD INUNDATION MAP INDICATE THE POTENTIAL INUNDATION AREAS OF LAKE MICHIGAN IF THE LAKE IS IN A LONG-TERM RISING TREND. THESE INUNDATION AREAS ARE INTENDED TO BE ADVISORY TO ENGINEERS AND ARCHITECTS INVOLVED IN PROJECT DESIGN AND ARE NOT INTENDED TO BE USED FOR REGULATORY PURPOSES. THIS RANGE OF ADVISORY LEVELS WAS DEVELOPED ASSUMING THAT THE LAKE IS IN A LONG-TERM RISING TREND AS SOME HYDROLOGISTS, CLIMATOLOGISTS, AND GEOLOGISTS HAVE INDICATED MAY BE POSSIBLE. CONSEQUENTLY, THE ADVISORY LEVELS ARE HIGHER THAN THE REGULATORY LEVEL INDICATED, WHICH IS BASED UPON A STATISTICAL ANALYSIS OF THE LAKE LEVEL DATA SYSTEMATICALLY COLLECTED AT MILWAUKEE OVER THE PERIOD 1915 THROUGH 1985.

GRAPHIC SCALE

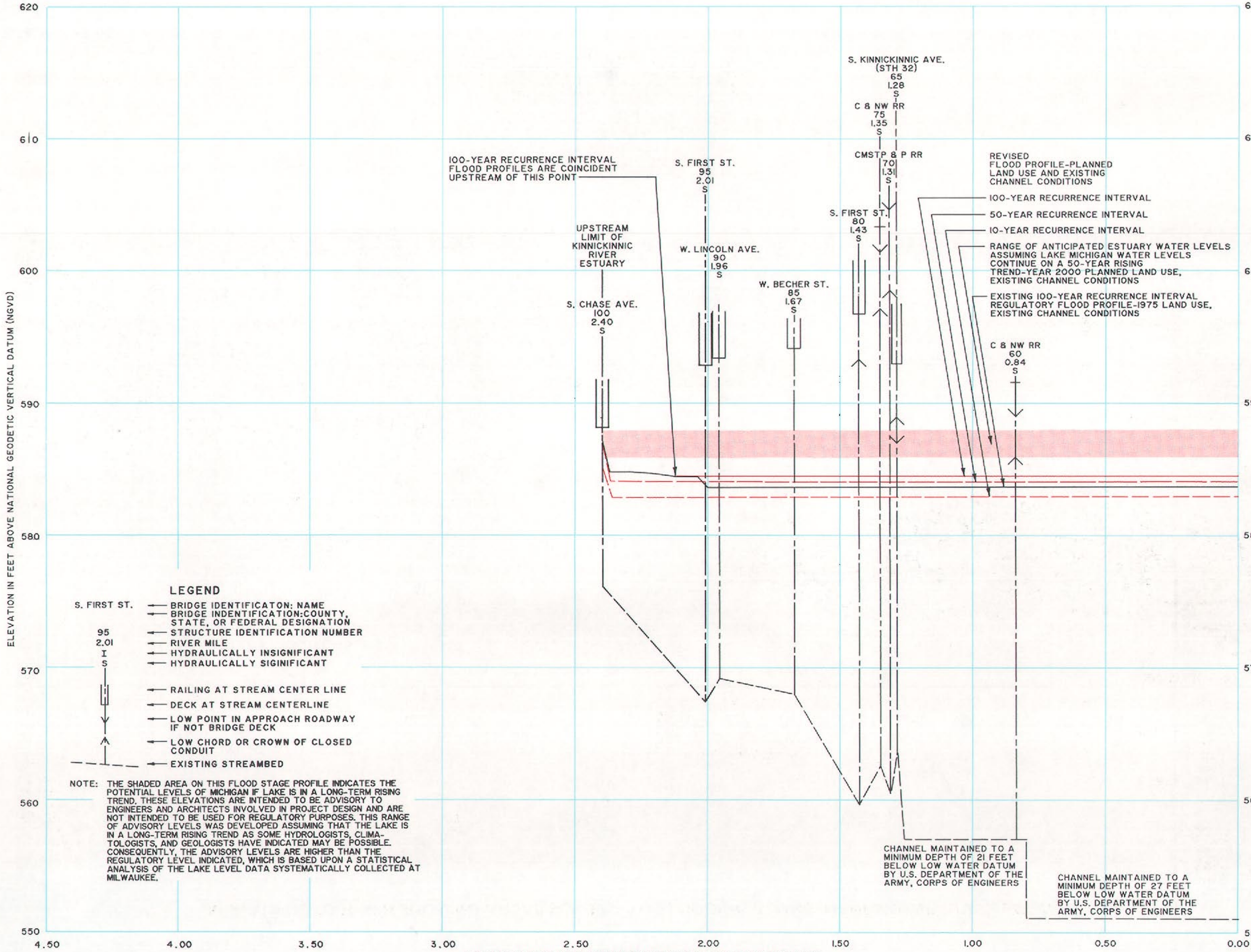
0 — 1/2 — 1 MILE

DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Figure B-1

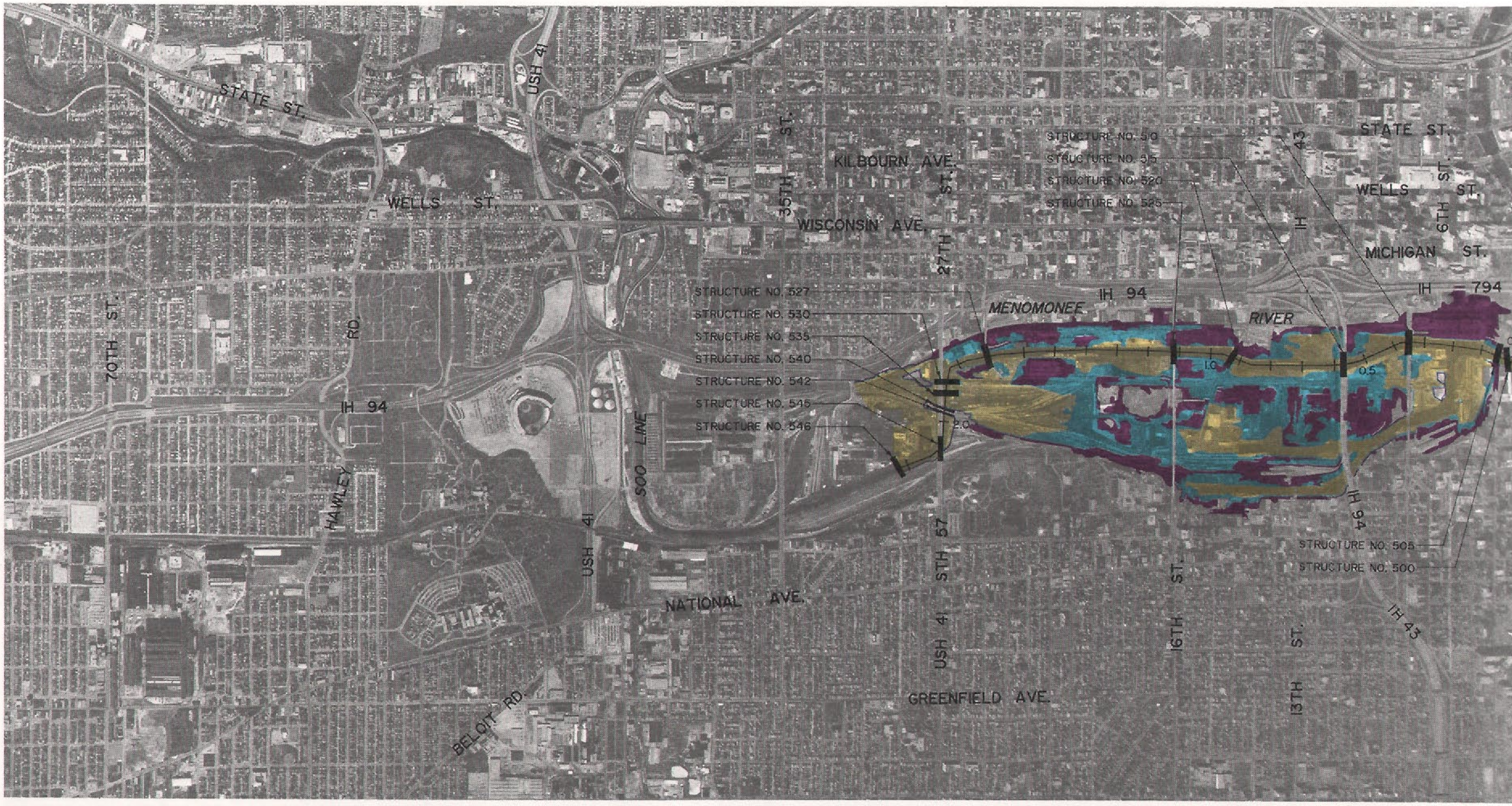
FLOOD STAGE AND STREAMBED PROFILE FOR THE KINNICKINNIC RIVER ESTUARY



Source: SEWRPC.

Map B-2

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG MENOMONEE RIVER ESTUARY



LEGEND

- RECOMMENDED REVISED REGULATORY FLOODPLAIN
- ADDITIONAL FLOODPLAIN ASSUMING A 50-YEAR RISING TREND WITH A TWO-FOOT RISE IN LAKE MICHIGAN OVER 1985 LEVEL
- ADDITIONAL FLOODPLAIN ASSUMING A 50-YEAR RISING TREND WITH A FOUR-FOOT RISE IN LAKE MICHIGAN OVER 1985 LEVEL
- 1.0 APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATONING

NOTE: THE BLUE AND PURPLE SHADED AREAS ON THIS FLOOD INUNDATION MAP INDICATE THE POTENTIAL INUNDATION AREAS OF LAKE MICHIGAN IF THE LAKE IS IN A LONG-TERM RISING TREND. THESE INUNDATION AREAS ARE INTENDED TO BE ADVISORY TO ENGINEERS AND ARCHITECTS INVOLVED IN PROJECT DESIGN AND ARE NOT INTENDED TO BE USED FOR REGULATORY PURPOSES. THIS RANGE OF ADVISORY LEVELS WAS DEVELOPED ASSUMING THAT THE LAKE IS IN A LONG-TERM RISING TREND AS SOME HYDROLOGISTS, CLIMATOLOGISTS, AND GEOLOGISTS HAVE INDICATED MAY BE POSSIBLE. CONSEQUENTLY, THE ADVISORY LEVELS ARE HIGHER THAN THE REGULATORY LEVEL INDICATED, WHICH IS BASED UPON A STATISTICAL ANALYSIS OF THE LAKE LEVEL DATA SYSTEMATICALLY COLLECTED AT MILWAUKEE OVER THE PERIOD 1915 THROUGH 1985.

Source: SEWRPC.

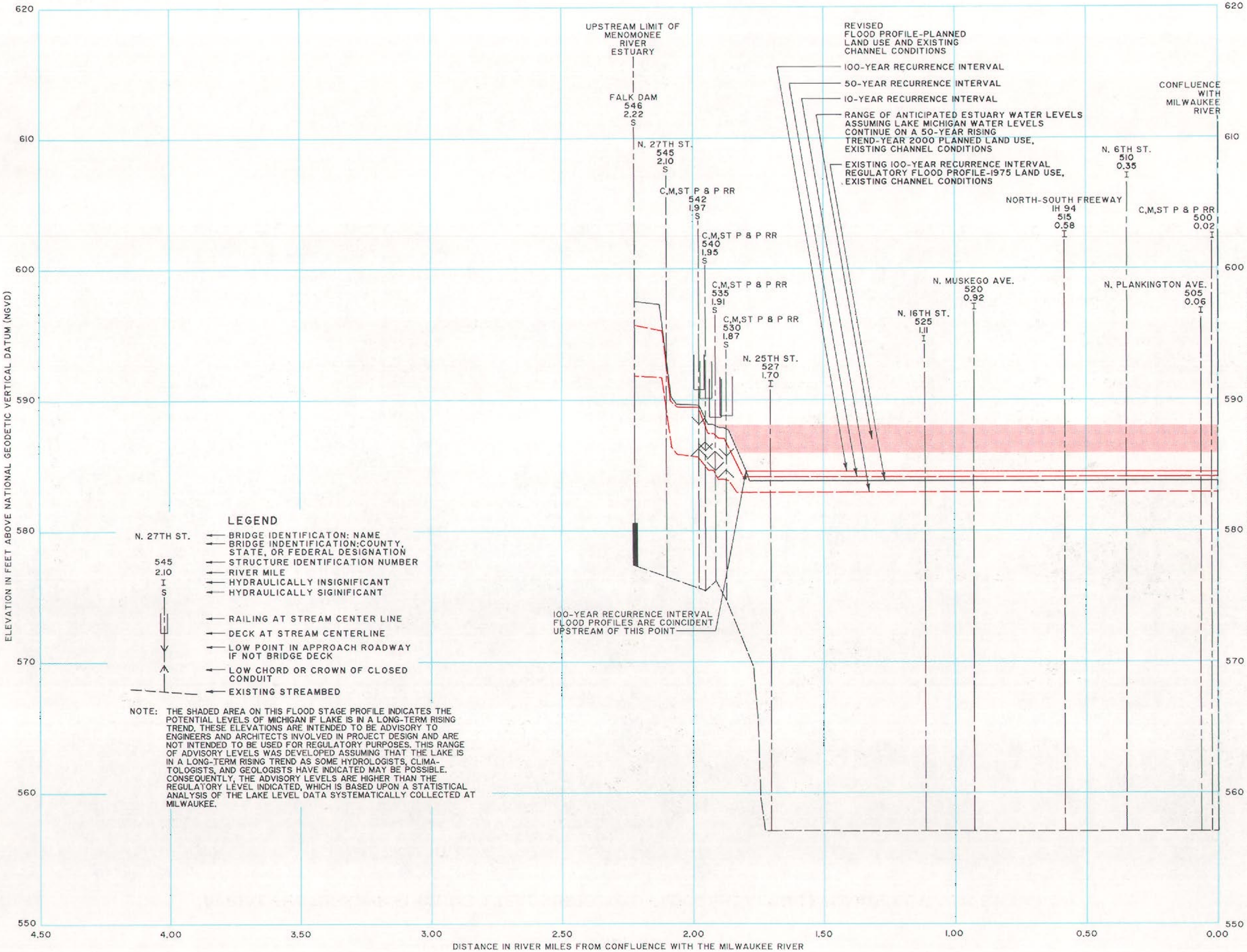
GRAPHIC SCALE

0 — 1/2 — 1 MILE

DATE OF PHOTOGRAPHY: APRIL 1986

Figure B-2

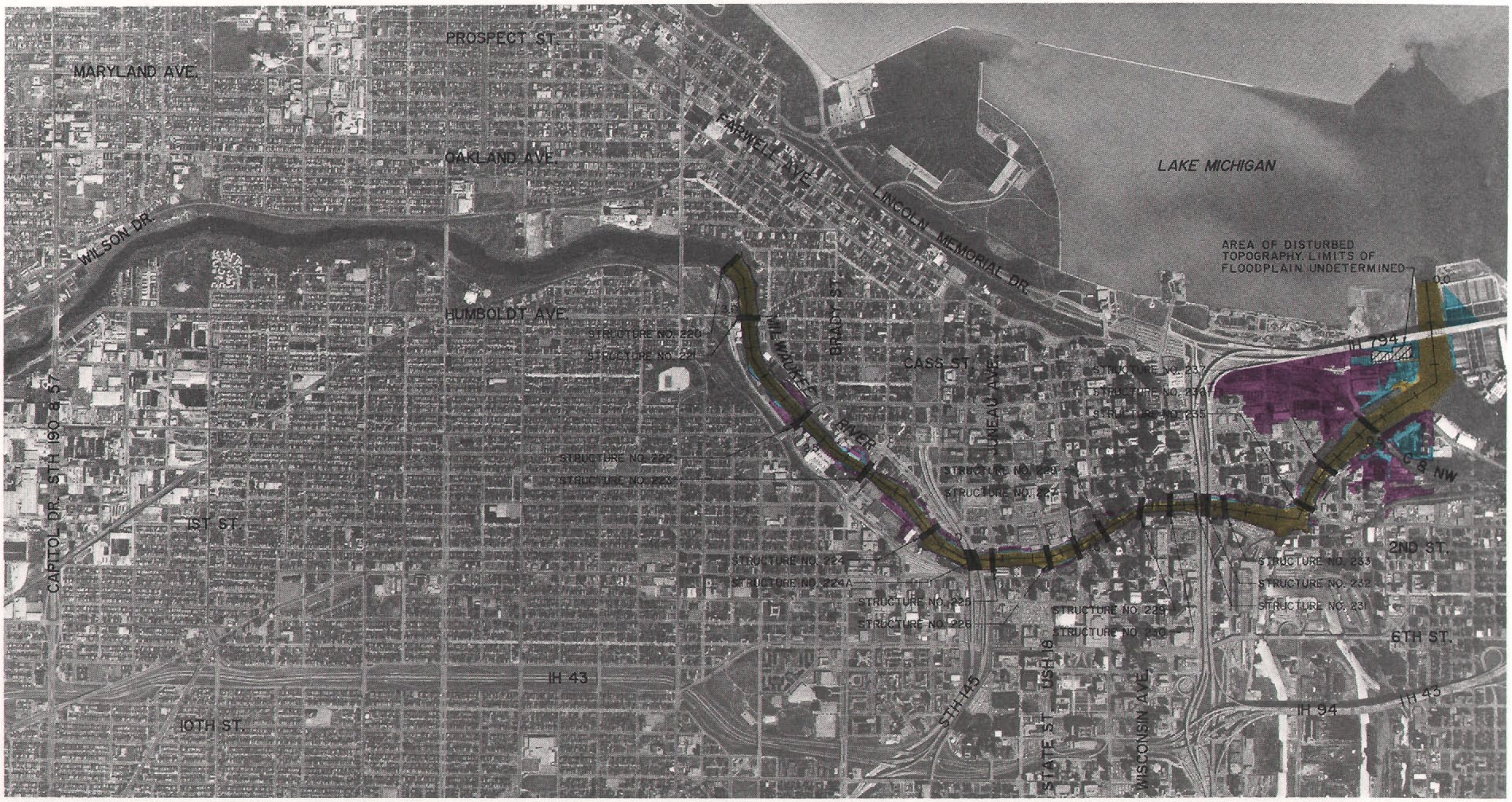
FLOOD STAGE AND STREAMBED PROFILE FOR THE MENOMONEE RIVER ESTUARY



Source: SEWRPC.

Map B-3

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG MILWAUKEE RIVER ESTUARY



LEGEND

RECOMMENDED REVISED REGULATORY FLOODPLAIN

ADDITIONAL FLOODPLAIN ASSUMING A 50-YEAR RISING TREND WITH A TWO-FOOT RISE IN LAKE MICHIGAN OVER 1985 LEVEL

ADDITIONAL FLOODPLAIN ASSUMING A 50-YEAR RISING TREND WITH A FOUR-FOOT RISE IN LAKE MICHIGAN OVER 1985 LEVEL

1.0 — APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

NOTE: THE BLUE AND PURPLE SHADED AREAS ON THIS FLOOD INUNDATION MAP INDICATE THE POTENTIAL INUNDATION AREAS OF LAKE MICHIGAN IF THE LAKE IS IN A LONG-TERM RISING TREND. THESE INUNDATION AREAS ARE INTENDED TO BE ADVISORY TO ENGINEERS AND ARCHITECTS INVOLVED IN PROJECT DESIGN AND ARE NOT INTENDED TO BE USED FOR REGULATORY PURPOSES. THIS RANGE OF ADVISORY LEVELS WAS DEVELOPED ASSUMING THAT THE LAKE IS IN A LONG-TERM RISING TREND AS SOME HYDROLOGISTS, CLIMATOLOGISTS, AND GEOLOGISTS HAVE INDICATED MAY BE POSSIBLE. CONSEQUENTLY, THE ADVISORY LEVELS ARE HIGHER THAN THE REGULATORY LEVEL INDICATED, WHICH IS BASED UPON A STATISTICAL ANALYSIS OF THE LAKE LEVEL DATA SYSTEMATICALLY COLLECTED AT MILWAUKEE OVER THE PERIOD 1915 THROUGH 1985.

GRAPHIC SCALE

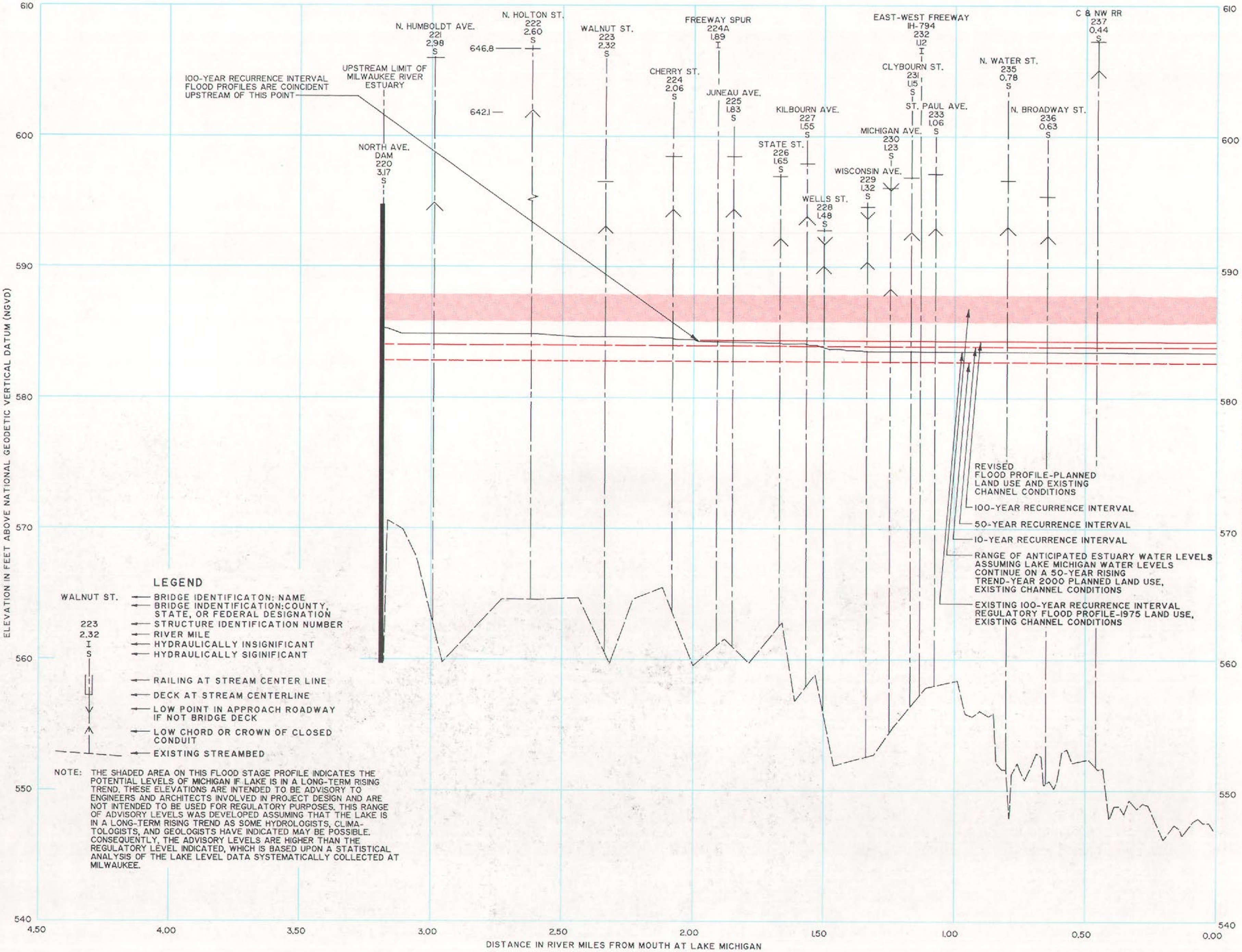
0 — 1/2 — 1 MILE

DATE OF PHOTOGRAPHY: APRIL 1986

Source: SEWRPC.

Figure B-3

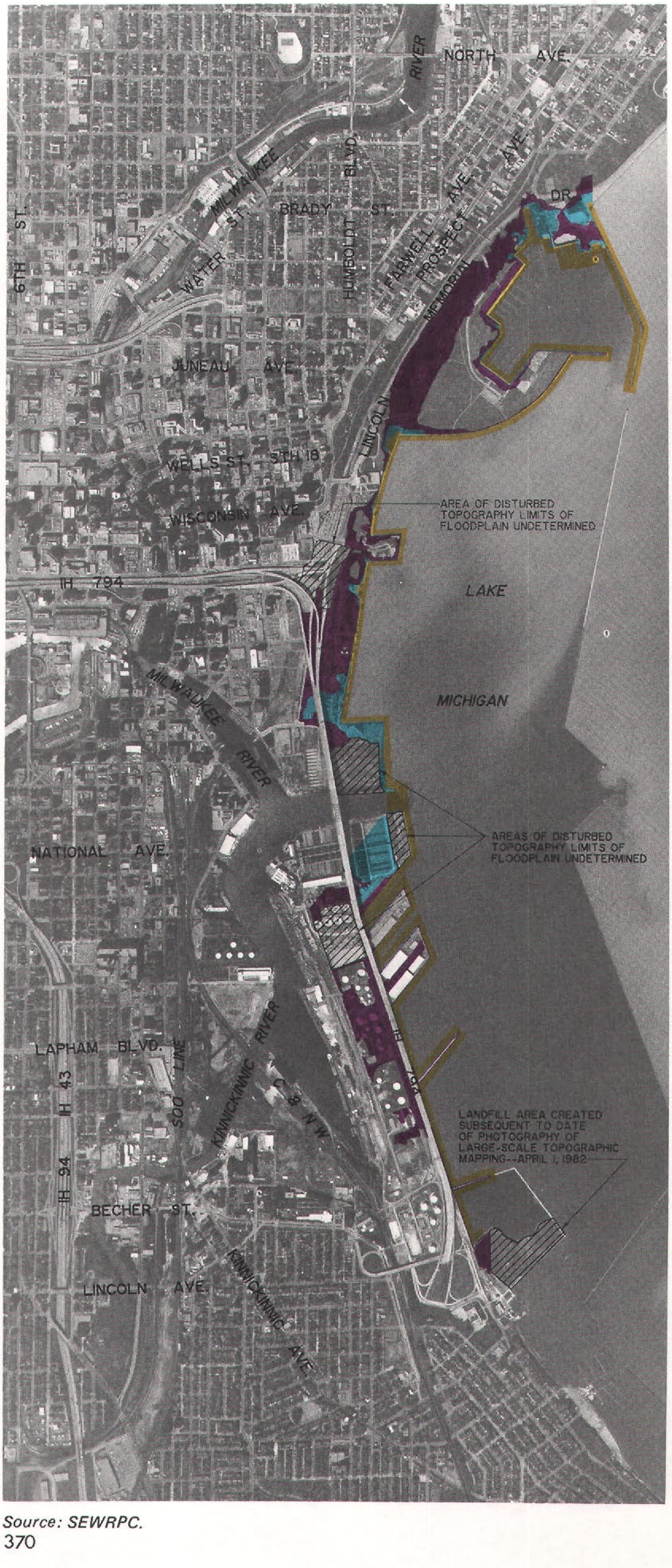
FLOOD STAGE AND STREAMBED PROFILE FOR THE MILWAUKEE RIVER ESTUARY



Source: SEWRPC.

Map B-4

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG MILWAUKEE OUTER HARBOR



LEGEND

RECOMMENDED REVISED REGULATORY FLOODPLAIN

ADDITIONAL FLOODPLAIN ASSUMING A 50-YEAR RISING TREND WITH A TWO-FOOT RISE IN LAKE MICHIGAN OVER 1985 LEVEL

ADDITIONAL FLOODPLAIN ASSUMING A 50-YEAR RISING TREND WITH A FOUR-FOOT RISE IN LAKE MICHIGAN OVER 1985 LEVEL

NOTE: THE BLUE AND PURPLE SHADED AREAS ON THIS FLOOD INUNDATION MAP INDICATE THE POTENTIAL INUNDATION AREAS OF LAKE MICHIGAN IF THE LAKE IS IN A LONG-TERM RISING TREND. THESE INUNDATION AREAS ARE INTENDED TO BE ADVISORY TO ENGINEERS AND ARCHITECTS INVOLVED IN PROJECT DESIGN AND ARE NOT INTENDED TO BE USED FOR REGULATORY PURPOSES. THIS RANGE OF ADVISORY LEVELS WAS DEVELOPED ASSUMING THAT THE LAKE IS IN A LONG-TERM RISING TREND AS SOME HYDROLOGISTS, CLIMATOLOGISTS, AND GEOLOGISTS HAVE INDICATED MAY BE POSSIBLE. CONSEQUENTLY, THE ADVISORY LEVELS ARE HIGHER THAN THE REGULATORY LEVEL INDICATED, WHICH IS BASED UPON A STATISTICAL ANALYSIS OF THE LAKE LEVEL DATA SYSTEMATICALLY COLLECTED AT MILWAUKEE OVER THE PERIOD 1915 THROUGH 1985.

GRAPHIC SCALE

0 1/2 1 MILE

DATE OF PHOTOGRAPHY: APRIL 1986

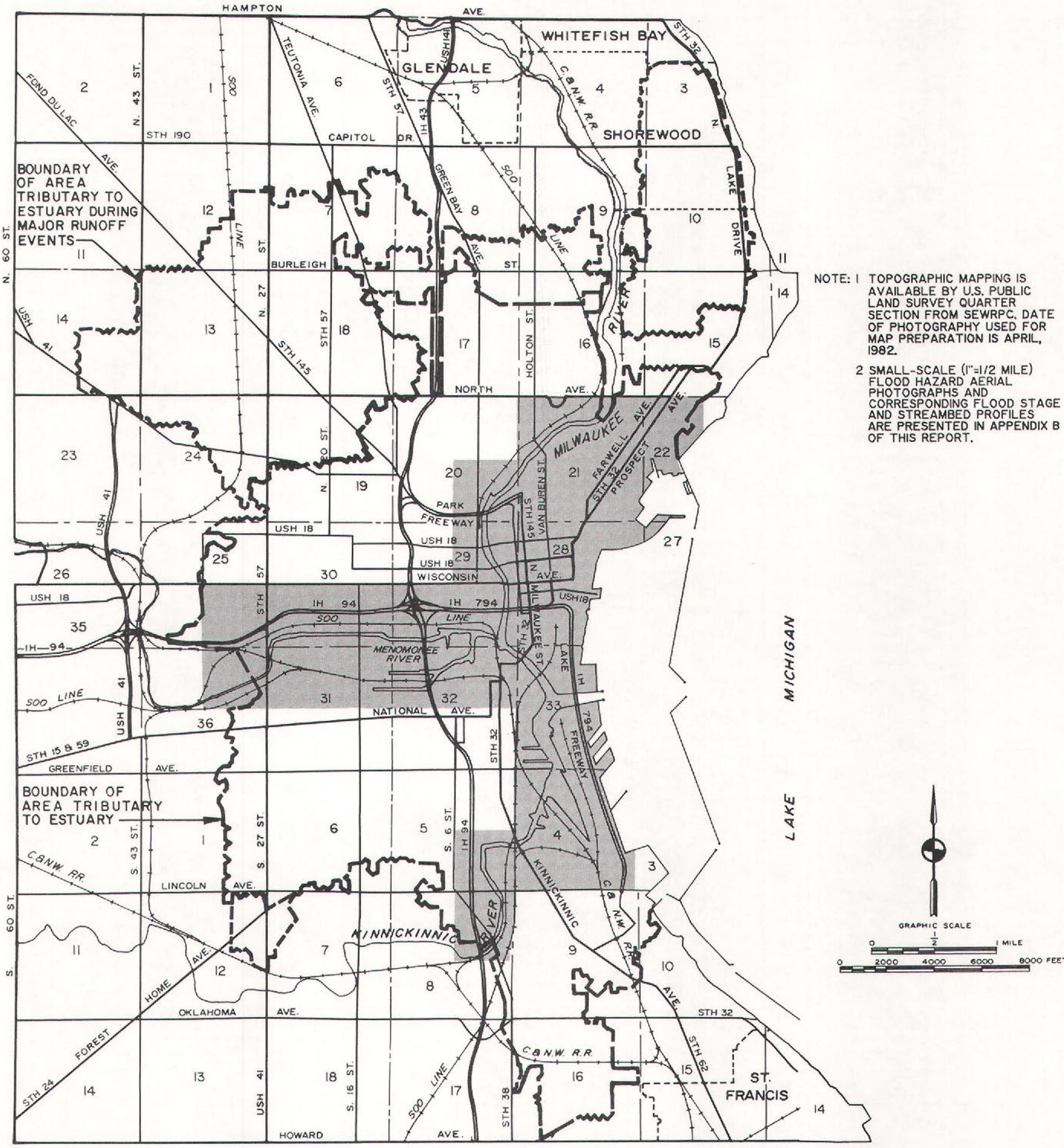
Source: SEWRPC.

Appendix C

LARGE-SCALE TOPOGRAPHIC MAPPING IN FLOOD HAZARD AREAS OF THE MILWAUKEE HARBOR ESTUARY

Map C-1

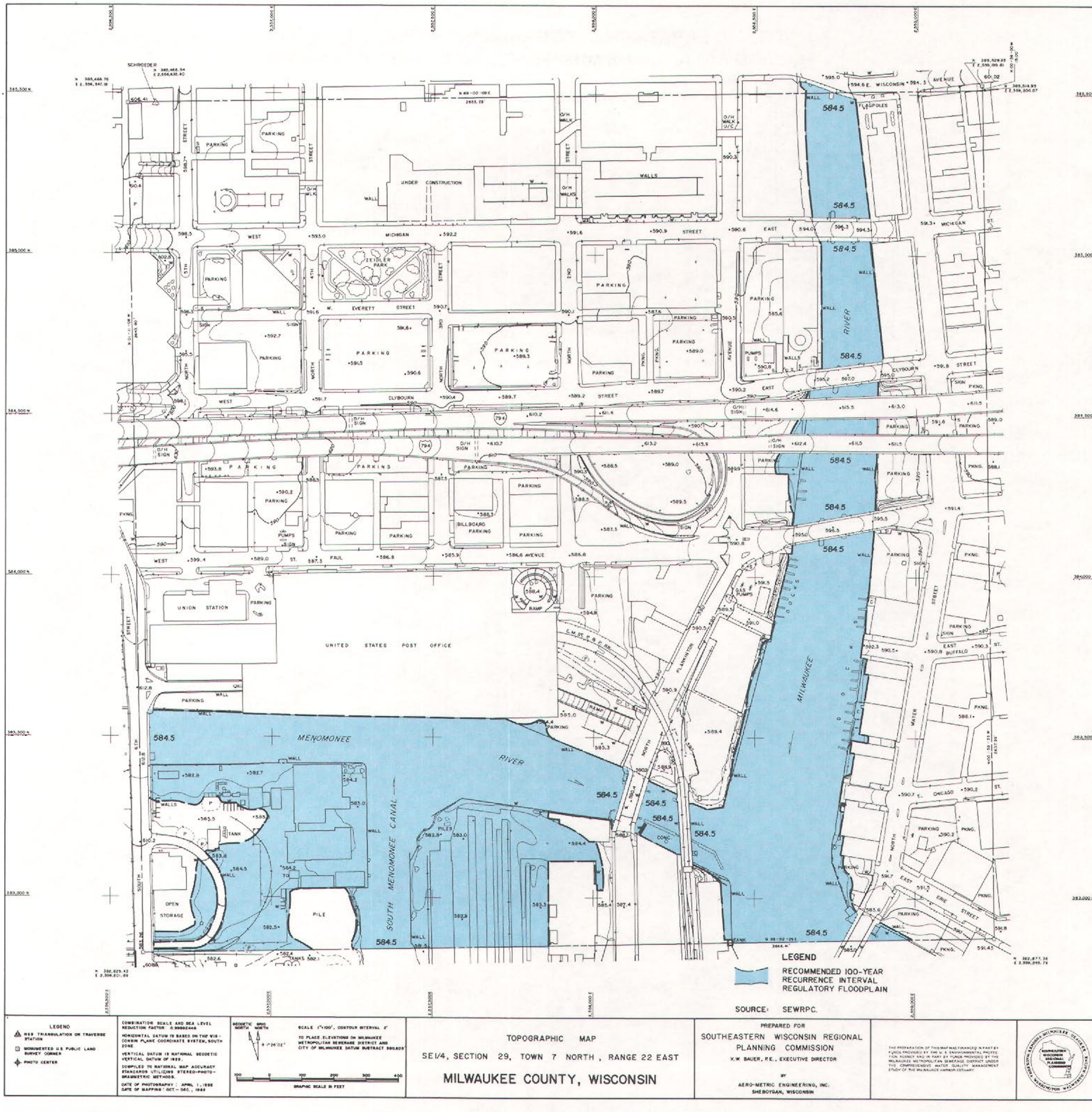
INDEX TO LARGE-SCALE TOPOGRAPHIC MAPPING IN FLOOD HAZARD AREAS IN THE MILWAUKEE HARBOR ESTUARY: 1987



Source: SEWRPC.

Map C-2

TYPICAL FLOOD HAZARD MAP OF A PORTION OF THE MILWAUKEE HARBOR ESTUARY



Source: SEWRPC.

Appendix D

U. S. ENVIRONMENTAL PROTECTION AGENCY PRIORITY POLLUTANTS

1. Acanapthene
2. Acrolein
3. Acrylonitrile
4. Benzene
5. Benzidine
6. Carbon Tetrachloride

Chlorinated Benzenes (other than Dichlorobenzenes)

7. Chlorobenzene
8. 1,2,4-Trichlorobenzene
9. Hexachlorobenzene

Chlorinated Ethanes

10. 1,2-Dichloroethane
11. 1,1,1-Trichloroethane
12. Hexachloroethane
13. 1,1-Dichloroethane
14. 1,1,2-Trichloroethane
15. 1,1,2,2-Tetrachloroethane
16. Chloroethane

Chloroalkyl Ethers

17. Bis (Chloromethyl) Ether[a]
18. Bis (2-chloroethyl) Ether
19. 2-Chloroethyl Vinyl Ether (mixed)

Chlorinated Naphthalene

20. 2-Chloronaphthalene

Chlorinated Phenols (other than those listed elsewhere)

21. 2,4,6-Trichlorophenol
22. Parachlorometa Cresol

23. Chloroform
24. 2-Chlorophenol

Dichlorobenzenes

25. 1,2-Dichlorobenzene
26. 1,3-Dichlorobenzene
27. 1,4-Dichlorobenzene

Dichlorobenzidine

28. 3,3′-Dichlorobenzidine

Dichloroethylenes

29. 1,1-Dichloroethylene
30. 1,2-Trans-dichloroethylene

31. 2,4-Dichlorophenol

Dichloropropane and Dichloropropene

32. 1,2-Dichloropropane
33. 1,2-Dichloropropylene (1,3-dichloropropene)

34. 2,4-Dimethylphenol

Dinitrotoluene

35. 2,4-Dinitrotoluene
36. 2,6-Dinitrotoluene

37. 1,2-Diphenylhydrazine
38. Ethylbenzene
39. Fluoranthene

Haloethers (other than those listed elsewhere)

40. 4-Chlorophenyl Phenyl Ether
41. 4-Bromophenol Phenyl Ether
42. Bis (2-chloroisopropyl) Ether
43. Bis (2-chloroethoxy) Methane

Halomethanes (other than those listed elsewhere)

44. Methylene Chloride (Dichloromethane)
45. Methyl Chloride (Chloromethane)
46. Methyl Bromide (Bromomethane)
47. Bromoform (Tribromomethane)
48. Dichlorobromomethane
49. Trichlorofluoromethane[a]
50. Dichlorodifluoromethane[a]
51. Chlorodibromomethane

52. Hexachlorobutadiene
53. Hexachlorocyclopentadiene
54. Isophorona
55. Naphthalene
56. Nitrobenzene

Nitrophenols

57. 2-Nitrophenol
58. 4-Nitrophenol
59. 2,4-Dinitrophenol
60. 4,6-Dinitro-o-cresol

Nitrosamines

61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine

64. Pentachlorophenol
65. Phenol

Phthalate Esters

66. Bis (2-ethylhexyl) Phthalate
67. Butyl Benzyl Phthalate
68. Di-n-butyl Phthalate
69. Di-n-octyl Phthalate
70. Diethyl Phthalate
71. Dimethyl Phthalate

Polynuclear Aromatic Hydrocarbons

72. Benzo (a) anthracene (1,2-benzanthracene)
73. Benzo (a) pyrene (3,4-benzopyrene)
74. 3,4-Benzofluoranthene
75. Benzo (k) fluoranthane (11,12-benzofluoranthene)
76. Chrysene
77. Acenaphthylene
78. Anthracene
79. Benzo (ghi) perylene (1,12-benzoperylene)
80. Fluorene
81. Phenanthrene
82. Dibenzo (a,h) anthracene (1,2,5,6-dibenzanthracene)
83. Indeno (1,2,3-cd) pyrene (2,3-o-phenylenepyrene)
84. Pyrena

85. Tetrachloroethylene (perchloroethylene)
86. Toluene
87. Trichloroethylene
88. Vinyl Chloride

Pesticides and Metabolites

89. Aldrin
90. Dieldrin
91. Chlordane (technical mixture and metabolites)

DDT and Metabolites

92. 4,4′-DDT
93. 4,4′-DDE (p,p-DDX)
94. 4,4′-DDD (p,p-TDE)

Endosulfan and Metabolites

95. α-endosulfan-Alpha
96. β-endosulfan-Beta
97. Endosulfan Sulfate

Endrin and Metabolites

98. Endrin
99. Endrin Aldehyde

Heptachlor and Metabolites

100. Heptachlor
101. Heptachlor Epoxide

Hexachlorocyclohexane

102. α-BHC-Alpha
103. β-BHC-Beta
104. γ-BHC (Lindane)-Gamma
105. △-BHC-Delta

Polychlorinated Biphenyls (PCB's)

106. PCB-1242 (Arochlor 1242)
107. PCB-1254 (Arochlor 1254)
108. PCB-1221 (Arochlor 1221)
109. PCB-1232 (Arochlor 1232)
110. PCB-1248 (Arochlor 1248)
111. PCB-1260 (Arochlor 1260)
112. PCB-1016 (Arochlor 1016)

113. Toxaphene
114. Asbestos
115. 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)
116. Antimony
117. Arsenic
118. Beryllium
119. Cadmium
120. Chromium
121. Copper
122. Cyanide
123. Lead
124. Mercury
125. Nickel
126. Selenium
127. Silver
128. Thallium
129. Zinc

[a]In 1981, these pollutants were removed from the list of priority pollutants. There are currently 126 priority pollutants.

Source: U. S. Environmental Protection Agency.

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