PLANNING REPORT NO. 32

A COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED

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Special acknowledgement is due Mr. Stuart G. Walesh and Mr. Gary E. Raasch, formerly of the Commission staff, for their efforts in the conduct of this study and in the preparation of this report.

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Milwaukee County Park Commission

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A COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED

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The preparation of this report was financed in part through a planning grant from the Wisconsin Department of Natural Resources and in part through a planning grant from the U. S. Department of Housing and Urban Development under the provisions of Section 701 of the Federal Housing Act of 1954, as amended. Necessary local funding was provided by the Milwaukee County Board of Supervisors.

December 1978

Inside Region $10.00
Outside Region $20.00

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STATEMENT OF THE CHAIRMAN

This report documents the findings and recommendations of a two-year study of the serious and costly flooding and water pollution problems of the Kinnickinnic River watershed. The study was undertaken by the Commission in response to a formal request of the Common Council of the City of Milwaukee. The conduct of the study was guided by the Kinnickinnic River Watershed Committee, a Committee of 12 local officials and concerned citizens created by the Commission for this purpose. Following the preparation of a prospectus a comprehensive plan for the development of the watershed was prepared in accordance with that prospectus—a plan designed to assist the local, state, and federal units and agencies of government concerned in solving the flooding, water pollution, and related land use problems of this intensely urbanized and industrialized watershed.

This report presents a summary of the factual findings of the planning and engineering inventories conducted under the watershed study; identifies and, to the extent possible, quantifies the water resource-related problems of the watershed; presents pertinent forecasts of anticipated growth and change within the watershed; sets forth recommended watershed development objectives, principles, and standards; presents a comparative evaluation of alternative flood control, water quality management, and related land use plan elements; and presents a recommended comprehensive plan for the watershed. A preliminary version of the recommended plan was presented for public hearing on October 12, 1978; and while very well received at the hearing, the plan was revised as it relates to required improvements to the Edgerton Channel in the City of Cudahy at the request of the City of Cudahy.

This report also contains recommendations on how to carry out the recommended plan. Full implementation of the established plan set forth herein should result in resolution of the costly and disruptive flooding and water pollution problems of this watershed, and should thoroughly contribute to the preservation and, overtime, renewal of an older, intensely developed, yet still vital, area of the Region.

The recommended watershed plan, as set forth in this report, represents another important element of the evolving comprehensive plan for the physical development of the Southeastern Wisconsin Region. As is true of all of the Commission's work, the Kinnickinnic River watershed plan is entirely advisory to the local, state, and federal units and agencies of government concerned. The recommended plan is intended to provide a point of departure against which watershed development proposals can be evaluated on a day-to-day basis by concerned officials and interested citizens. Upon formal adoption of the watershed plan by the Commission, an official copy thereof will be transmitted to all affected units and agencies of government, along with a request for their consideration and formal adoption or endorsement and subsequent appropriate implementing action. Plan implementation must necessarily be achieved through the cooperative action of all of the governmental units and agencies within the watershed.

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

Respectfully submitted,

George C. Berteau
Chairman

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Chapter I

INTRODUCTION

The Kinnickinnic River watershed study is the fifth comprehensive watershed planning program to be carried out by the Southeastern Wisconsin Regional Planning Commission. Since this watershed study is an integral part of the overall work program of the Commission, an understanding of the need for, and objectives of, regional planning and the manner in which these needs and objectives are being met in southeastern Wisconsin is necessary to a proper appreciation of the Kinnickinnic River watershed study and its findings and recommendations.

NEED FOR REGIONAL PLANNING

In recent years, regional planning has become increasingly accepted as a necessary governmental function in most of the large urban areas of the United States. This tendency reflects growing awareness that certain pressing problems of physical and economic development and of environmental deterioration transcend the geographic limits, as well as the fiscal capabilities, of local units of government and require the cooperation of all units and agencies of government concerned for sound resolution.

The term region, as it is used in this context, applies to an area larger than a county but smaller than a state, united by economic interests and geography and by common problems brought about by rapid urbanization and changing regional settlement patterns. A regional basis is unquestionably necessary to provide a meaningful technical approach to the sound development of such areawide systems of public works as highway and transit, sewerage and water supply, and park and related open space facilities. A regional basis also is necessary to a sound approach to the resolution of such areawide problems as flooding, air and water pollution, deterioration or destruction of the natural resource base, and rapidly changing land use.

State, community, and private interests all are vitally affected by such areawide problems and by proposed solutions to these problems. It appears neither desirable nor possible for any one level or agency of government to impose the decisions required to solve these areawide problems. Such decisions can better come from a consensus of the various levels and agencies of government and private interests concerned, based on a common interest in the welfare of the entire Region. Regional planning is imperative for promoting such a consensus and the necessary cooperation between urban and rural, local and state, and private and public interests.

THE REGIONAL PLANNING COMMISSION

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) represents an attempt to provide the necessary areawide planning services for one of the large urbanizing regions of the nation. The Commission was created in August 1960, under the provisions of Section 66.945 of the Wisconsin Statutes, to serve and assist the local, state, and federal units of government in planning for the orderly and economic development of southeastern Wisconsin. The role of the Commission is entirely advisory, and participation by local units of government in the work of the Commission is on a voluntary, cooperative basis. The Commission itself is composed of 21 citizen members, three from each county within the Region, who serve without pay.

The powers, duties, and functions of the Commission and the qualifications of the Commissioners are carefully set forth in the state enabling legislation. The Commission is authorized to employ experts and a staff as necessary for the execution of its responsibilities. Basic funds necessary to support Commission operations are provided by the member counties, the budget being apportioned among the several counties on the basis of relative equalized valuation. The Commission is authorized to request and accept aid in any form from all levels and agencies of government for the purpose of accomplishing its objectives and is authorized to deal directly with the state and federal governments for this purpose. The organizational structure of the Commission and its relationship to the constituent units and agencies of government comprising or operating within the Region are shown in Figure 1.

THE REGIONAL PLANNING CONCEPT IN SOUTHEASTERN WISCONSIN

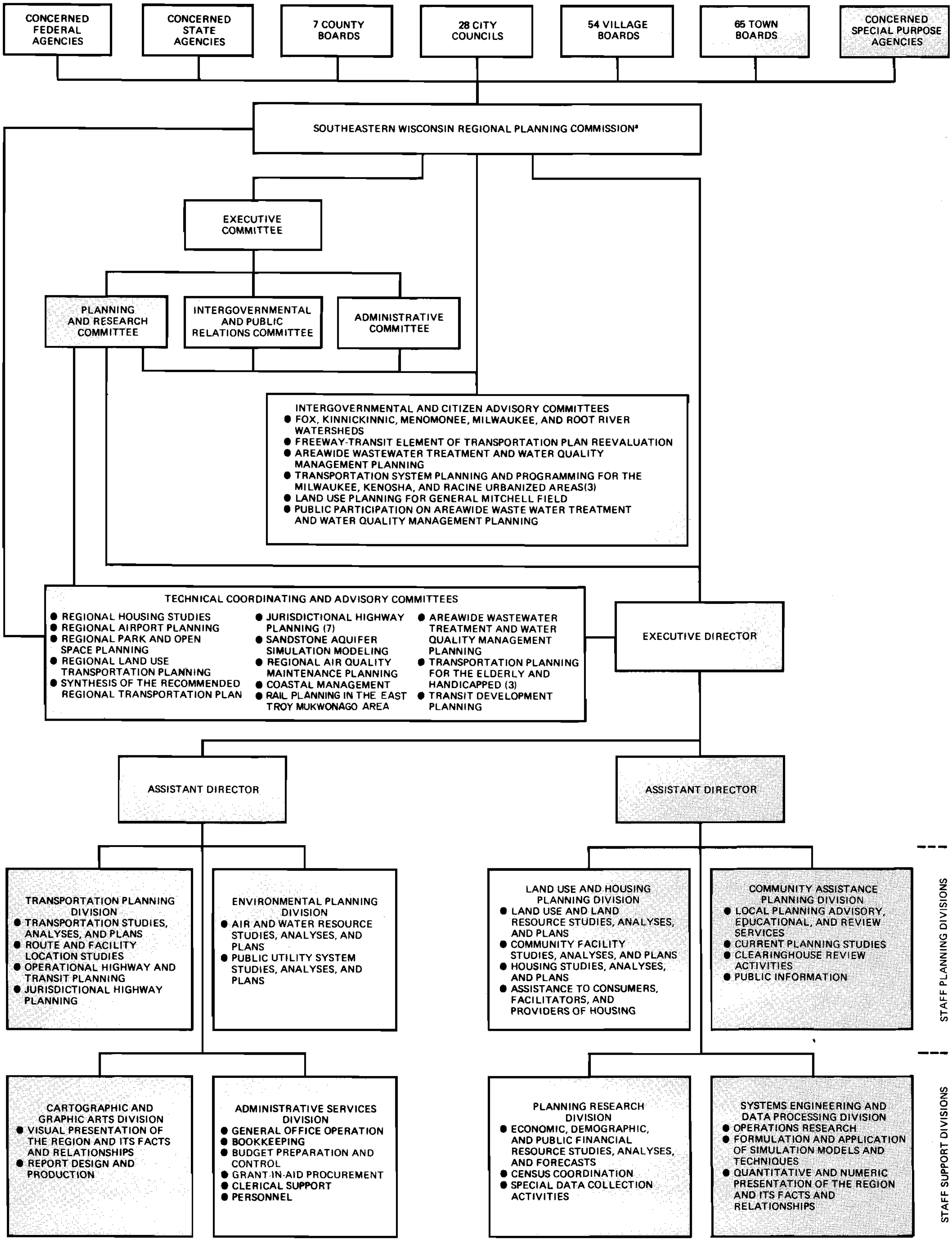
Regional planning as conceived by the Commission is not a substitute for but a supplement to local, state, and federal planning efforts. Its objective is to aid the various levels and units of government in finding solutions to areawide developmental and environmental problems which cannot be properly resolved within the framework of a single municipality or a single county. As such, regional planning has three principal functions:

1. Inventory—the collection, analysis, and dissemination of basic planning and engineering data on a uniform, areawide basis so that, using such data, the various levels and agencies of government and private investors operating within the Region can better make decisions concerning community developments.

2. Plan Design—the preparation of a framework of long-range plans for the physical development of the Region; these plans being limited to those functional elements having areawide significance. To this end, the Commission is charged by law with the function and duty of "making and adopting a master plan for the physical develop-

Figure 1

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION: ORGANIZATIONAL STRUCTURE



*THE COMMISSION IS COMPOSED OF 21 CITIZEN MEMBERS, THREE FROM EACH COUNTY, WHO SERVE WITHOUT PAY.

Source: SEWRPC.

ment of the Region." The permissible scope and content of this plan, as outlined in the enabling legislation, extend to all phases of regional development, implicitly emphasizing, however, the preparation of alternative spatial designs for the use of land and for the supporting transportation and utility facilities.

3. Plan Implementation—the provision of a center for the coordination of the many planning and plan implementation activities carried on by the various levels and agencies of government operating within the Region. To this end, all of the Commission work programs are intended to be carried out within the context of a continuing planning program which provides for the periodic reevaluation of the plans produced, as well as for the extension of planning information and advice necessary to convert the plans into action programs at the local, regional, state, and federal levels.

THE REGION

The Southeastern Wisconsin Planning Region, as shown on Map 1, is composed of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties in southeastern Wisconsin. Exclusive of Lake Michigan, these seven counties have a total area of 2,689 square miles, and together comprise about 5 percent of the total area of the State of Wisconsin. About 40 percent of the state population, however, resides within these seven counties, which contain three of the eight and one-half standard metropolitan statistical areas in the state. The Region contains approximately 40 percent of all the tangible wealth in the State of Wisconsin as measured by equalized valuation, and represents the greatest wealth-producing area of the State, with about 40 percent of the state labor force employed within the Region. The seven-county Region contains 154 local units of government, exclusive of school and other special-purpose districts, and encompasses all or parts of 11 natural watersheds. The Region has been subject to rapid population growth and urbanization and, in the decade from 1960 to 1970, accounted for about 40 percent of the total population increase of the entire State.

Geographically the Region is located in a relatively good position with regard to continued growth and development. It is bounded on the east by Lake Michigan, which provides an ample supply of fresh water for both domestic and industrial use as well as being a recreational attraction and an integral part of the major international transportation network. It is bounded on the south by the rapidly expanding northeastern Illinois metropolitan region and on the west and north by the fertile agricultural lands and desirable recreational areas of the rest of the State of Wisconsin. Many of the most important industrial areas and heaviest population concentrations in the Midwest lie within a 250-mile radius of the Region, and over 33 million people reside within this radius.

COMMISSION WORK PROGRAMS

The Kinnickinnic River watershed planning program was conducted within the context of, and has been fully coordinated with, the Commission's ongoing comprehensive planning program for southeastern Wisconsin. It is appropriate to review briefly selected aspects of the Commission's past and current work programs inasmuch as some of the data obtained and some analytic techniques developed under those programs were used in the Kinnickinnic River watershed planning program. Furthermore, water control facility recommendations contained within the Kinnickinnic River watershed plan are based in part on, and are coordinated with, land use and other recommendations from other Commission planning programs.

Initial Work Program

The initial work program of the Commission was directed entirely toward basic data collection. It included six basic regional planning studies, which were initiated in July 1961 and completed by July 1963: a statistical program and data processing study, a base mapping program, an economic base and structure study, a population study, a natural resources inventory, and a public utilities study. All of these initial studies were directed toward providing a basic foundation of planning and engineering data for regional planning and were documented in six published planning reports. None of these studies involved the preparation of plans. Their findings, however, provided a valuable point of departure for all subsequent Commission work, including the Kinnickinnic River watershed planning program.

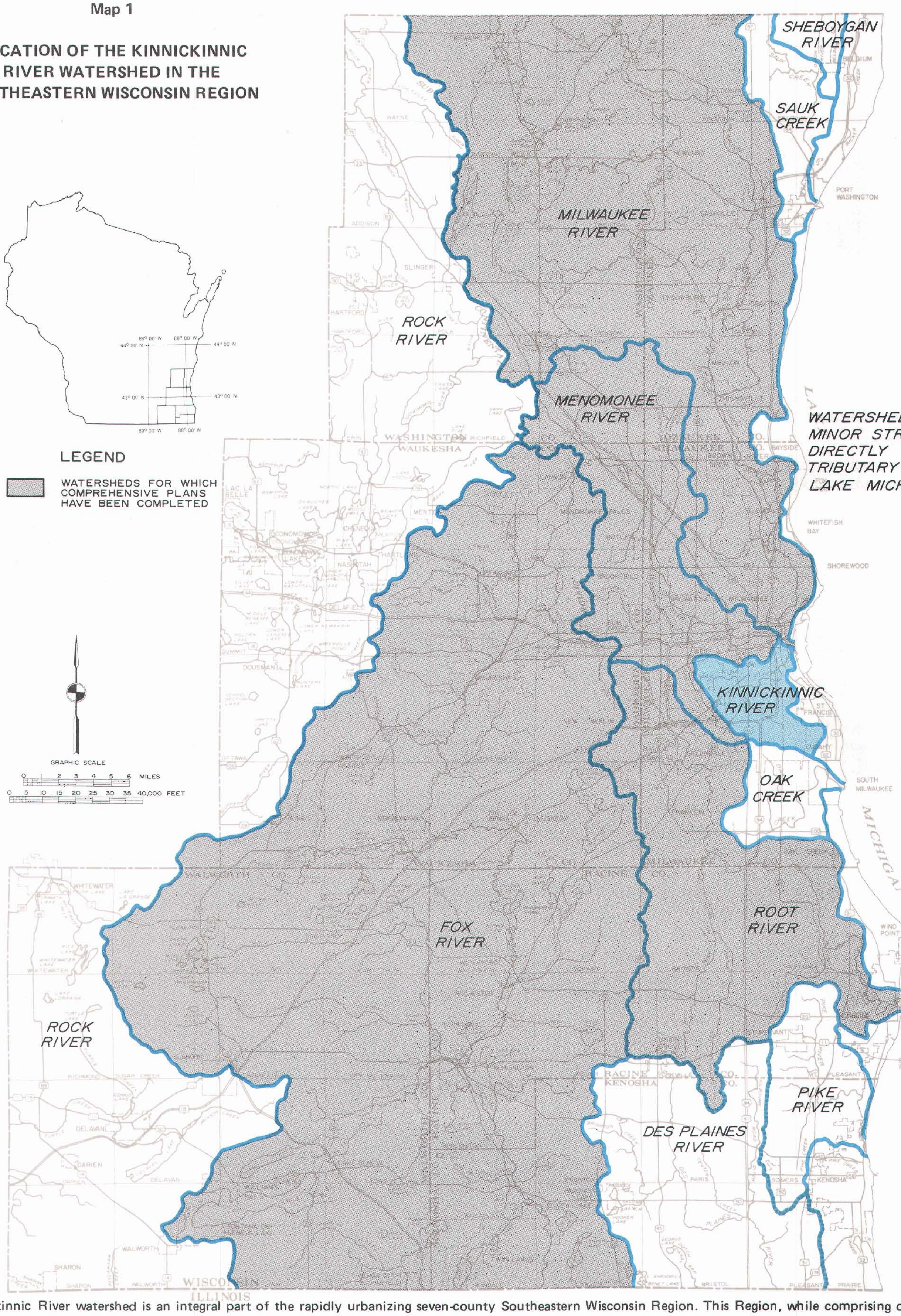
Also as part of its initial work program, the Commission adopted a policy of community planning assistance in which functional guidance and advice on planning problems are extended to local units of government and through which regional planning studies are interpreted locally and regional plans may be integrated with local plans. Six local planning guides have been prepared to date under this community assistance program to provide municipalities throughout the Region with information helpful in the preparation of sound local planning and plan implementation codes and ordinances. These guides will aid in implementing both regional and local plans and will further assist local public officials in carrying out their day to day planning functions. The subjects of these guides are land development, official mapping, zoning, organization of local planning agencies, floodland and shoreland development, and use of soil survey data in planning and development. All include model ordinances, and all provide a framework for plan implementation through local land use control measures.

Land Use-Transportation Study

The first major work program of the Commission actually directed toward the preparation of long-range development plans was a regional land use-transportation study, initiated in January 1963 and completed in December 1966. This plan was recently reevaluated and updated

Map 1

LOCATION OF THE KINNICKINNIC RIVER WATERSHED IN THE SOUTHEASTERN WISCONSIN REGION



The Kinnickinnic River watershed is an integral part of the rapidly urbanizing seven-county Southeastern Wisconsin Region. This Region, while comprising only 5 percent of the total area of the State, contains about 40 percent of the state's population, provides employment for about 40 percent of the state's labor force, and contains approximately 40 percent of all of the tangible wealth of the State. The Kinnickinnic River watershed is the second smallest of the 11 major watersheds located wholly or partly in the Region. About 9 percent of the 1975 population of the Region resides within this extensively urbanized watershed, which comprises only about 1 percent of the area of the Region.

Source: SEWRPC.

to the year 2000 and is fully documented in SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin—2000, Volume 2, Alternative and Recommended Plans. This plan contains two key elements of a comprehensive plan for the physical development of the Region: a land use plan and a transportation (highway and transit) plan. The findings and recommendations of the original and recently reevaluated and updated land use-transportation study have provided many important contributions to the comprehensive watershed planning programs of the Commission.

Root River Watershed Study

The Root River watershed study was the first comprehensive watershed planning program undertaken by the Commission. This study was initiated in July 1964 and completed in July 1966. The findings and recommendations were published in SEWRPC Planning Report No. 9, A Comprehensive Plan for the Root River Watershed, and in supporting SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin. The comprehensive watershed plan documented in these reports contains specific recommendations for the abatement of the flooding, water quality, and related land use and natural resource conservation problems of this 197 square mile watershed. Substantial progress has been made toward implementation of this plan as documented in the Commission's series of annual reports.

Fox River Watershed Study

The Fox River watershed study was the second comprehensive watershed planning program undertaken by the Commission. This study was initiated in November 1965 and completed in February 1970. The findings and recommendations were published in SEWRPC Planning Report No. 12, A Comprehensive Plan for the Fox River Watershed, Volume 1, Inventory Findings and Forecasts, and Volume 2, Alternative Plans and Recommended Plan. The comprehensive watershed plan documented in this report contains recommendations for the abatement of the flooding, water quality, water supply, recreation, and related land use and natural resource conservation problems of this watershed. The study also produced special lake use reports for selected major lakes of the watershed. Progress toward implementation of the plan is documented in the Commission's series of annual reports.

Milwaukee River Watershed Study

The Milwaukee River watershed study was the third comprehensive watershed planning program undertaken by the Commission. The study was initiated in October 1967 and was completed in October 1971. The findings and recommendations were published in SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed, Volume 1, Inventory Findings and Forecasts, and Volume 2, Alternative Plans and Recommended Plan. Like the plan for the Fox River watershed, the plan for the Milwaukee River watershed contains recommendations for the abatement of the flooding, water quality, water supply, recreation, and related land and natural resource conservation problems of this important watershed. The study also produced special lake use reports for selected major lakes of the watershed. Of particular importance to the Kinnickinnic River watershed study are the recommendations for abatement of water pollution from combined sewer overflows produced by the Milwaukee River watershed study. These recommendations extend to all of the combined sewer service areas in Milwaukee, including such areas within the Kinnickinnic River watershed. Progress toward implementation of the plan is documented in the Commission's series of annual reports.

Regional Sanitary Sewerage System Planning Program

The Commission initiated a regional sanitary sewerage system planning program in July 1969 after determining that preparation of a regional sanitary sewerage system plan would be the logical next step in the preparation of a comprehensive plan for the physical development of the Region. This projected long-range plan was directed at resolving problems associated with the need for new sanitary sewer service within the Region; with the need to improve existing inadequate sanitary sewer service, particularly in newly developed areas of the Region; with serious surface water quality pollution, together with increasing conflicts over water uses and demand for water pollution abatement; with the widespread occurrence within the Region of soils unsuited to the use of onsite septic tank sewage disposal systems; and with the development of small, isolated sewage treatment plants on an uncoordinated basis. The findings and recommendations of the sanitary sewerage system planning program, which was completed in 1974, were published in SEWRPC Planning Report No. 16, A Regional Sanitary Sewerage System Plan for Southeastern Wisconsin.

Menomonee River Watershed Study

The Menomonee River watershed study was the fourth comprehensive watershed planning program undertaken by the Commission. The study was initiated in February 1972 and was completed in October 1976. The findings and recommendations were published in October 1976 in SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume 1, Inventory Findings and Forecasts, and Volume 2, Alternative Plans and Recommended Plan. The Menomonee River watershed plan contains recommendations for the abatement of the flooding, water pollution, recreation, and related land and natural resource conservation problems of this important urbanizing basin.

Areawide Water Quality Planning and Management Program

In July 1975 the Commission undertook a major new water quality planning program that will facilitate the updating and refinement of previous water quality and related plan elements such as regional sanitary sewerage system plan and earlier comprehensive watershed plans. At the same time this planning program will extend those previous water quality and related plan elements to the portions of the Region not covered with watershed plans and will update all the plan recommendations to the new plan design year 2000. The areawide water quality management plan consists of the following four major elements: (1) an element addressed to the elimination of pollution from point sources; (2) an element addressed to the elimination of pollution from nonpoint sources; (3) an element addressed to the handling, recycling, and disposal of the sewage sludge; and (4) an element addressed to water quality management, including the designation of land use and wastewater treatment management agencies. The findings and recommendations are set forth in SEWRPC Planning Report No. 29, A Regional Sludge Management Plan for Southeastern Wisconsin, and SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin.

Other Regional and Subregional Planning Programs

Five additional regional planning programs have been undertaken by the Commission. A regional library system planning program was completed in 1974; a regional airport system planning program was completed in 1975; a regional housing planning program was completed in 1975; a regional park, outdoor recreation, and related open space study was completed in 1977; and a regional air quality maintenance planning program has been scheduled for completion in 1978. The Commission also has completed more detailed urban development plans for certain subareas of the Region, including the Kenosha and Racine Planning Districts.

THE KINNICKINNIC RIVER WATERSHED STUDY

The Kinnickinnic River watershed study is the fifth comprehensive watershed planning program to be undertaken by the Commission and the second such study to be conducted by the Commission for a watershed which is extensively urbanized. Although the 25 square mile basin encompasses only 1 percent of the planning region area, 165,000 people, or about 9 percent of the population of southeastern Wisconsin, reside within the watershed.

Initiation of the Kinnickinnic River Watershed Study

The Kinnickinnic River watershed study was initiated upon the specific request of the City of Milwaukee. This request reflected the growing concern of local officials and citizen leaders over increasing problems of flooding, water pollution, and changing land use in the watershed. All of these problems interact to adversely affect the quality of urban life and to cause further deterioration and destruction of the natural resource base of the watershed.

Concern over what at first seemed to be local problems within subareas of the watershed was followed by a growing awareness among public officials that the causes and effects of these problems transcend local municipal boundaries and are related to the entire stream network and tributary drainage areas. Recognizing the Commission as the logical and best equipped agency to find practical and permanent solutions to these problems, the Common Council of the City of Milwaukee on March 20, 1973, formally requested the Commission to undertake a comprehensive planning study of the Kinnickinnic River watershed, looking to the ultimate resolution of the aforementioned water resource and water resource-related problems. The Commission accordingly on November 27, 1973, formed the Kinnickinnic River Watershed Committee, comprised of knowledgeable state and local public officials and citizen leaders from throughout the watershed. This Committee was created to assist the Commission in its study of the problems of the Kinnickinnic River watershed, and the Committee began at once to prepare a Prospectus for the necessary comprehensive watershed planning program. The full membership of the Kinnickinnic River Watershed Committee is listed in Appendix A.

The Committee identified and described in the Prospectus two basic problems within the watershed that required areawide study: (1) flooding and flood damage and (2) surface water uses and pollution. The Committee at its meeting of October 3, 1974, unanimously recommended that the Southeastern Wisconsin Regional Planning Commission approve the Prospectus and seek the funding necessary to perform the required study.

The Prospectus prepared by the Committee was endorsed by the Commission on November 19, 1974; was published; and, in accordance with the advisory role of the Commission, transmitted to the governmental agencies concerned for their consideration and action. The Milwaukee County Board as well as the Wisconsin Department of Natural Resources formally endorsed the Prospectus and agreed to provide the state and local funds necessary for execution of the recommended planning program. The U. S. Department of Housing and Urban Development also endorsed the Prospectus and agreed to provide the federal funds necessary for initiation of the program. However, all the necessary monetary commitments from these local, state, and federal agencies were not received until mid-1976.

To finance the study as outlined in the Prospectus, the Commission had to effect separate agreements with the U. S. Department of Housing and Urban Development; the Wisconsin Department of Natural Resources; and Milwaukee County. The total estimated study cost of $154,000 recommended in the Prospectus and agreed upon in the agreements was distributed as follows: U. S. Department of Housing and Urban Development, 36 percent; Wisconsin Department of Natural Resources, 46 percent; and Milwaukee County, 18 percent.

The Prospectus was not a finished study design. It was a preliminary design prepared to obtain support and financing for the necessary study, an objective which was fully achieved. Major work elements, a staff organization, a time schedule, and cost estimates were set forth in the Prospectus. Work on the study, as outlined in the Prospectus, began in July 1976.

Study Objectives

The primary objective of the Kinnickinnic River watershed planning program, as set forth in the Prospectus, is to help abate the serious water resource and water resource-related problems of the Kinnickinnic River basin by developing a workable plan to guide the staged development of multipurpose water resource facilities and related resource conservation and management programs for the watershed. This plan, to be effective, must be amenable to cooperative adoption and joint implementation by all levels and agencies of government concerned. It must be capable of functioning as a practical guide for decisionmaking on both land and water resource development within the watershed so that, through such implementation, the major water resource and water resource-related problems within the watershed may be abated and the full development potential of the watershed realized. More specifically, the objectives of the planning program are to:

1. Prepare a plan for the management of floodlands along the major waterways of the Kinnickinnic River watershed, including measures for the mitigation of existing flood problems and elements for the minimization of future flood problems.

2. Prepare a plan for surface quality management for the Kinnickinnic River watershed, incorporating measures to abate existing pollution problems and elements intended to prevent future pollution problems.

3. Refine and adjust the regional land use plan to reflect the conveyance, storage, and waste assimilation capabilities of the waterways and floodlands of the watershed; to include feasible water control facilities; and generally to promote the rational adjustment of land uses in this urbanizing basin to the surface water resources.

Special Consideration with Respect to the Lake Michigan Estuary

The entire Kinnickinnic River watershed, from its headwater areas in the Cities of West Allis, Greenfield, and Cudahy to its confluence with the Milwaukee River near the Lake Michigan shoreline, was included in the comprehensive watershed planning program for purposes of the flood control and floodland management plan elements of the study. Primary attention with respect to the other elements of the study—water pollution and changing land use—was focused on that part of the watershed lying upstream of Chase Avenue in the City of Milwaukee. That 2.40 mile reach of the Kinnickinnic River lying below Chase Avenue, in combination with the Milwaukee River lying below the North Avenue Dam and the Menomonee River lying below the low head dam at 29th Street extended, forms an estuary of Lake Michigan as shown on Map 2. Chase Avenue was selected as the upstream terminus of the Kinnickinnic River arm of the estuary because of: (1) the change in channel grade at this location—from a grade of about 16 feet per mile downstream of Chase Avenue to a steeper grade of about 23 feet per mile upstream of Chase Avenue—and the associated termination of the Lake Michigan backwater effect immediately upstream of Chase Avenue; (2) the abrupt change in flow depth at these two locations—ranging from about 7 feet of channel depth downstream of Chase Avenue to only about 4 feet immediately upstream of Chase Avenue; and (3) the abrupt change in channel width in the vicinity of Chase Avenue—from about 100 feet wide downstream of Chase Avenue to about 50 feet wide upstream of Chase Avenue.

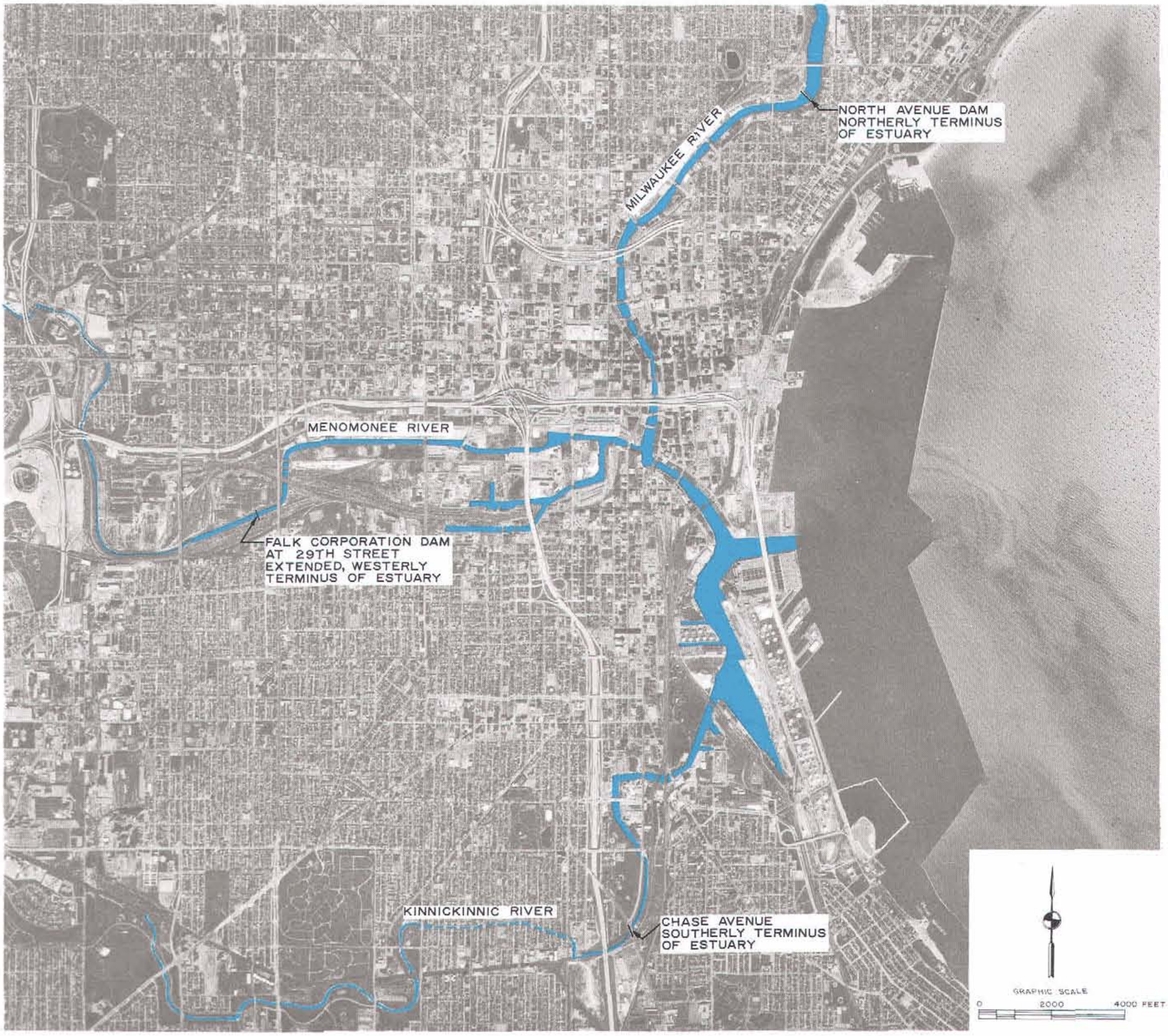
It is the Commission's position that, with the exception of floodland management, the "harbor" estuary should be studied separately from the tributary Milwaukee, Menomonee, and Kinnickinnic River watersheds. There are physical as well as planning reasons—the latter relating to the community of interest concept discussed below—for the position that the estuary area should be excluded from the watershed studies in general and the Kinnickinnic River watershed study in particular. From a physical standpoint, the hydraulic characteristics and behavior of the three tributary streams above the point at which they enter the estuary is distinctly different from, and considerably less complex than, the hydraulic characteristics and behavior of the estuary area. Rivers upstream of the estuary exhibit essentially continuous, downstream flow and, except for extremely high lake levels which must be accounted for in watershed studies, are unaffected by Lake Michigan water levels. In contrast, the estuary portion of each of the three rivers exhibits flow reversals, stage fluctuations, thermal stratification and related currents, and periods of relative calm, all attributable to the hydraulic connection between the estuary and Lake Michigan.

The complete resolution of water quality problems in any portion of the estuary—for example, the Kinnickinnic River downstream of Chase Avenue—must be based ultimately upon an analysis of the entire estuary. The data and analyses contained in the completed comprehensive plans for the Milwaukee, Menomonee, and Kinnickinnic River watersheds will permit the ultimate proper analysis of the problems of the estuary. These three watershed studies provide information on flow contributions to the estuary and include recommendations for the elimination of pollution sources lying entirely outside of the estuary area and of one major pollution source—combined sewer overflows—shared by both the estuary and the Milwaukee, Menomonee, and Kinnickinnic River watersheds. The ultimate solution of estuary problems, one of which is water pollution, must await a detailed planning study of the estuary, however, because of the hydraulic interdependence of the estuary and Lake Michigan.

The Commission believes that the delineation of watersheds as planning areas must recognize not only the physical features—for example, topographic divides and hydraulic interconnections—that influence a technically sound watershed planning operation, but also the existence of a significant community of interest that facilitates the active participation of local officials and citizen leaders in the planning effort. Although the Menomonee, Milwaukee, and Kinnickinnic Rivers physically join in the estuary at the Lake Michigan shoreline, the promotion of a single community of interest throughout all three of these river basins would be most difficult. Residents of the Milwaukee and Menomonee River basins have little in common with residents of the Kinnickinnic River basin on land and water resource problems. The strong community of interest is shared, however, by those private and public segments of the Milwaukee metropolitan area population having some involvement in any aspect of the estuary and immediate lakeshore area.

Map 2

THE LAKE MICHIGAN ESTUARY AS FORMED BY THE CONFLUENCE OF THE MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVERS



The Menomonee, Milwaukee, and Kinnickinnic Rivers all join in the Lake Michigan estuary and harbor within the City of Milwaukee before discharging to Lake Michigan. The westerly terminus of the estuary is located 2.40 miles up the Kinnickinnic River at Chase Avenue in the City of Milwaukee. With the exception of incorporating certain upstream hydraulic effects directly attributable to high lake levels, it is the Commission's position that the estuary should be studied separately from the three tributary watersheds after comprehensive plans are completed for those watersheds, since the estuary has common physical characteristics that differ from those of the tributary watersheds, and it also constitutes a single community of interest for business, commercial, industrial, and recreational activities.

Source: SEWRPC.

Commercial Great Lakes shipping and interconnections between that shipping and land, rail, and truck transportation may be expected to be of common concern to the estuary area business community. This commercial activity is bound to conflict with, and be affected by, existing and potential recreational uses of the estuary area as well as the nearby beaches. For example, the increased popularity of Lake Michigan pleasure boating and sportfishing will increase the need for marinas and other related services, with the impact of these pressures being shared by most of the estuary community. As part of an effort to improve retail activity and the provision of services in the Miwaukee business district, busines leaders may be expected to become increasingly interested in the protection and even restoration of the rivers and the Lake Michigan shoreline in and near the central urban area. Such efforts by the estuary-harbor community could provide for additional park and open space areas and would, at least indirectly, reflect on the success of retail and service activities.

Thus, while a portion of the estuary area would be included in the Kinnickinnic River watershed, under a strict topographic divide definition, it has been excluded from the watershed study because that 2.40 mile reach of the river hydraulically functions as an estuary of Lake Michigan and, equally important, because that portion of the Kinnickinnic River shares a community of interest with the estuary and immediate lakeshore areas that is markedly stronger than its ties with those portions of the Kinnickinnic River watershed lying above the estuary.

The watershed study, accordingly, will incorporate only those aspects of the estuary that have direct bearing on the watershed above the estuary. An example of the study content is the necessity of determining the effect of Lake Michigan levels on Kinnickinnic River flood stages above Chase Avenue.

Staff, Cooperating Agency, Consultant, and Committee Structure

The basic organizational structure for the study is outlined in Figure 2, and consists of the cooperating state and federal agencies, consultants, and Commission staff reporting to the Chief Environmental Planner as the interstaff project coordinator, who reports to the Executive Director, as project sponsor. The Executive Director, in turn, reports to the Southeastern Wisconsin Regional Planning Commission. The responsibilities of the cooperating federal and state agencies, consultants, and Commission staff for the conduct of major elements of the planning study are also indicated in Figure 2.

A comprehensive watershed planning program necessarily covers a broad spectrum of related governmental and private development programs, and no agency, whatever its function or authority, can operate independently in the conduct of such a study. The basic Commission organization provides for the attainment of the necessary interagency coordination through the establishment of advisory committees, as well as through interagency staff assignment.

One such advisory committee created by the Commission for watershed planning is the Kinnickinnic River Watershed Committee, established in November 1973. The purpose of this Committee is to actively involve governmental bodies, technical agencies, and private interest groups within the watershed in the planning study. The Committee helps the Commission determine and coordinate policies involved in the conduct of the study and in the resultant plans and plan implementation programs. Active involvement of state and federal, as well as of local, public officials in the watershed planning program through this Committee is particularly important to any ultimate implementation of the watershed plans in view of the advisory role of the Commission in shaping regional and subregional development. The Watershed Committee also performs an important educational function in familiarizing local leadership within the watershed with the study and its findings, in generating an understanding of basic watershed development objectives and implementation procedures, and in encouraging plan implementation.

The watershed planning work program has been conducted by the resident Commission staff, supplemented as needed by contractual services provided by two consulting engineering firms. The Commission staff managed and directed all phases of the engineering and planning work. More specifically, the Commission staff was responsible for preparation of the detailed study design; formulation of watershed development objectives, principles, and standards; conduct of certain inventories; conduct of all analyses of the inventory data to identify the problems and development potential of the watershed; synthesis and evaluation of alternative plan elements; and report preparation.

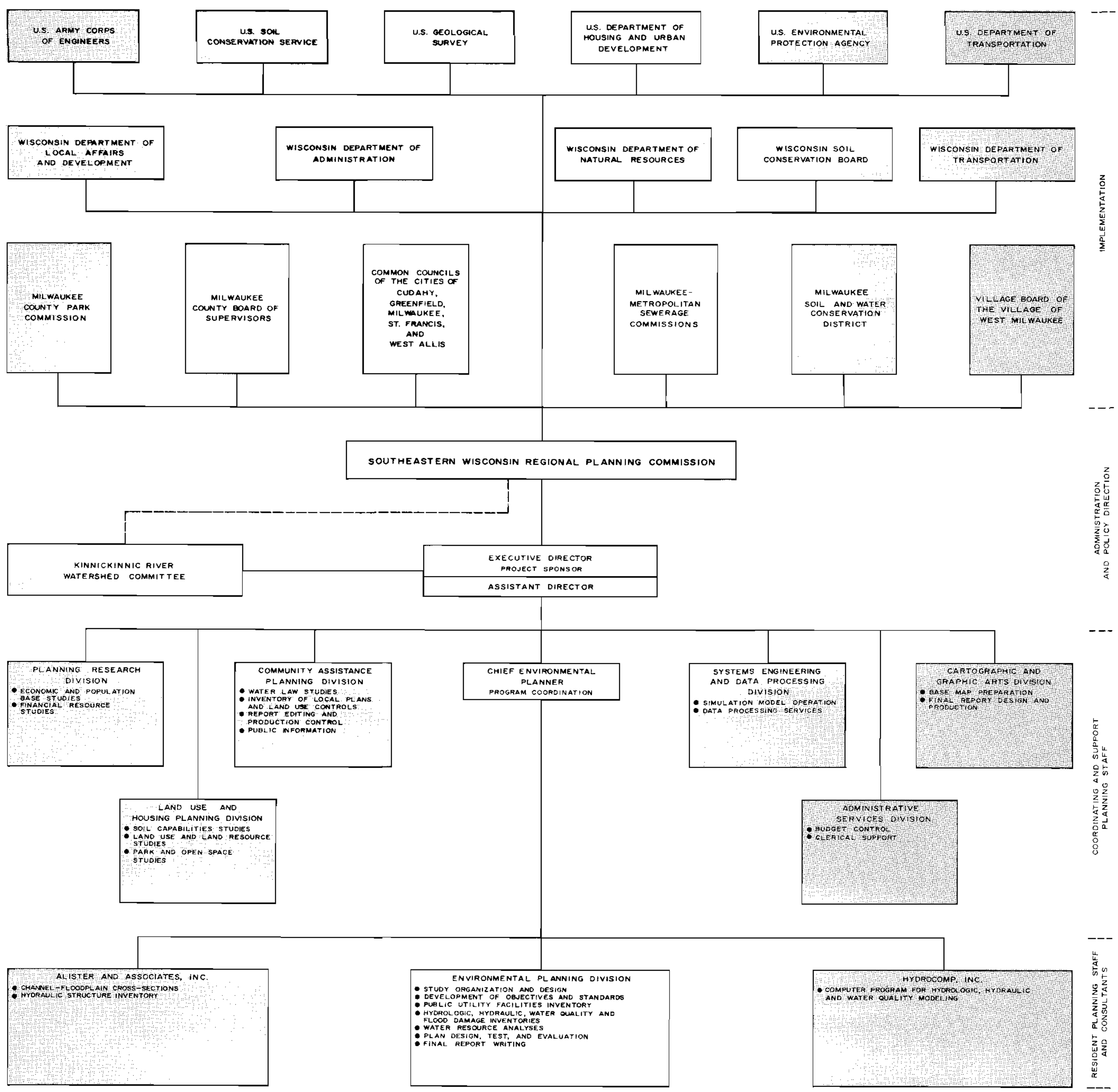
The efforts of the Commission's professional and supporting staff were supplemented with the services of specialists in the areas of surveying and hydrologic-hydraulic-simulation modeling. A contractual agreement was executed with the firm of Alster and Associates, Inc., of Madison, Wisconsin, for the conduct of the necessary horizontal and vertical control surveys within the watershed and the provision of channel-floodplain cross sections and physical data on selected hydraulic structures in the watershed. Similarly, a contractual agreement was executed with Hydrocomp, Inc., of Chicago, Illinois, for the provision of the computer programs used in simulating the hydrologic, hydraulic, and water quality characteristics of the watershed surface water system.

Scheme of Presentation

The major findings and recommendations of the Kinnickinnic River watershed planning program are documented and presented in this report. The report first sets forth the basic concepts underlying the study and the factual findings of the extensive inventories conducted under the study. It identifies and, to the extent possible, it quantifies the developmental and environmental problems of the watershed, and sets forth forecasts of future economic activity, population growth, and land use and concomitant environmental problems. The report

Figure 2

ORGANIZATIONAL STRUCTURE OF THE KINNICKINNIC RIVER WATERSHED STUDY



Source: SEWRPC.

presents alternative plan elements relating to floodland management, pollution abatement, and land use, and sets forth a recommended plan for the development of the watershed based upon regional and watershed development objectives adopted by the Watershed Committee and the Commission. In addition, it contains financial and institutional analyses and specific recommendations for plan implementation. This report is intended to allow careful, critical review of the alternative plan elements by public officials, agency staff personnel, and citizen leaders within the watershed, and to provide the basis for plan adoption and implementation by the federal, state, and local agencies of government concerned.

This report can only summarize briefly the large volume of information assembled in the extensive data collection, analysis, and forecasting phases of the Kinnickinnic watershed study. Although the reproduction of all of this information in report form is impractical due to the magnitude and complexity of the data collected and analyzed, all of the basic data are on file in the Commission offices and are available to member units and agencies of government and to the general public upon specific request. This report, therefore, serves the additional purpose of indicating the types of data which are available from the Commission and which may be of value in assisting federal, state, and local units of government and private investors in making better decisions about community development within the Region.

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Chapter II

BASIC PRINCIPLES AND CONCEPTS

INTRODUCTION

Watershed planning is not new. Plans have been developed in the past for many watersheds, both large and small, throughout the United States. Most of these plans, however, have been developed either to meet the needs of one or more specific revenue-producing functions, such as irrigation or hydroelectric power generation, or to fulfill a single-purpose requirement for which specific benefits are assignable to existing properties, such as flood control or soil and water conservation. Generally speaking, watershed planning efforts have traditionally employed a narrow range of means to achieve essentially a narrow range of goals, with emphasis on those goals for which attainment could be directly measured in monetary terms.

The application of comprehensive planning principles and practices to water and water-related resource problems as described in this report, however, is a relatively new concept. Consequently, at the time the Commission undertook its first comprehensive watershed planning program, that for the Root River watershed, little practical experience had been accumulated in such comprehensive watershed planning, and the now widely accepted principles governing such planning had not been established. Moreover, the need to carry out comprehensive watershed planning as an integral part of a broader regional planning effort required the adaption and modification of the limited body of watershed planning experience which did exist to the specific needs of the Root River watershed planning program.

These factors necessitated, as part of the Root River watershed study, the development of a unique approach to watershed planning, an approach which proved to be sound and which was, therefore, adopted for use in subsequent studies of the Fox, Milwaukee, Menomonee, and Kinnickinnic River watersheds. This approach can only be explained in terms of the conceptual relationships existing between watershed planning and regional planning and the basic principles applicable to watershed planning set within the framework of regional planning. Once this foundation of conceptual relationships and applicable principles has been established, the approach taken to the specific problems of the Kinnickinnic River watershed and the recommended solutions to these problems, as presented herein, can then be properly understood.

THE WATERSHED AS A PLANNING UNIT

Planning for water and water-related natural resources could conceivably be carried out by geographic units, including areas defined by governmental jurisdictions, economic linkages, or watershed boundaries. None of these is perfect as a water and water-related resources planning unit. There are many advantages, however, to selecting the watershed as a water and water-related resources planning unit because many problems of both rural and urban development and of natural resource conservation are water-oriented.

Floodland management measures and flood control and storm water drainage facilities should form a single integrated system in an entire watershed. Streams and watercourses, as hydraulic systems, must be capable of carrying both present and future runoff loads generated by changing land use and changing water control facility patterns within the watershed. Therefore, flood control and storm drainage problems and facilities can best be considered on a watershed basis. Drainage and flood control problems are closely related to other land and water use problems. Consequently, floodland protection, park and related open space reservation, and other recreational needs associated with surface water resources also can best be studied on a watershed basis.

Water supply and sewerage frequently involve problems that cross watershed boundaries, but strong watershed implications are involved if the source of water supply comes from the surface water resources of the watershed or if the sewerage systems discharge pollutants into the surface water system. Groundwater divides do not necessarily coincide with surface water divides, and therefore planning for groundwater use and protection must incorporate both intrawatershed and interwatershed considerations. Changes in land use and transportation requirements ordinarily are not controlled primarily by watershed factors, but can have major effects on watershed problems. The land use and transportation patterns may significantly affect the amount and spatial distribution of the hydraulic and pollution loadings to be accommodated by water control facilities. In turn, the water control facilities and their effect upon the historic floodlands determine to a considerable extent the use to which such land areas may be put.

Finally, the related physical problems of a watershed tend to create a strong community of interest among the residents of the watershed, and citizen action groups can readily be formed to assist in solving water-related problems. The existence of a community of interest around which to organize enlightened citizen participation in the planning process is one of the most important factors contributing to the success of such a process.

It may be concluded, therefore, that the watershed is a logical areal unit to be selected for water resources planning purposes, provided that the relationships existing between the watershed and the surrounding region are recognized. Accordingly, the regional planning program in southeastern Wisconsin embodies a recognition of the need to consider watersheds within the Region as rational planning units if workable solutions are to be found to intensifying interrelated land and water use problems.

The foregoing discussion implies that the term watershed may have two meanings. Defined in a strictly physical sense, a watershed is simply a geographic area of overland drainage contributing surface runoff to the flow of a particular stream or watercourse at a given point. Under this definition, the terms watershed and drainage basin are synonymous. The meaning of the term watershed may be expanded to include planning concepts, however, by adding to the above definition the phrase: whose natural and man-made features are so interrelated and mutually interdependent as to create a significant community of interest among its residents. This expanded definition of the term watershed contains within it the characteristics which a drainage basin, such as that of the Kinnickinnic River, must exhibit if it is to form a rational unit for comprehensive water resources planning. This expanded definition, moreover, had a particularly important impact upon the geographic area to be encompassed in a study of the Kinnickinnic River watershed by the Regional Planning Commission, for careful consideration of the communities of interest involved led the Commission to exclude from its delineation of the Kinnickinnic River watershed the drainage areas of the Milwaukee and Menomonee Rivers as well as the estuary shared by all three of these streams. It is thus recognized that a watershed is far more than a system of interconnected waterways and floodlands which, in fact, comprise only a small proportion of the total watershed area. Land treatment measures, soil and water management practices, and land use over the entire watershed, as well as all related water resource problems, are of major importance in the proper development of watershed resources.

RELATIONSHIP OF WATERSHED TO REGION

Although recognizing the importance of the watershed as a rational planning unit within the Region, the regional planning program in southeastern Wisconsin also recognizes the need to conduct individual watershed planning programs within the broader framework of areawide, comprehensive regional planning. This is essential for two reasons. First, areawide urbanization and the developmental and environmental problems resulting from such urbanization indiscriminately cross watershed boundaries and exert an overwhelming external influence on the physical development of the affected watershed. Second, the meandering pattern of natural watershed boundaries rarely, if ever, coincides with the artificial, generally rectangular boundaries of minor civil divisions and special-purpose districts.

Important elements of the necessary comprehensive, areawide planning program have been provided by the Regional land use-transportation study and by other areawide planning programs of the Commission such as the regional sanitary sewerage system planning program and the areawide water quality management planning program. Conversely, within the context of the regional planning program, the comprehensive watershed planning programs provide, within the limits of each watershed, one of the key elements of a comprehensive regional development plan, namely, a long-range plan for water-related community facilities. While the proposed watershed plans may be centered on water quality and flood control facilities and on floodland management measures, it must be recognized that these facility plans and management measures must reflect consideration of the related problems of land and water use and of park and related open space reservation needs. Recognition of the need to relate water control facility plans and management measures to areawide regional development plans is the primary factor which determines the unique nature of the Commission watershed planning efforts. Ultimate completion of planning studies covering all of the watersheds within the Region will provide the Commission with a framework of plans encompassing drainage, flood control, and water pollution control facilities as well as floodland management measures properly related to comprehensive, areawide development plans.

THE WATERSHED PLANNING PROBLEM

Although the water-related resource planning efforts of the Commission are focused on the watershed as a rational planning unit, the watershed planning problem is closely linked to the broader problem of protecting and maintaining the quality of the environment in urban and urbanizing areas. In the past environmental protection, or what was then more commonly called "conservation," was largely concerned with protecting large natural tracts in rural areas and with the possible future shortages of mineral or other resources resulting from chronic mismanagement. The major problem which environmental protection now faces is occasioned by the kind of environment being created by the ever-increasing areawide diffusion of urban development over large areas of the earth's surface together with the relentless pursuit of an ever higher material standard of living.

Enlightened public officials and citizen leaders are gradually becoming aware of this new and pressing need for the protection and, in some cases, the enhancement of the physical environment in urban areas. The need to adjust the physical fabric of urban development to the ability of the underlying natural resource base to sustain such development is perhaps most critical in heavily urbanized areas such as the Kinnickinnic River watershed. In such urban areas, as opposed to more sparsely settled rural watersheds, the overall quality of the environment is highly dependent on present and future land use activities and supporting public facilities; the viable options remaining for environmental protection and enhancement are limited. For example, ready access to attractive and functional public open space is an important factor in determining the quality of life in an urban setting. As the urbanization process proceeds to the point where essentially all land is used for or committed to residential, commercial, industrial, and similar urban uses—as is the case in the Kinnickinnic River watershed—it is absolutely imperative that public open space requirements be identified and that steps be taken to assure that necessary additional open space be reserved while the opportunities still exist.

The growing awareness of the need for environmental protection in urban areas is often heightened by a major disaster or the imminent threat of such a disaster. In many cases, such as in the Kinnickinnic River watershed, the initial concern with environmental protection is centered in such highly visible problems as flooding and water pollution. Even then, however, the magnitude and degree of the interrelationship of environmental problems may not always be fully realized.

The manner in which these problems are ultimately resolved will involve many important public policy determinations. These determinations must be made in view of an urbanizing Region which is constantly changing, and therefore should be based upon a comprehensive planning process able to objectively scale the changing resource demands against the ability of the limited natural resource base to meet these demands. Only within such a planning process can the effects of different land and water use and water control facility construction proposals be evaluated, the best course of action intelligently selected, and the available funds most effectively invested.

The ultimate purposes of such a planning process are twofold: (1) to permit public evaluation and choice of alternative development and environmental protection and enhancement policies and plans and (2) to provide, through the medium of a long-range plan for water-related community facilities, for the full coordination of local, state, and federal development and environmental protection programs within the Region and within the watersheds of the Region. Important among the goals to be achieved by this process are the protection of floodlands; the protection of water quality and supply; the preservation of land for park and open space; and, in general, promotion of the wise and judicious use of the limited land and water resources of the watershed and of the Region of which the watershed is an integral part.

BASIC PRINCIPLES

Based upon the foregoing considerations, eight basic principles were developed under the Root River watershed study. Together these form the basis for the specific watershed planning process applied by the Commission in that study. These same principles were used in the Fox, Milwaukee, and Menomonee River watershed studies, and provide the foundation for the planning process applied in the Kinnickinnic River watershed study:

1. Watersheds must be considered as rational planning units if workable solutions are to be found to water and water-related resource problems.
2. A comprehensive, multipurpose approach to water resource development and to the control and abatement of the water-related problems is preferable to a single-purpose approach.
3. Watershed planning must be conducted within the framework of a broader areawide regional planning effort, and watershed development objectives must be compatible with, and dependent upon, regional development objectives and plans based on those objectives.
4. Water control facility planning must be conducted concurrently with, and inseparably from, land use planning.
5. Both land use and water control facility planning must recognize the existence of a limited natural resource base to which urban and rural development must be properly adjusted to ensure a pleasant and habitable environment.
6. The capacity of each water control facility in the integrated watershed system must be carefully fitted to the present and probable future hydraulic loads, and the hydraulic performance and hydrologic feasibility of the proposed facilities must be determined and evaluated.
7. Primary emphasis should be placed on in-watershed solutions to water resource problems. The export of water resource problems to downstream areas is unwise on a long-range and regional basis.
8. Plans for the solution of watershed problems and development of resources should offer as flexible as possible an approach to avoid "dead-end" solutions and should provide latitude for continued adaptation to changing conditions.

THE WATERSHED PLANNING PROCESS

Based upon the foregoing principles, the Commission has developed a seven-step planning process by which the principal functional relationships existing within a watershed can be accurately described, both graphically and numerically; the hydrologic, hydraulic, and water quality characteristics of the basin simulated; and the effect of the different courses of action on land use and water control facility development evaluated. The watershed planning process not only provides for the integration of all the complex planning and engineering studies required to prepare a comprehensive watershed plan but also, importantly, provides a means whereby the various private and public interests concerned may actively participate in the plan preparation. The process thus provides a mechanism for resolving actual and potential conflicts between such interests; a forum in which the various interests may better understand the interrelated problems of the watershed and the alternative solutions available for such problems; and finally, a means whereby all watershed interests may become committed to implementation of the best alternative for the resolution of the problems.

The seven steps involved in this planning process are: 1) study design, 2) formulation of objectives and standards, 3) inventory, 4) analysis and forecast, 5) plan synthesis, 6) plan test 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.

The principal results of the above process are land use and water control facility plans scaled to future land use and resource demands and consistent with regional development objectives. In addition, the process represents the beginning of a continuing planning effort that permits modification and adaption of the plans and the means of implementation to changing conditions. Each step in this planning process includes many individual operations which must be carefully designed, scheduled, and controlled to fit into the overall process. An understanding of this planning process is essential to an appreciation and understanding of the results. Each step in the process, together with its major component operations, is diagrammed in Figure 3 and described briefly below.

Study Design

Every planning program must embrace a formal structure or study design so that the program can be carried out in a logical and consistent manner. This study design must specify the content of the fact-gathering operations, define the geographic area for which data will be gathered and plans prepared, outline the manner in which the data collected are to be processed and analyzed, specify requirements for forecasts and forecast accuracy, and define the nature of the plans to be prepared and the criteria to be used in their evaluation and adoption.

The need for, and objectives of, the Kinnickinnic River watershed study were set forth in the Kinnickinnic River Watershed Planning Program Prospectus prepared by the Kinnickinnic River Watershed Committee. The Prospectus also identified major work elements to be included in the comprehensive watershed study and set forth in the study design framework. In addition, a public hearing was held by the Watershed Committee on March 9, 1977, to elicit public opinions concerning the need for, objectives of, and scope and content of the proposed watershed study. The testimony presented at this hearing, which was attended by about 30 interested persons, is set forth in the published minutes of the hearing.[1] The Prospectus, supplemented by the testimony presented at the initial public hearing on the Kinnickinnic River watershed study, was used by the Commission staff to prepare a detailed study design which was used for project management purposes throughout the duration of the study.

The staff of the Southeastern Wisconsin Regional Planning Commission expanded and refined this study design during the course of the study as a result of continuous staff level communication with those governmental agencies and private consultants contributing certain specialized services to the Kinnickinnic River watershed planning program, and with the Watershed Committee.

Formulation of Objectives and Standards

In its most basic sense, planning is a rational process for establishing and meeting objectives. The formulation of objectives is, therefore, an essential task to be undertaken before plans can be prepared. In order to be useful in the regional and watershed planning process, the objectives to be defined must not only be clearly stated and logically sound but must also be related in a demonstrable way to alternative physical development proposals. This is essential because it is the duty and function of the Commission to prepare a comprehensive plan for the physical development of the Region and its component parts and, more particularly, because it is the objective of the Kinnickinnic River watershed planning study to prepare one of the key elements of such a physical development plan: a long-range plan for water-related community facilities. Only if the objectives are clearly relatable to physical development and subject to objective test can a choice be made from among alternatives in order to select that plan which best meets the agreed-upon objectives. Finally, logically conceived and well expressed objectives must be translated into detailed design standards to provide the basis for plan preparation, test, and evaluation. Because the formulation of objectives and standards involves both technical and nontechnical policy determinations, all objectives and standards were carefully reviewed and adopted by the Kinnickinnic River Watershed Committee and the Commission.

The objectives and standards ranged from general development goals for the watershed as a whole to detailed engineering and planning analytical procedures and design criteria covering rainfall intensity-duration-frequency relationships; digital computer simulation of hydrology, hydraulics, and water quality; flood frequency analyses, design floods; and economic and financial analyses. Most of the general development goals were superimposed on the watershed study from previous watershed planning programs, the regional land use-transportation planning program, the regional sanitary sewerage system planning program, and the areawide water quality planning and management program.

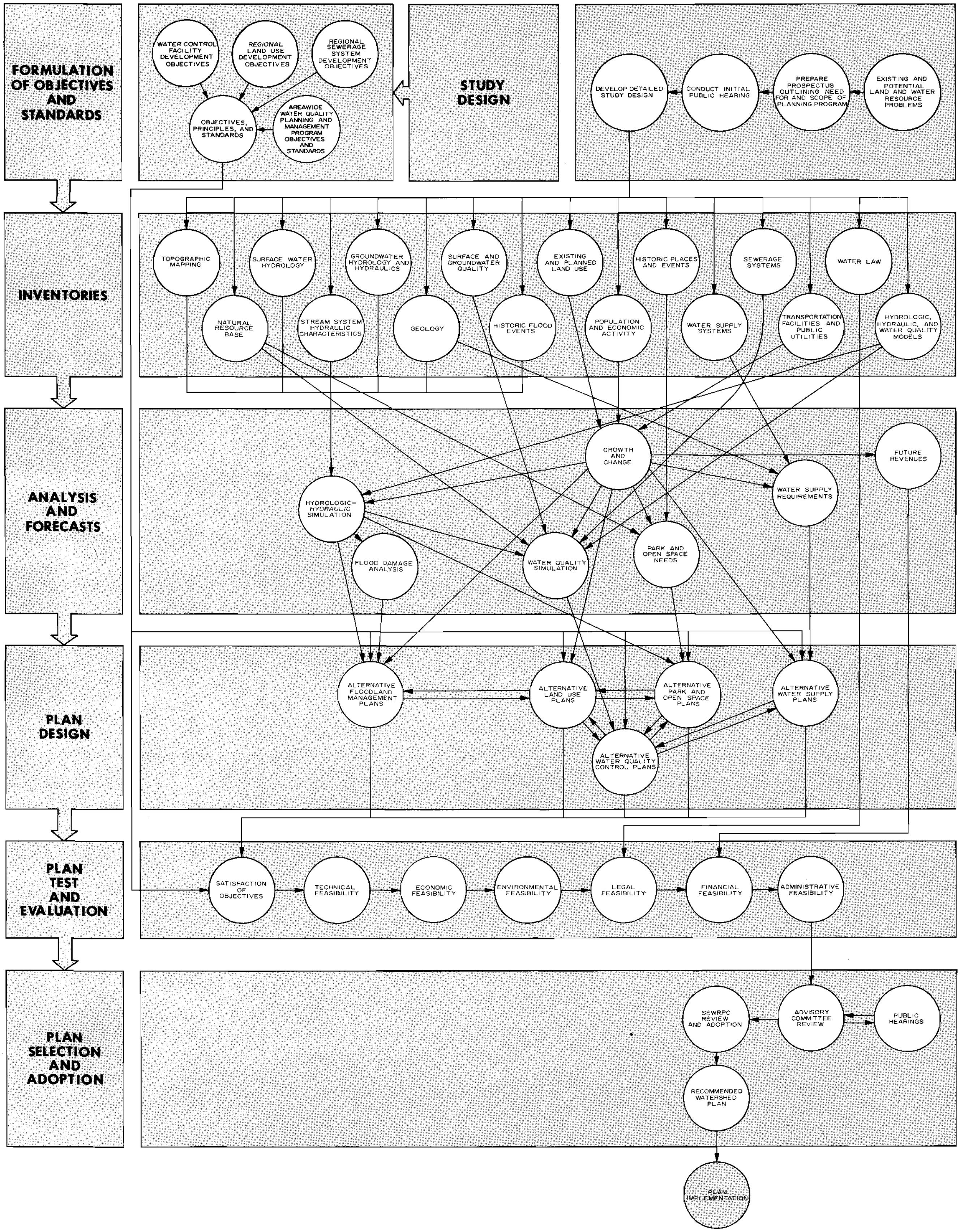
Inventory

Reliable basic planning and engineering data collected on a uniform, watershed-wide basis are absolutely essential to the formulation of workable development plans. Consequently, inventory growing out of the study design becomes the first operational step in any planning process. The crucial need for factual information in the planning process should be evident since no intelligent forecasts can be made or alternative courses of action selected without knowledge of the historic and current state of the system being planned.

[1] *SEWRPC, Minutes of the Initial Public Hearing—Kinnickinnic River Watershed Study, March 9, 1977.*

Figure 3

GENERAL STEPS IN A COMPREHENSIVE WATERSHED PLANNING PROGRAM



Source: SEWRPC.

The sound formulation of comprehensive watershed development plans requires that factual data must be developed on topographic features, the quantity of surface and ground water, precipitation, hydraulic characteristics of the stream system, historic flooding, flood damages, water quality and wastewater sources, water use, soil capabilities, land use, economic activity, population, recreation facilities, fish and wildlife habitat, unique natural areas, historic sites, water supply and sewerage systems and other public utilities, and water law.

In the Kinnickinnic River watershed study, the most expedient methods of obtaining adequate information of the necessary quality were followed. These included review of prior publications, perusal of agency files, personal interviews with private citizens and public officials, committee meetings of staff and technical advisors, and original field investigations.

Analysis and Forecast

Inventories provide factual information about historic and present situations, but analyses and forecasts are necessary to provide estimates of future needs for land, water, and water control facilities. These future needs must be determined from a sequence of interlocking forecasts. Economic activity and population forecasts enable determination within the watershed of future growth which, in turn, can be translated into future demands for land, other resources, and water control facilities. These future demands can then be scaled against the existing supply and plans formulated to meet deficiencies.

To illustrate the complexity of this task in comprehensive watershed planning, consider that to prepare a forecast of future floodland management and flood control facility needs it was necessary to analyze and to interrelate the following factors: precipitation characteristics; relationship between basin morphology and runoff; effect of urbanization and soil properties on runoff volume and timing; effect of the hydraulic characteristics of the stream network on streamflow; relationships between streamflow, flood stage, and frequency of flood occurrence; seasonal influence; and influence of floodland storage and conveyance.

Two important considerations involved in the preparation of the necessary forecasts are the target date and accuracy requirements. Both the land use pattern and the floodland management measures, particularly water control facilities, must be planned for anticipated demand at some future point in time. In the planning of water control facilities, this "design year" is usually established by the expected life of the first facilities to be constructed in implementation of the plan. Although it may be argued that the design year for land use development should be extended further into the future than that for facilities because of the basic irreversibility of many land development decisions, practical considerations dictate that the land use planning design year be scaled to the facility design year requirement. In the Kinnickinnic River watershed study, the necessary forecast period was set as approximately 25 years, both as a very conservative approximation of facility life and as a means for locking the watershed forecast periods into the previously determined regional land use-transportation study forecast periods.

Forecast accuracy requirements depend on the use to be made of the forecasts. As applied to land use and water control facility planning, the critical question relates to the effect of any forecast inaccuracies on the basic structure of the plans to be produced. It is important to keep the forecast tolerances within that range in which only the timing and not the basic structure of the plans will be affected.

Plan Synthesis

Plan synthesis or design forms the heart of the planning process. The most well conceived objective; the most sophisticated data collection, processing, and analysis operations; and the most accurate forecasts are of little value if they do not ultimately result in sound plans. The outputs of each of the three previously described planning operations—formulation of objectives and standards, conduct of inventories, and preparation of forecasts—become inputs to the design problem of plan synthesis.

The land use plan design problem consists essentially of determining the allocation of a scarce resource—land—between competing and often conflicting demands. This allocation must be accomplished so as to satisfy the aggregate needs for each land use and comply with all of the design standards derived from the plan objectives, all at a feasible cost. The water control facility plan design problem requires a similar reconciliation between hydrologic, hydraulic, and pollution loading derived from the land use plan; adopted facility design standards; existing facilities; and new facility costs.

Plan Test and Evaluation

If the plans developed in the design stage of the planning process are to be realized in terms of actual land use and water control facility development, some measures must be applied to quantitatively test alternative plans in advance of their adoption and implementation. The alternative plans must be vigorously subjected to all the necessary levels of review and inspection, including: 1) engineering and technical feasibility, 2) environmental impact, 3) economic and financial feasibility, 4) legality, and 5) political reaction and acceptability. Devices used to test and evaluate the plans range from the use of digital computer simulation programs to evaluate hydrologic-hydraulic responses under alternative plan elements through interagency meetings and public hearings. Plan test and evaluation should demonstrate clearly which alternative plans or portions of plans are technically sound, economically and financially feasible, legally possible, and politically realistic.

Plan Selection and Adoption

It is proposed for the Kinnickinnic River watershed study to develop a land use plan representing a refinement of the adopted regional land use plan. This land use plan is supported by various combinations of water control facility system plans for both flood control and pollution abatement, thus providing a number of alternative watershed development plans. The desirability of the recommended comprehensive plan is supported by an analysis of some of the consequences that may be expected under conditions of uncontrolled development.

The general approach contemplated for the selection of one plan from among alternatives is to proceed through the use of the Kinnickinnic River Watershed Committee structure, interagency meetings, and informational meetings and hearings to a final decision and plan adoption by the Commission in accordance with the provisions of the state enabling legislation. The role of the Commission is to recommend the final plan to federal, state, and local units of government and private investors for their consideration and action. The final decisive step to be taken in the process is acceptance or rejection of the plan by the local governmental units concerned, and subsequent plan implementation by public and private action. Therefore, plan selection and adoption must be founded in the active involvement of the various governmental bodies, technical agencies, and private interest groups concerned with development in the watershed. The use of advisory committees and both formal and informal hearings appears to be the most practical and effective procedure for achieving such involvement in the planning process, and of openly arriving at agreement among the affected governmental bodies and agencies on objectives and on a final watershed plan which can be cooperatively adopted and jointly implemented.

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Chapter III

DESCRIPTION OF THE WATERSHED MAN-MADE FEATURES AND NATURAL RESOURCE BASE

INTRODUCTION

The water resource and water resource-related problems of a watershed, as well as the ultimate solutions to those problems, are a function of the activities of man within the watershed and of the ability of the underlying natural resource base to sustain those activities. This is especially true in the Kinnickinnic River watershed where urban land uses and related activities occupy most of the basin. Comprehensive watershed planning seeks to rationally direct the future course of human actions within the watershed so as to favorably affect the overall quality of life.

The purpose of this chapter is to describe the natural resource base and man-made features of the Kinnickinnic watershed, thereby establishing a factual base upon which the watershed planning process may proceed. This description of the watershed is presented in this chapter in two major sections, the first of which describes the man-made features and the second of which describes the natural resource base of the watershed.

DESCRIPTION OF THE WATERSHED: MAN-MADE FEATURES

The man-made features of a watershed, which are important to any comprehensive planning effort directed at the resolution of water resource and related problems, include its political boundaries, land use pattern, public utility network, and transportation system. Together with the population residing in and the economic activities taking place within the watershed, these features may be thought of as the socioeconomic base of the watershed. A description of this base is essential to sound watershed planning, for any attempt to protect and improve the environment must be founded in an understanding of not only the various demands for land and public facilities and resources generated by the population and economic activities of an area, but also the ability of the existing land use pattern and public facility systems to meet these demands.

In order to facilitate such understanding, the description of the socioeconomic base of the watershed is herein presented in five sections. The first section places the watershed in proper perspective as a rational planning unit within a regional setting by delineating its internal political and governmental boundaries and relating these boundaries to the Region as a whole. The second section describes the demographic and economic base of the watershed in terms of population size, distribution, and composition and in terms of commercial and industrial activity and employment levels and distribution. The third section describes the pattern of land use in the watershed both in terms of historical development and existing (1975) conditions. The fourth and fifth sections describe the public utility and transportation facility systems within the watershed. A final section summarizes the information presented on the man-made features and activities as well as on the natural resource base.

Regional Setting of Watershed and Political Boundaries

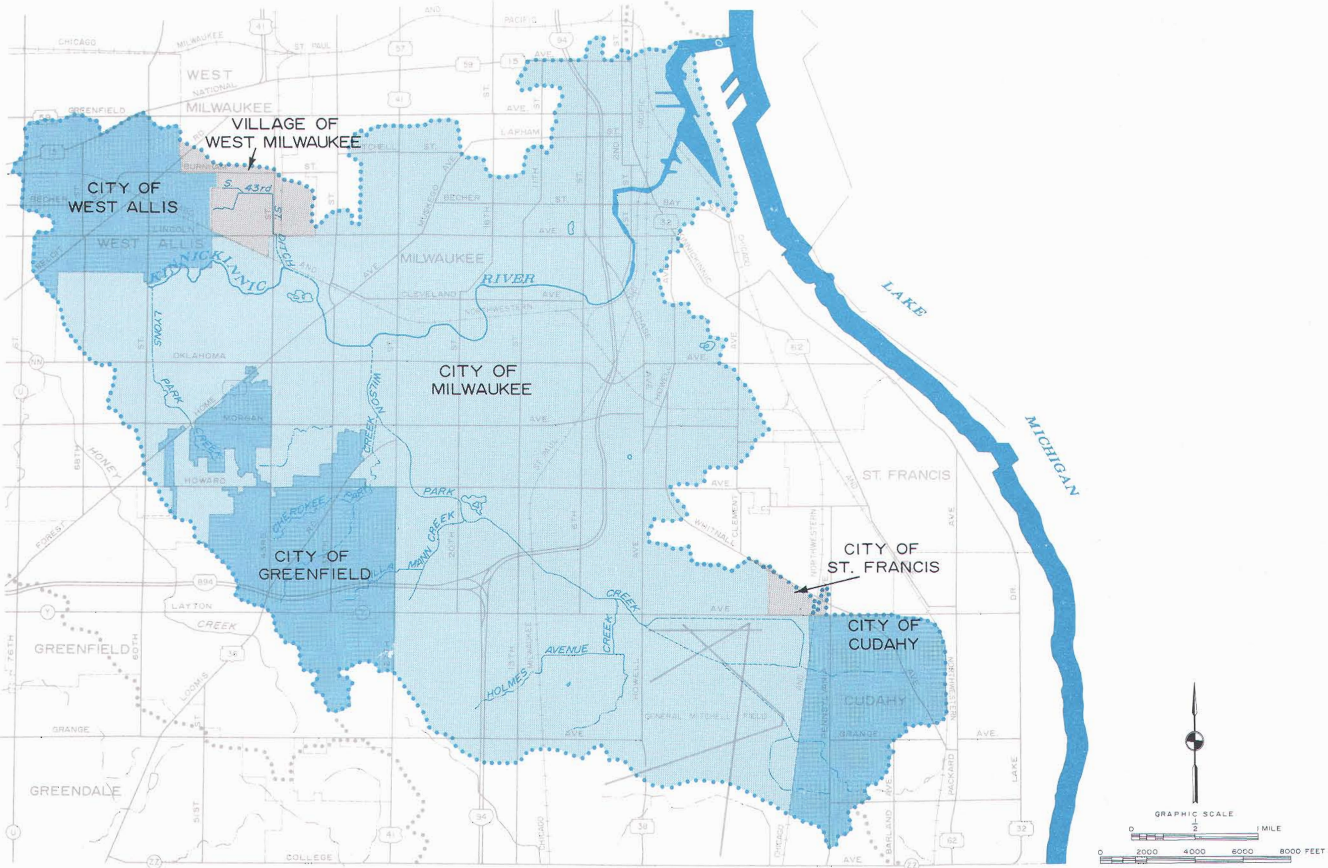
The Kinnickinnic River watershed, as shown on Map 3, is a surface water drainage unit, 24.78 square miles in areal extent, discharging to the Milwaukee River within the City of Milwaukee 0.33 mile upstream of where the Milwaukee River enters Lake Michigan. The watershed is bounded on the north and west by the Menomonee River watershed; on the south by the Oak Creek watershed; and on the east by minor catchment areas that are directly tributary to Lake Michigan. The Kinnickinnic River watershed, which is wholly contained within Milwaukee County, is the second smallest of the 11 distinct watersheds located wholly or partly within the Region. It comprises only 1 percent of the total area of the Southeastern Wisconsin Region.

As shown on Map 3, the Kinnickinnic River has its source at a storm sewer outfall located at S. 60th Street immediately south of W. Kinnickinnic River Parkway Drive in the City of Milwaukee. Immediately downstream of its source, the Kinnickinnic River is joined by Lyons Park Creek, a straightened and channelized stream that flows into the Kinnickinnic River from the south and southeast. From its confluence with Lyons Park Creek, the Kinnickinnic River flows in a generally easterly direction within the City of Milwaukee, being joined at about S. 43rd Street by the S. 43rd Street Ditch that flows into the Kinnickinnic River from the north and northwest; and at about S. 30th Street by Wilson Park Creek, a major tributary that originates east of Mitchell Field and flows in a generally northwesterly direction into the Kinnickinnic River. From its confluence with Wilson Park Creek, the Kinnickinnic River continues in a generally easterly direction to about S. 4th Street, at which point it turns to flow in a north-northeasterly direction to join the Milwaukee River near Lake Michigan. Nearly the entire length of the Kinnickinnic River lies within the City of Milwaukee. Tributaries of Wilson Park Creek include Cherokee Park Creek, Villa Mann Creek, and Holmes Avenue Creek as shown on Map 3.

Civil Divisions: Superimposed on the irregular watershed boundaries is a generally rectilinear pattern of local political boundaries as shown on Map 3. The watershed lies entirely within Milwaukee County and contains parts of five cities—Cudahy, Greenfield, Milwaukee, St. Francis, and West Allis—and the Village of West Milwaukee. None of the six minor civil divisions lies entirely within the

Map 3

CIVIL DIVISIONS IN THE KINNICKINNIC RIVER WATERSHED



The Kinnickinnic River watershed is a 25-square-mile natural surface water drainage basin located entirely within Milwaukee County and containing parts of five cities and one village. The watershed is bounded on the north and west by the Menomonee River watershed; on the south by the Oak Creek watershed; and on the east by areas directly tributary to Lake Michigan. Serious flooding and pollution problems exist within the watershed—problems which require a comprehensive study of the entire basin for sound resolution.

Source: SEWRPC.

boundaries of the watershed but all of the watershed lies within the five incorporated cities and the one incorporated village. The area and proportion of the watershed lying within the jurisdiction of each of the civil divisions, as of 1975, are set forth in Table 1. Geographic boundaries of the civil divisions are an important factor which must be considered in any areawide planning effort, like the Kinnickinnic River watershed planning program, since the civil divisions form the basic foundation of the decisionmaking framework within which intergovernmental environmental and developmental problems must be addressed.

Metropolitan Sewerage District of the County of Milwaukee: A special purpose areawide unit of government having important responsibilities for provision of sanitary sewer service and sewage treatment and for water pollution control and authorization for flood control serves the entire watershed. The Metropolitan Sewerage District of the County of Milwaukee provides sanitary sewer service to the five cities and one village lying within the watershed. The District also has water pollution abatement, drainage, and flood control responsibilities. The Metropolitan Sewerage District, with its service area encompassing the entire Kinnickinnic River watershed, is a particularly important agency with respect to the Kinnickinnic River watershed planning program because it provides an institutional structure for resolving not only areawide surface water pollution problems but also drainage and flood control problems.

Other Agencies Having Resource Responsibilities: Superimposed upon these local and areawide units and agencies of government are the state and federal governments,

Table 1

AREAL EXTENT OF CIVIL DIVISIONS IN THE KINNICKINNIC RIVER WATERSHED: 1975

County or Civil Division	Total County or Civil Division Area (square miles)	County or Civil Division Area Included Within Watershed (square miles)	Percent of County or Civil Division Area Within Watershed	Percent of Watershed Area Within County or Civil Division
Milwaukee County.	242.19	24.78	10.23	100.00
Cities				
Cudahy.	4.77	1.47	30.82	5.93
Greenfield.	12.08	2.32	19.21	9.36
Milwaukee.	95.96	18.70	19.49	75.47
St. Francis.	2.56	0.12	4.69	0.48
West Allis	11.38	1.66	14.58	6.70
Village				
West Milwaukee	1.11	0.51	45.95	2.06
Total	--	24.78[a]	--	100.00

[a] *The areas in this table were determined by map delineation and measurement. Some data used in this report have been determined through approximating the watershed boundary by U. S. Public Land Survey quarter section and summing the quarter section totals. The actual measured watershed total is 24.78 square miles, or 15,859 acres. The watershed area as approximated by 103 quarter sections is 25.62 square miles, or 16,400 acres. The areas in this table differ somewhat from those set forth in Table 2 of the Kinnickinnic River Watershed Planning Program Prospectus. The differences reflect a refined delineation of the watershed boundaries made possible by the availability of large scale topographic mapping and street grade data.*

Source: SEWRPC.

certain agencies of which have important responsibilities for resource conservation and management. These include the Wisconsin Department of Natural Resources; the University Extension of the University of Wisconsin; the State Board of Soil and Water Conservation Districts; the U. S. Department of the Interior, Geological Survey; the U. S. Environmental Protection Agency; the U. S. Department of Agriculture, Soil Conservation Service; and the U. S. Army Corps of Engineers.

Demographic and Economic Base

Because of the direct relationships which exist between population levels and the demand for land, water, and other important elements of the natural resource base, as well as the demand for various kinds of transportation, utility, and community facilities and services, an understanding of the size, characteristics, and spatial distribution of this population is basic to any watershed planning effort. The size and other characteristics of the population of an area are greatly influenced by growth and other changes in economic activity. Population features and economic activity must, therefore, be considered together. It is important to note, however, that because the Kinnickinnic River watershed is an integral part of the urbanizing Milwaukee metropolitan area, many of the economic forces that influence population growth within the watershed are centered outside the watershed proper. Thus, an economic analysis for watershed planning purposes must relate the economic activity within the watershed to the economy of the Milwaukee metropolitan area and the urbanizing Southeastern Wisconsin Region. Similarly, the size, other characteristics, and distribution of the population residing within the watershed must be viewed in relation to similar characteristics of the population within the Milwaukee metropolitan area as well as within the Region.

Demographic Base: A study of the demographic base of the watershed includes consideration of population size, distribution, and composition.

Population Size: The 1975 resident population of the watershed was estimated at about 165,000 persons, or about 16 percent of the population of Milwaukee County and about 9 percent of the total population of the Region. As shown in Table 2 and Figure 4, the population of the watershed increased rapidly from 1900 to 1930 in a manner similar to that of the City of Milwaukee, Milwaukee County, and the Region. From 1930 to 1940 the population of the watershed grew very slowly, consistent with trends in the population growth of the City of Milwaukee, Milwaukee County, and the Region, and reflecting the effects of the severe economic depression of the 1930's. From 1940 to 1960, the population of the watershed again increased at a relatively rapid rate in a manner similar to the City of Milwaukee, Milwaukee County, and the Region. From 1960 to 1970, the population of the watershed decreased in a manner similar to the City of Milwaukee—while the population of the

Table 2

POPULATION IN THE KINNICKINNIC RIVER WATERSHED, THE CITY OF MILWAUKEE, MILWAUKEE COUNTY, AND THE REGION: SELECTED YEARS 1900-1975

Year	Population								
	Kinnickinnic River Watershed		City of Milwaukee		Milwaukee County		Southeastern Wisconsin Region		
	Number	Percent Change During Preceding Period	Number	Percent Change During Preceding Period	Number	Percent Change During Preceding Period	Number	Percent Change During Preceding Period	Watershed Population as Percent of Regional Population
1900	66,525	--	285,315	--	330,017	--	501,808	--	13
1910	85,503	29	373,857	31	433,187	31	631,161	26	14
1920	104,256	22	457,157	22	539,449	24	783,681	24	13
1930	135,645	30	578,249	26	725,263	34	1,006,118	28	13
1940	139,689	3	587,472	2	766,885	6	1,067,699	6	13
1950	153,286	10	637,392	8	871,047	14	1,240,618	16	12
1960	177,598[a]	16	741,324	16	1,036,041	19	1,573,620	27	11
1970	173,914[a]	-2	717,372	-3	1,054,249	2	1,756,086	12	10
1975	165,088	-5	670,663	-6	1,012,536	-4	1,789,871	2	9

[a] *The figures in this table differ somewhat from those set forth in Table 3 of the Kinnickinnic River Watershed Planning Program Prospectus. The differences reflect a refined delineation of the watershed boundaries made under the watershed study and population estimates by quarter section.*

Source: U. S. Bureau of the Census, Wisconsin Department of Administration, and SEWRPC.

County and of the Region continued to increase. The decline in watershed population continued from 1970 to 1975, paralleling trends for both the City and County of Milwaukee.

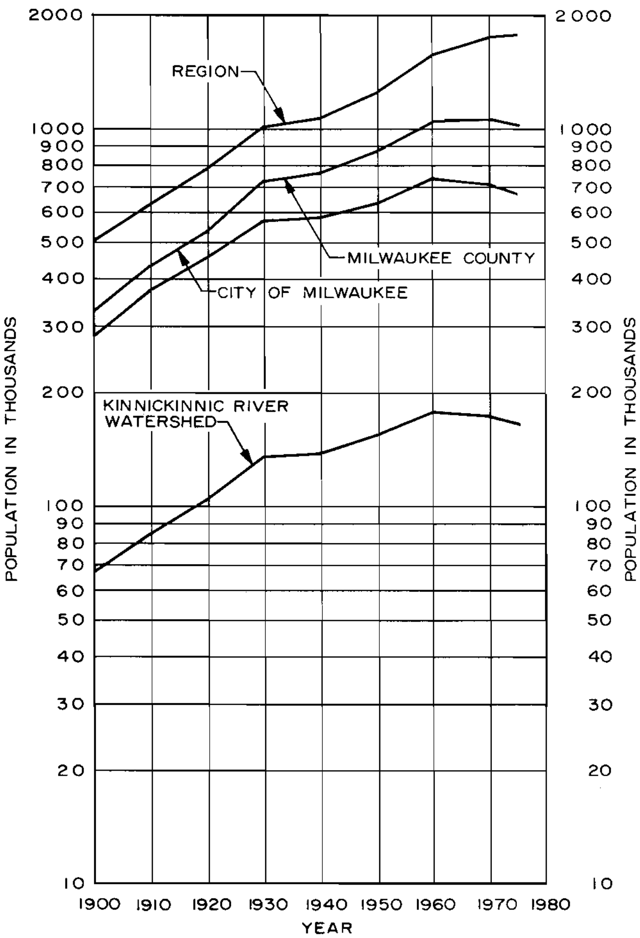
As in many of the large older metropolitan centers of the United States, migration trends in Milwaukee County have been reversed from high rates of in-migration during the 1950's to high rates of out-migration during the 1960's. This exodus reflects nationwide trends which indicate that older metropolitan centers are no longer the most favored areas of residence. Milwaukee County experienced a population decline for the first time beginning in 1970. The net out-migration from the County for the 1970-1975 period is estimated to have been about the same as for the City of Milwaukee.

Population Distribution: The 1950, 1960, 1970, and 1975 watershed population by civil division is presented in Table 3. The largest absolute and proportional increase of watershed population from 1960 to 1975 for any civil division occurred in the City of Greenfield, where the population increased by 54 percent, or by about 4,500 persons, and the proportion of watershed residents residing in that City increased over 3 percent, from about 5 percent in 1960 to about 8 percent in 1975. The largest absolute and proportional decrease in watershed population from 1960 to 1975 occurred in the City of Milwaukee, where the population decreased by 12 percent, or by about 17,000 persons, and the proportion of watershed residents residing in the City of Milwaukee decreased by over 4 percent, from about 82 percent in 1960 to 78 percent in 1975. The Cities of Milwaukee and West Allis and the Village of West Milwaukee all have experienced a decrease in population within the watershed during the 1960 to 1975 period, while the Cities of Cudahy, Greenfield, and St. Francis have experienced an increase in population within the watershed.

As shown on Map 4, a wide range in population density exists within the Kinnickinnic River watershed. Such density varies from less than 350 persons per gross square mile in some areas of Cudahy, Milwaukee, and West Milwaukee to a maximum of about 22,000 persons per gross square mile in highly urbanized portions of the watershed in the Cities of Greenfield, Milwaukee, and West Allis. The highly urban character of the watershed, however, is reflected in the fact that most of the watershed exhibits population densities in excess of 3,950 persons per gross square mile—the average population density of urban areas in the region in 1975.

Figure 4

POPULATION OF THE KINNICKINNIC RIVER WATERSHED, THE CITY OF MILWAUKEE, MILWAUKEE COUNTY, AND THE REGION: 1900-1975



Source: U. S. Bureau of the Census and SEWRPC.

From 1960 to 1975, the overall population density of the watershed decreased from about 7,100 to about 6,700 persons per square mile, a decrease of about 400 persons per square mile, or about 6 percent. The overall 1975 watershed population density, together with the population density of those portions of the various minor civil divisions within the watershed and the proportion of the watershed population residing in these minor civil divisions, is presented in Table 4.

The urban character of the watershed, with its dense concentration of people, is a major factor contributing to developmental, environmental, and resource-related problems of the watershed. These problems will be discussed in greater detail in subsequent chapters of this report.

Population Composition: The median age of the resident population of the watershed was 30.6 years in 1970, while the median age of the resident population of Milwaukee County was about 28.6 years and of the Region as a whole about 27.6 years. This reflects the general concentration of older people in the central cities of the Region. The average household size in the watershed in 1970 was 3.06 persons, while the average household size in Milwaukee County was 3.04 persons and in the Region as a whole was 3.18 persons. This reflects the general tendency of concentration of smaller households in the central cities of the Region. In 1970, the average annual income for families and unrelated individuals within the watershed was estimated at $9,680, slightly below that of $9,960 for Milwaukee County, and $10,330 for the Region as a whole. The highest average family and unrelated individual income within the watershed—over $13,000—was concentrated in the City of Greenfield, while the lowest average incomes—less than $8,000—were concentrated in the lower reaches of the watershed in the central part of the City of Milwaukee.

Economic Base: The Kinnickinnic River watershed is a very small and integral part of the Milwaukee urbanized area. As such its economic base cannot be differentiated in any meaningful way from that of the greater Milwaukee area. The resident population of the watershed can readily commute to jobs located outside of the watershed, while other residents in the greater Milwaukee area can readily commute to jobs located in the watershed. Some appreciation of the general character of the watershed can, nevertheless, be gained by an examination of the size and character of economic activities in the basin.

Figure 5 shows the relative concentration of jobs by eight major industrial divisions in 1972 for the Kinnickinnic River watershed. Full employment within the watershed in the eight major categories, estimated at a total of 77,000 jobs, was highly concentrated in manufacturing with over 45 percent of the total jobs being in that group. Wholesale and retail trade, private services, and government services and education encompass the next three largest employment categories within the watershed, with 19, 18, and 9 percent of the total jobs, respectively. Agricultural economic activity was of little consequence because, as of 1972, only about 80 persons were estimated to be employed in agriculture and related jobs within the Kinnickinnic River watershed.

The relative concentration of jobs within manufacturing—the dominant industrial division—for 1972 is presented in Figure 6 for Milwaukee County and the Kinnickinnic River watershed. As indicated in Figure 6, the principal type of manufacturing is electrical machinery, which accounts for about 33 percent of all manufacturing employment within the watershed, while the manufacturing and processing of primary metal, clay, and glass products ranks second, with over 27 percent of the total manufacturing employment.

Table 3

POPULATION IN THE KINNICKINNIC RIVER WATERSHED BY CIVIL DIVISION: 1950, 1960, 1970, AND 1975

Civil Division[a]	1950 Population Within Watershed	1950 Percent of Watershed Population	1960 Population Within Watershed	1960 Percent of Watershed Population	1970 Population Within Watershed	1970 Percent of Watershed Population	1975 Population Within Watershed	1975 Percent of Watershed Population
Cities								
Cudahy	1,047	0.7	3,270	1.8	5,650	3.3	5,534	3.3
Greenfield[b]	--	--	8,313	4.7	11,011	6.3	12,800	7.8
Milwaukee	118,108	77.0	145,741	82.1	138,278	79.5	128,568	77.9
St. Francis[c]	--	--	646	0.4	708	0.4	670	0.4
West Allis	19,387	12.6	18,886	10.6	17,619	10.1	16,959	10.3
Village								
West Milwaukee	1,357	0.9	742	0.4	648	0.4	557	0.3
Towns								
Greenfield[d]	4,872	3.2	--	--	--	--	--	--
Lake[d]	8,515	5.6	--	--	--	--	--	--
Total	153,286	100.0	177,598[e]	100.0	173,914[e]	100.0	165,088	100.0

[a] *Civil division boundaries within the Kinnickinnic River Watershed have changed over time because of annexations.*

[b] *Greenfield City was incorporated from parts of Greenfield Town in 1957.*

[c] *St. Francis was incorporated from parts of Lake Town in 1951.*

[d] *All parts of the Towns of Greenfield and Lake were annexed or incorporated subsequent to 1950.*

[e] *The figures in this table differ somewhat from those set forth in Table 3 of the Kinnickinnic River Watershed Planning Program Prospectus. The differences reflect a refined delineation of the watershed boundaries made under the watershed study and population estimates by quarter section.*

Source: U. S. Bureau of the Census, Wisconsin Department of Administration, and SEWRPC.

Table 4

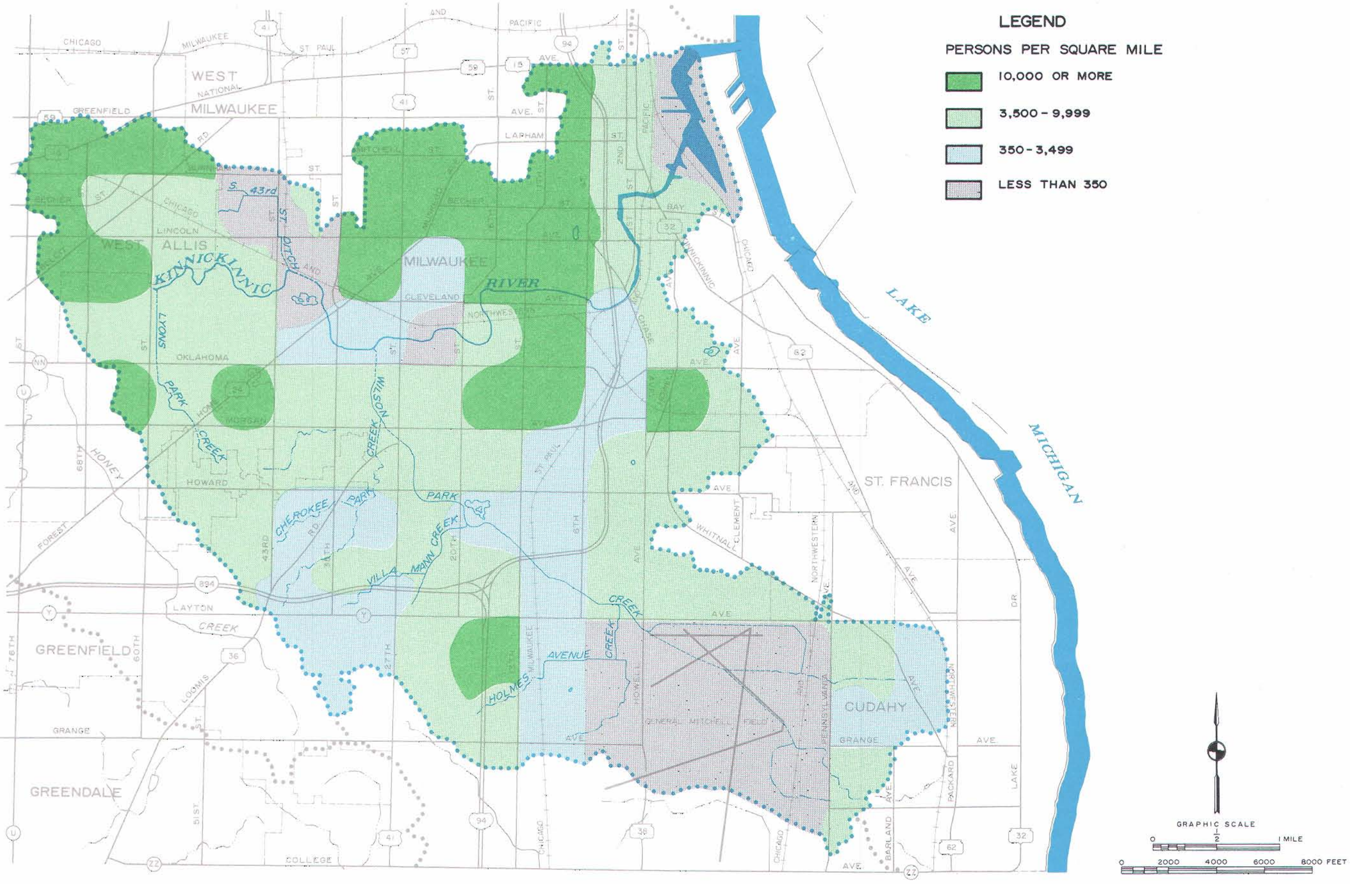
TOTAL POPULATION AND POPULATION DENSITY IN THE KINNICKINNIC RIVER WATERSHED BY CITIES AND VILLAGE: 1975

Civil Division	Population Within Watershed	Percent of Watershed Population	Area Included in Watershed (square miles)	Percent of Area in Watershed	Average Gross Population Density (per square mile)
Cities					
Cudahy	5,534	3.35	1.47	5.93	3,764
Greenfield	12,800	7.75	2.32	9.36	5,517
Milwaukee	128,568	77.88	18.70	75.47	6,875
St. Francis	670	0.41	0.12	0.48	5,583
West Allis	16,959	10.27	1.66	6.70	10,216
Village					
West Milwaukee	557	0.34	0.51	2.06	1,092
Total	165,088	100.00	24.78	100.00	6,662

Source: U. S. Bureau of the Census and SEWRPC.

Map 4

GROSS POPULATION DENSITY IN THE KINNICKINNIC RIVER WATERSHED: 1975



The 1975 resident population of the Kinnickinnic River watershed is estimated at about 165,000 persons. Gross population densities within the watershed range from a low of about 350 persons per square mile in portions of the Cities of Cudahy and Milwaukee and the Village of West Milwaukee to a high of about 22,000 persons per square mile in the Cities of West Allis, Greenfield, and Milwaukee. From 1960 to 1975, the overall population density of the watershed decreased from about 7,100 to 6,600 persons per square mile, a decrease of about 500 persons per square mile or 7 percent.

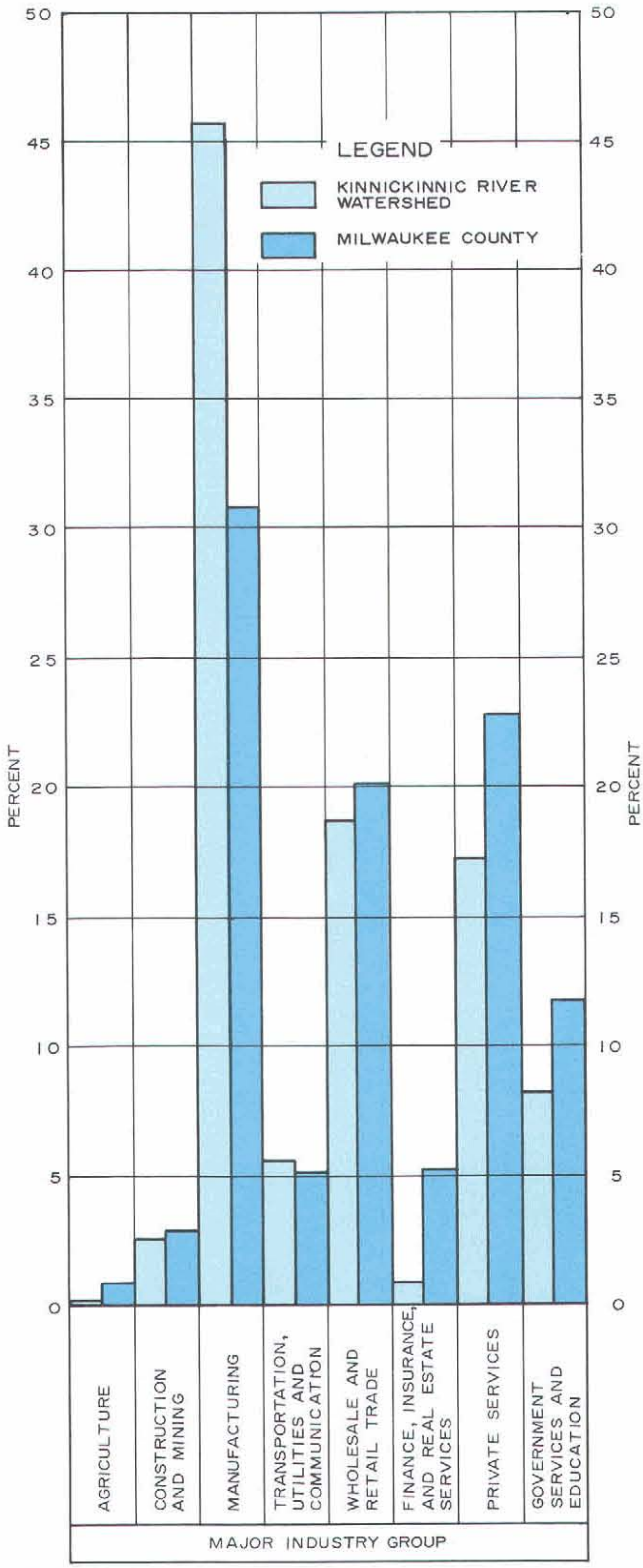
Source: SEWRPC.

Land Use

An important concept underlying the watershed planning effort is that an adjustment must be effected between land use development and the ability of the underlying natural resource base to sustain such development. The type, intensity, and spatial distribution of land uses determine, to a large extent, the resource demands within a watershed. Water resource demands can be correlated directly with the quantity and type of land use, as can water quality deterioration. The existing land use pattern can best be understood within the context of its historical development. Thus, attention is focused herein upon historic as well as existing land use development and upon both regional and watershed factors influencing land use.

Figure 5

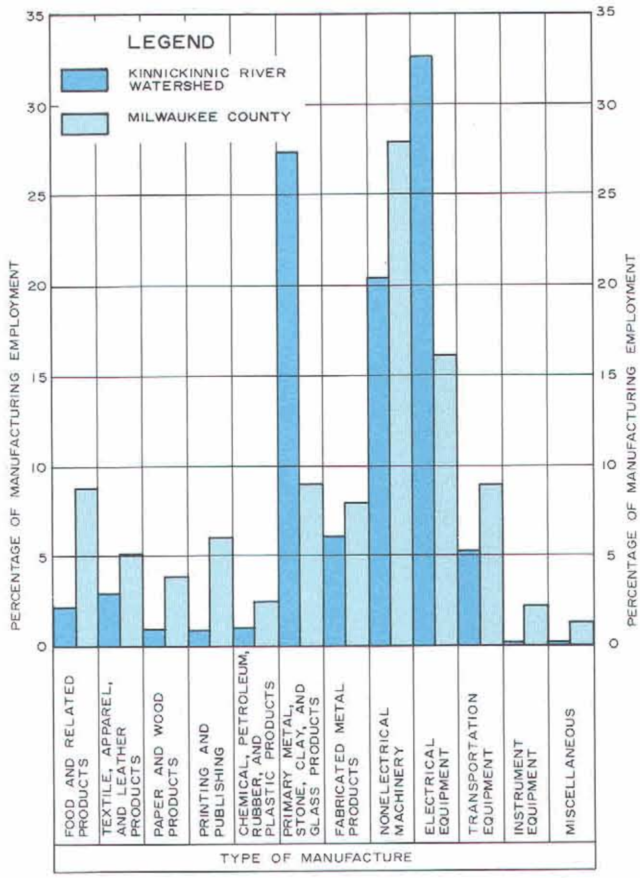
DISTRIBUTION OF TOTAL EMPLOYMENT BY MAJOR INDUSTRY GROUP FOR THE KINNICKINNIC RIVER WATERSHED: 1972



Source: U. S. Department of Industry, Labor and Human Relations and SEWRPC.

Figure 6

DISTRIBUTION OF MANUFACTURING EMPLOYMENT BY TYPE OF MANUFACTURING FOR MILWAUKEE COUNTY AND THE KINNICKINNIC RIVER WATERSHED: 1972



Source: Wisconsin Department of Industry, Labor and Human Relations and SEWRPC.

Historical Development:[1] The sheltered harbor formed by the confluence of the three rivers, as shown on Map 5, attracted early European settlers to what is now the Milwaukee area in the 1830's. Development of a port commenced in 1857 when the natural outlet of the

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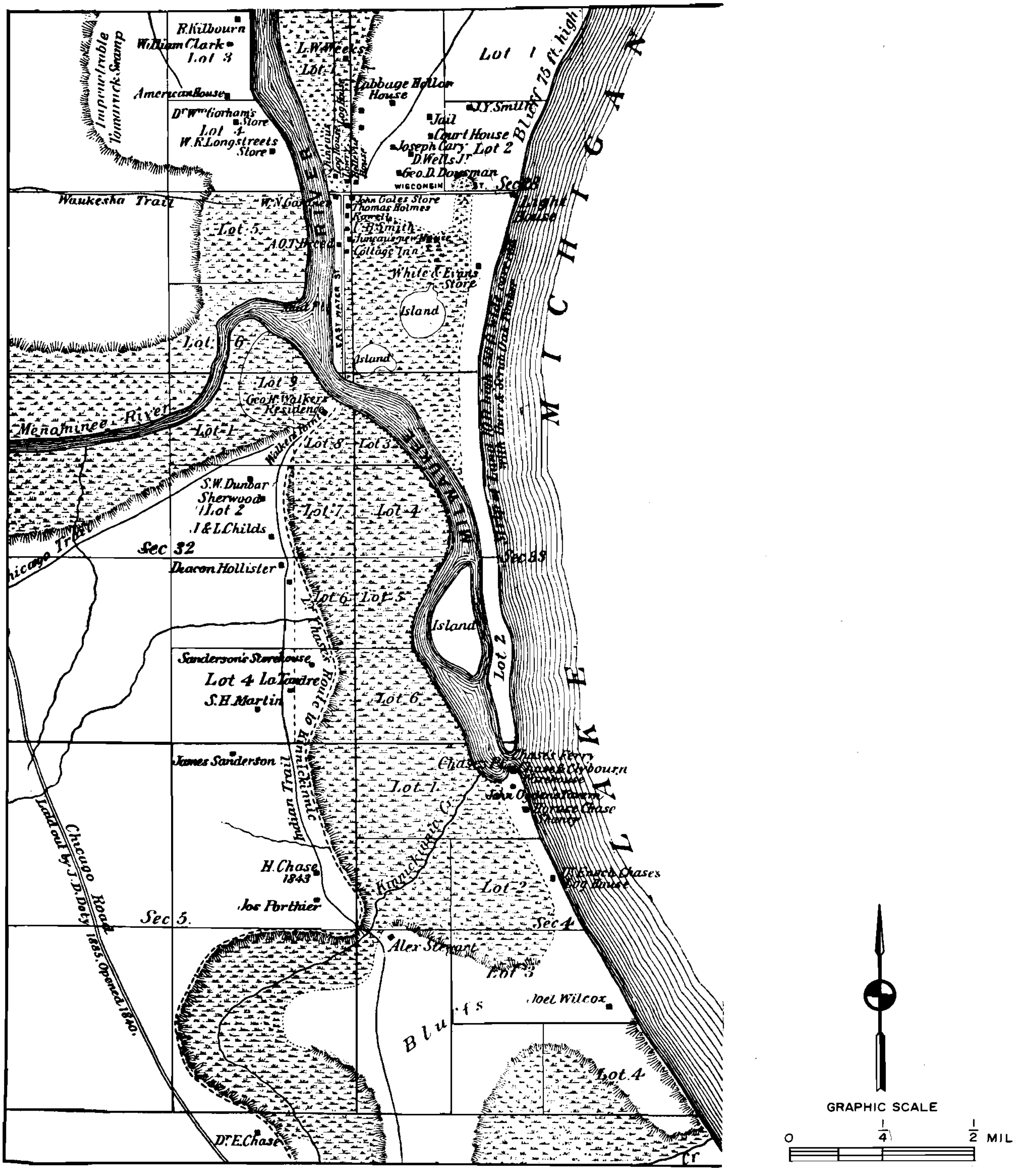
[1] *In addition to Commission inventories of historic places and events, the following references were used in preparing the brief account of the historical development of the Kinnickinnic River watershed:*

- *My South Side—A reprint of a series of articles by Edward S. Kerstein that appeared in the Milwaukee Journal, 1975-1976, The Milwaukee Journal, 1976, 30 pp.*
- *R. E. Gard and L. G. Sorden, "The Romance of Wisconsin Place Names," Milwaukee Public Library, Local History Department, 1968, 65 pp.*

Map 5

THE CONFLUENCE OF THE KINNICKINNIC, MENOMONEE, AND MILWAUKEE RIVERS: 1836

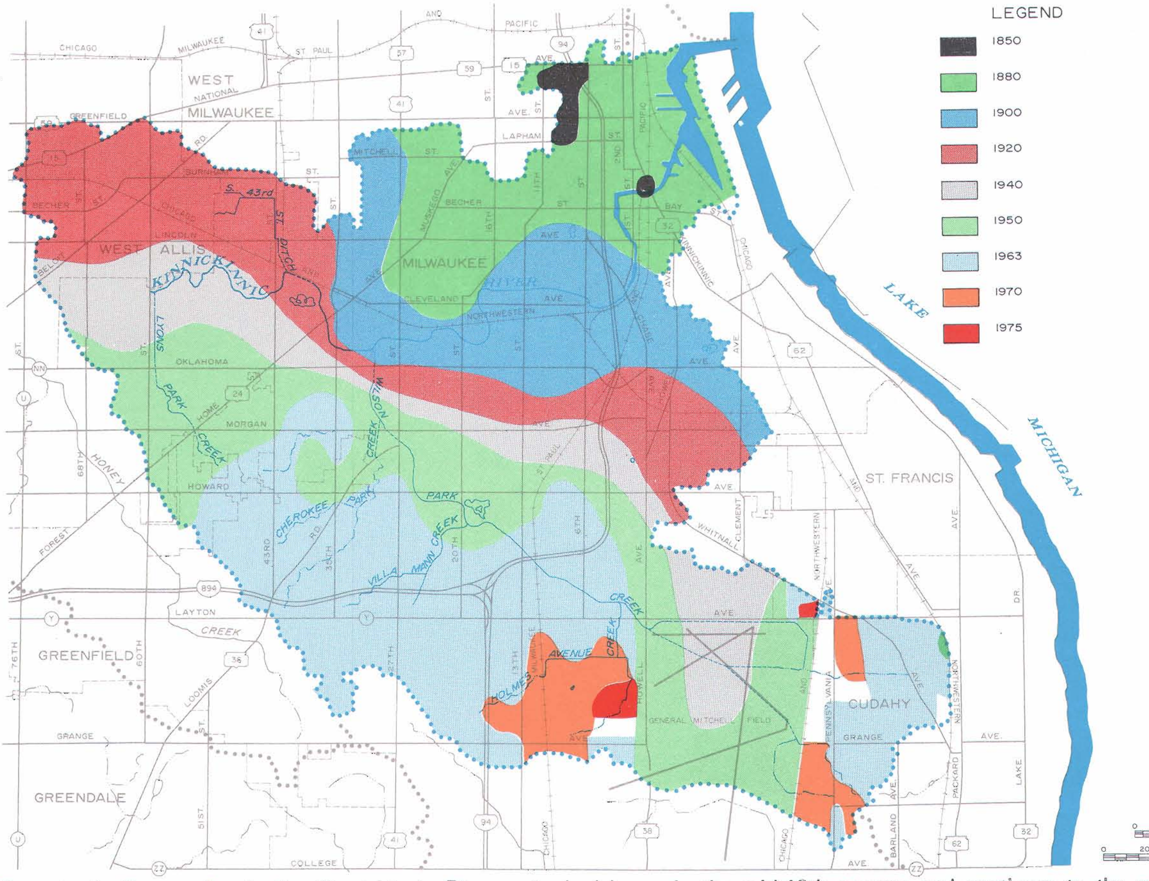


A sheltered harbor formed by the confluence of three rivers attracted the first of Milwaukee's European settlers in the 1830's and was an important factor in the development of the City of Milwaukee. Development of a port began in 1857 when the natural outlet of the Milwaukee and Kinnickinnic Rivers to Lake Michigan was filled and a new passage to Lake Michigan was cut about one-half mile north of the original river mouth. The extensive wetland area, including the "impenetrable Tamarack Swamp" that once existed near the confluence of the Kinnickinnic, Menomonee, and Milwaukee Rivers has since been filled and developed for industrial, commercial, navigational, and residential uses.

Source: Milwaukee County Historical Society and The Milwaukee River, Milwaukee River Technical Study Committee, 1968.

Map 6

HISTORICAL URBAN GROWTH IN THE KINNICKINNIC RIVER WATERSHED: 1850 TO 1970



The urbanization process in the Kinnickinnic River watershed began in the mid-19th century and continues to the present. Urbanization has generally occurred in a pattern emanating outward from the historic urban centers located near the confluence of the Kinnickinnic, Menomonee, and Milwaukee Rivers. The rate of urbanization has diminished in the past decade as the watershed approaches almost complete development. Approximately 94.3 percent of the total area of the watershed was in urban use in 1963. This increased to about 98.1 percent in 1970 and to 98.4 percent by 1975. The Kinnickinnic River watershed is the most highly urbanized watershed of all the basins for which the Commission has completed comprehensive watershed planning programs.

Source: SEWRPC.

Kinnickinnic River[2] was filled and a new passage cut through from the Milwaukee River to the lake about one-half mile north of the original mouth, thus forming what has become known as "Jones Island."

The movement of European settlers into the Region began in about 1830, and completion of the U. S. Public Land Survey in the Region by 1836 and subsequent sale of public lands brought many settlers into the area. The resulting expansion of urban development from about 1850 to the present within the Region is shown on Map 6.

By the mid-19th century, various immigrant groups were establishing their homes and business places in the watershed. In 1858 there were 40 businesses and residences located along National Avenue, between Barclay Street and 11th Avenue (now S. 16th Street). Farmlands stretched west of old 11th Avenue at that time, and these became urban neighborhoods in the ensuing decades for Scandinavians and Germans. One pioneer establishment still remaining on National Avenue is the Badger Mutual Insurance Co. founded in about 1885 as Der Deutsche Gegenseitige Feuer Unterstuetzungs Vereins (The German Mutual Fire Insurance Society). Polish immigrants moved into the southside after the Franco-Prussian War in the early 1870's settling south of Greenfield Avenue, building hundreds of small cottages and eventually developing an urban center large enough to constitute a city by itself. Mitchell Street developed into a budding southside market by 1883, where tons of vegetables were delivered from the farms of the surrounding countryside by horse-drawn wagons. Early mercantile firms that were owned as family businesses for decades included jewelry, furniture, and department stores.

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[2] *The meaning of the Chippewa word "Kinnickinnic" is "tobacco and red willow mixed for smoking." Red willow, which grew near the present Kinnickinnic Avenue was, in Chippewa, "squau-be-mish-king." When tobacco and red willow were mixed for smoking, the mixture became known as "Kinnickinnic" a name now applied to both the river and roadways—Kinnickinnic Avenue and Kinnickinnic River Parkway Drive—within the watershed.*

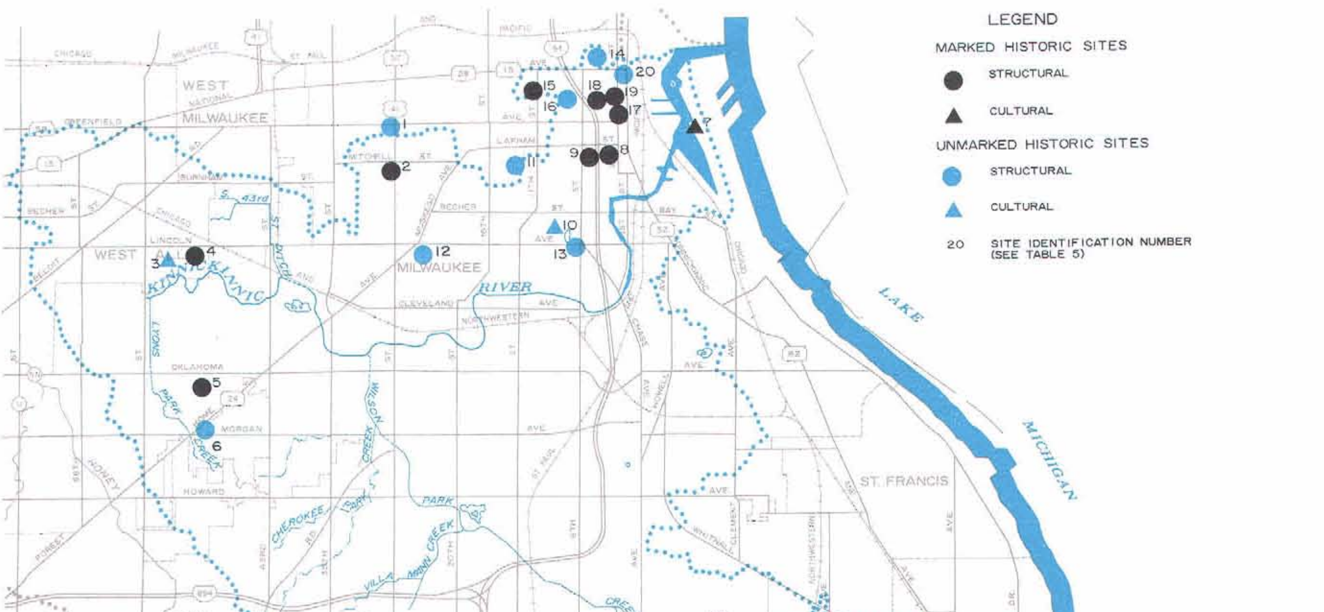
On the lakefront peninsula known as Jones Island, the quaint life of a fishing village was founded in the early 1870's. Immigrants from the shores of the North and Baltic Seas settled there and earned their livings as fisherman and small businessmen. By 1897 about 3,000 people resided in the fishing village. Condemnation proceedings, instituted by the City in 1914 to permit the Illinois Steel Company to recover land lost in the immigrant influx, finally forced them from their homes. City of Milwaukee Harbor and Sewerage Commission buildings and facilities have replaced those houses and no sign of the original settlement remains today other than a plaque commemorating the Kashzubes Community Site. During the early 20th century, the southern reaches of the watershed were sparsely settled and represented a rural-urban fringe area of the rapidly expanding Milwaukee urbanized area. The availability of large tracts of open land immediately south of the more densely populated central city encouraged the development by Milwaukee County of General Mitchell Field in 1956 as the area's only scheduled air transport airport.

As shown on Map 6, urbanization occurred in a generally outward pattern from the historic urban center near the harbor into the farmlands and woodlands of the watershed. By 1963, over 94 percent of the total area of the watershed, or approximately 24 square miles of land, was devoted to urban land uses. Between 1963 and 1975 approximately one square mile of additional land was converted from rural to urban use within the watershed, and over 98 percent of the total area of the watershed was in urban use.

A number of sites and buildings of historic interest—churches, homes, public buildings, factories and cemeteries—are located in and near the watershed. As shown on Map 7, these sites and buildings tend to be clustered

Map 7

HISTORIC SITES IN OR NEAR THE KINNICKINNIC RIVER WATERSHED: 1973



A relatively large number of sites and buildings of historic interest such as churches, homes, public buildings, factories, and cemeteries are located within the watershed. These sites and buildings tend to be concentrated along the lower reaches of the Kinnickinnic River near the harbor reflecting the tendency for both native Indian and early European settlers to locate near the waterways. This initial attraction to riverine areas and waterways, the early development of settlements there, and the subsequent concentration of urban development in those areas are important factors contributing to current flood problems in the watershed. Preservation of the best remaining historic sites and structures should be given careful consideration in the planning for, and development or redevelopment of, the watershed.

Source: SEWRPC.

near the mouth of the Kinnickinnic River in the area between the lower Kinnickinnic on the south and east and the Menomonee River industrial valley on the north. Table 5 contains a list of the 21 historic sites shown on Map 7 and presents selected information about each, including site locations, name, and significance. All but two of the 21 sites are located within the City of Milwaukee, and plaques or other types of identification have been placed or erected at 10 of the 21 historic sites.

The concentration of historic sites along the Kinnickinnic River near the harbor indicates that there was considerable motivation for both the native Indians and the early European settlers to locate near waterways. The rivers provided water supply and a means of wastewater disposal; they were a source of power to drive manufacturing processes; and they facilitated ready access to trade and commerce utilizing water transportation. That initial attraction to riverine areas, the early development of communities there, and the subsequent concentration of urban development in those areas are important factors contributing to current flood problems within the watershed. The comprehensive watershed planning process, in conjunction with local planning efforts, can assist in preserving and restoring many significant historic sites and the cultural and educational values inherent in such sites by recommending the development and maintenance of compatible contiguous park and related open space land uses.

Existing Land Use: The existing land use pattern in the Kinnickinnic River watershed is shown on Map 8 and existing land uses are quantified in Table 6. Figure 7 graphically depicts the types and relative amounts of existing land uses within the watershed in 1963 and 1975. The referenced map, table, and figure clearly illustrate the highly urbanized nature of this watershed.

As indicated in Table 6, almost 92 percent of the total area of the watershed is now in urban use although the rate of urbanization in recent years has been relatively modest. From 1963 to 1975, about 2.1 square miles, or 8 percent of the total area of the watershed, were converted from rural to urban land uses at a rate of about 0.2 square miles per year.

The extent of urban development within the Kinnickinnic River watershed is very high compared to any of the watersheds previously studied by the Commission. At the time plans were being prepared by the Commis-

Table 5

HISTORIC SITES IN OR NEAR THE KINNICKINNIC RIVER WATERSHED: 1973

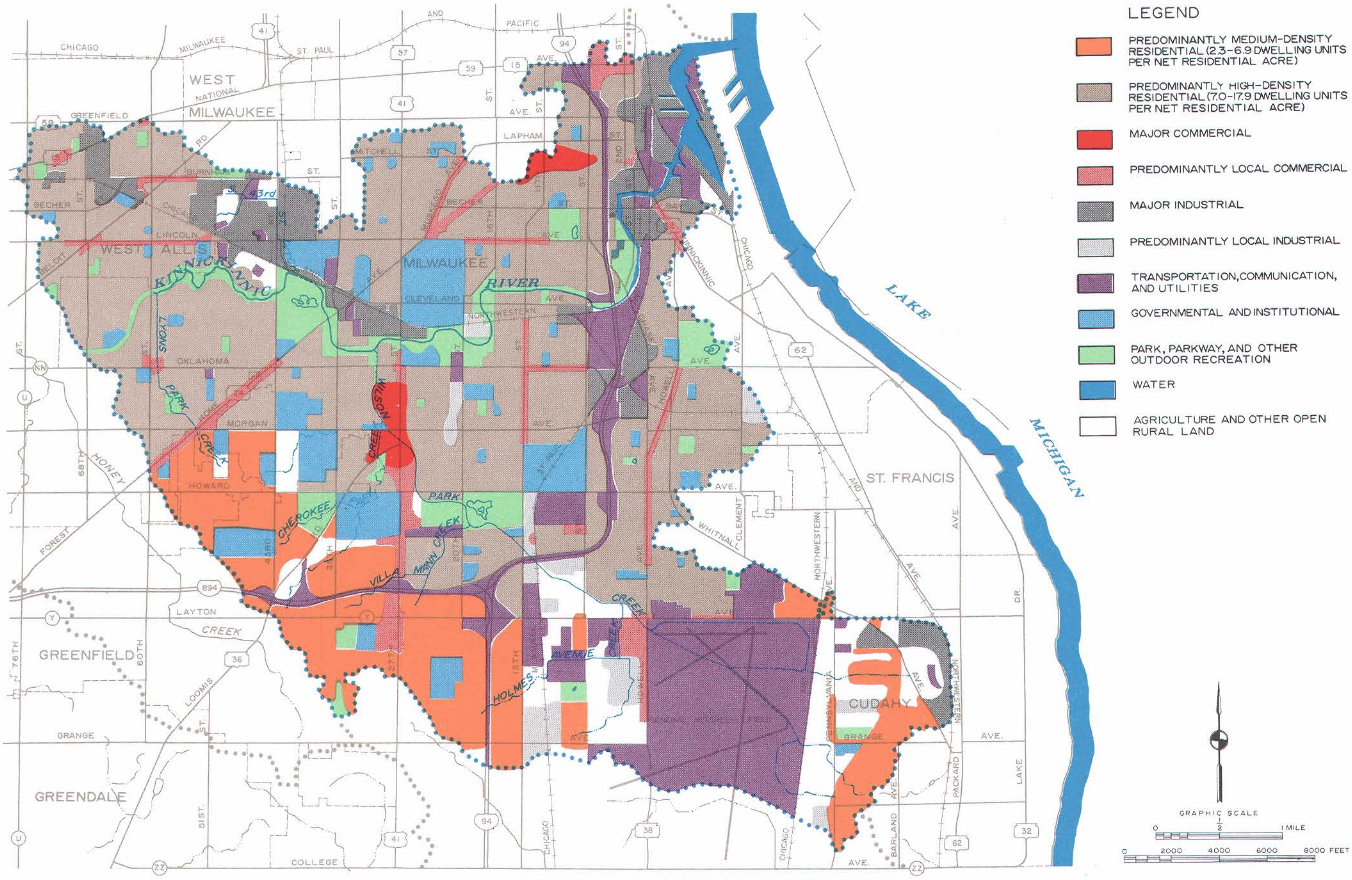
	Location								
	U. S. Public Land Survey				Civil Division				
Site Number[a]	Township (North)	Range (East)	Section	Quarter Section	County	City, Village, or Town	Site Name	Significant Date(s)	Significance
1	06	21	01	NE	Milwaukee	City of Milwaukee	St. Joseph's Convent Chapel	1914-1917	Historic Church
2	06	21	01	NE	Milwaukee	City of Milwaukee	American System Built Houses	1916-1917	Historic Home
3	06	21	11	NW	Milwaukee	City of West Allis	Meadowmere Marker	--	Monument
4	06	21	11	NW	Milwaukee	City of West Allis	St. Joseph's Home for the Aged	1870	Historic Home
5	06	21	14	NW	Milwaukee	City of Milwaukee	St. Sava Serbian Orthodox Cathedral	1956-1958	Architecture
6	06	21	14	NW	Milwaukee	City of Milwaukee	Evangelical United Brethern Church and Museum	1858	Historic Church and Cemetery
7	06	22	04	NW	Milwaukee	City of Milwaukee	Kashzubes Community Site	1872	Historic Community Site
8	06	22	05	NE	Milwaukee	City of Milwaukee	Public Natatorium	1893-1895	Historic Building
9	06	22	05	NE	Milwaukee	City of Milwaukee	St. Stanislaw Roman Catholic Church	1872-1873	Historic Church
10	06	22	05	SW	Milwaukee	City of Milwaukee	Kosciuszko Park	1905	Monument
11	06	22	06	NE	Milwaukee	City of Milwaukee	St. Jacobi Evangelical Lutheran Church Buildings	1873	Historic Church and School
12	06	22	07	NW	Milwaukee	City of Milwaukee	Forest Home Cemetery and Chapel	1890-1892	Historic Cemetery and Chapel
13	06	22	08	NW	Milwaukee	City of Milwaukee	St. Josephat Basilica	1896-1901	Historic Church
14	07	22	32	NE	Milwaukee	City of Milwaukee	Holy Trinity/Our Lady of Guadalupe Church Complex	1849-1850	Historic Church and School
15	07	22	32	SW	Milwaukee	City of Milwaukee	St. Michael's Ukranian Catholic Church	1874	Historic Church
16	07	22	32	SW	Milwaukee	City of Milwaukee	St. Patrick's Roman Catholic Church	1893-1895	Historic Church
17	07	22	32	SE	Milwaukee	City of Milwaukee	Allen-Bradley Company	1919	Historic Mill, Factory, and Clock
18	07	22	32	SE	Milwaukee	City of Milwaukee	St. Stephen Evangelical Lutheran Church	1901-1902	Historic Church
19	07	22	32	SE	Milwaukee	City of Milwaukee	South Office Wisconsin Telephone Company	1899	Historic Building
20	07	22	32	SE	Milwaukee	City of Milwaukee	Clinton Street Filling Station	1930	Historic Gas Station
21	06	22	28	All	Milwaukee	City of Milwaukee	General Mitchell Field	1926	Scheduled Air Transport Airport

[a]*See Map 7.*

Source: SEWRPC.

Map 8

GENERALIZED EXISTING LAND USE IN THE KINNICKINNIC RIVER WATERSHED: 1975



As of 1975, almost 92 percent of the area of the Kinnickinnic River watershed was devoted to urban land uses. The dominant urban land uses in the basin are the residential category and the transportation-communication-utility facilities category which encompass, respectively, 35 and 36 percent of the watershed area. The overall spatial distribution of land use in the watershed is characterized by high-density residential development in the northern three-fourths of the basin and medium-density residential development in the southern one-quarter. Retail sales and service land uses are scattered throughout the watershed and concentrations of industrial and transportation-communication-utilities occur at various locations in the watershed including the estuary area, most of the Village of West Milwaukee, and the southeastern corner of the watershed in and near General Mitchell Field.

Source: SEWRPC.

sion for the Menomonee, Milwaukee, Fox, and Root River watershed, the extent of urban land use in those watersheds totaled 54, 15, 11, and 23 percent, respectively. The extensive amount of urban development in the Kinnickinnic River watershed is significant in that it influences the types of analytic approaches that must be used in the watershed study, greatly reduces the variety and range of alternative land use plan subelements likely to be practically available for consideration, and it will be an important factor in the extent and duration of the water pollution problems in the watershed. The two dominant urban land uses in 1975 in the watershed are residential, which encompasses over 8.9 square miles, or 35 percent of the watershed area, and transportation-communication-utilities, which encompass over 9.1 square miles, or 36 percent of the watershed area. Included within the latter category are General Mitchell Field, which occupies about 1.7 square miles of the watershed area, and local, collector, and arterial streets and highway right-of-way which in aggregate occupy about 4.5 square miles of the watershed area. As illustrated on Map 8, the lower portion of the watershed is an integral part of one of the major concentrations of heavy industrial land use in the Milwaukee urbanized area.

Public Utility Base

Sanitary Sewer Service: The Kinnickinnic River watershed is unique among the 11 major watersheds of southeastern Wisconsin in that it lies entirely within the existing service area of the Metropolitan Sewerage District of the County of Milwaukee. All of the watershed is served by public sanitary sewerage facilities. Sanitary sewage is collected and transmitted, for treatment and disposal, to the Jones Island and South Shore treatment plants located outside of the watershed on the shore of Lake Michigan.

Table 6

LAND USE IN THE KINNICKINNIC RIVER WATERSHED: 1963 AND 1975

Land Use Category	1963			1975		
	Area in Square Miles	Percent of Watershed	Percent of Major Category	Area in Square Miles	Percent of Watershed	Percent of Major Category
Urban						
Residential	8.39	32.71	39.13	8.92	34.78	37.94
Retail and Service	0.68	2.65	3.17	0.83	3.24	3.53
Industrial	1.35	5.26	6.30	1.50	5.85	6.38
Transportation, Communication, and Utility Facilities.	8.20	31.97	38.24	9.12	35.55	38.79
Government and Institutional.	1.74	6.79	8.12	1.88	7.33	8.00
Park and Recreation.	1.08	4.21	5.04	1.26	4.91	5.36
Total Urban Land Use	21.44	83.59	100.00	23.51	91.66	100.00
Rural						
Agriculture and Related	0.70	2.73	16.63	0.23	0.90	10.75
Other Open Lands, Swamps, and Water Areas.	3.51	13.68	83.37	1.91	7.44	89.25
Total Rural Land Use	4.21	16.41	100.00	2.14	8.34	100.00
Total Land Use	25.65[a]	100.00	--	25.65[a]	100.00	--

[a] *This figure represents the total area of the watershed as determined through approximating the watershed boundary by U. S. Public Land Survey quarter sections and summing the quarter-section total. The actual measured watershed total is 24.78 square miles.*

Source: SEWRPC.

A 4.54 square mile portion of the watershed[3]—18 percent of the total area of the basin—is served by a combined sewer system as shown on Map 9. The Kinnickinnic River watershed combined sewer system is part of a large contiguous combined sewer service area within Milwaukee County encompassing a total of about 27 square miles and including portions of the City of Milwaukee and the Village of Shorewood. During most rainfall and snowmelt events, this large combined sewer service area discharges combined sewage to the Kinnickinnic, Menomonee, and Milwaukee Rivers and to Lake Michigan.

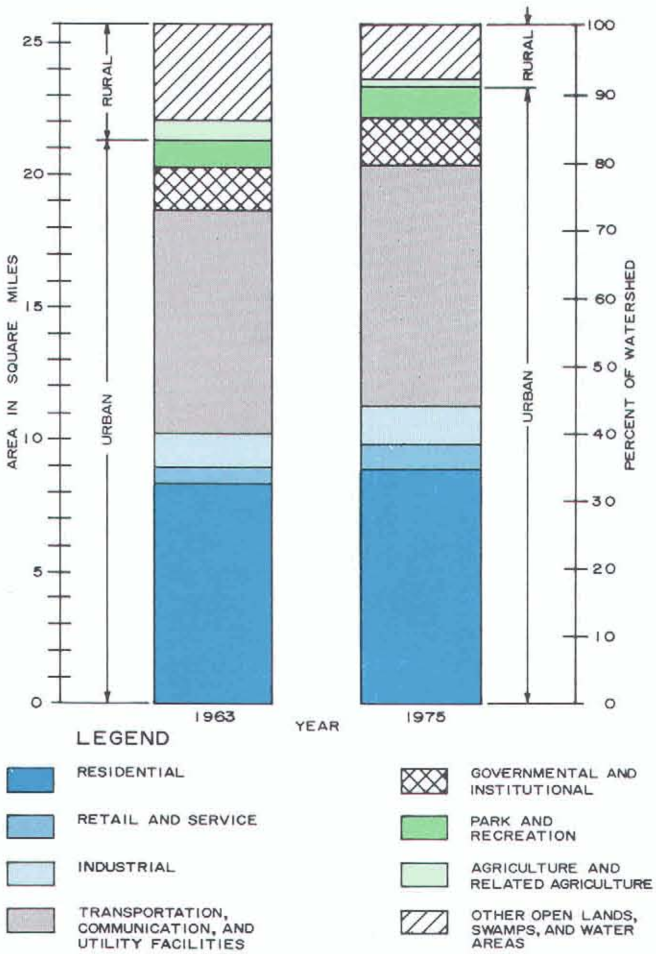
Water Supply Service: All of the Kinnickinnic River watershed is served by public water supply facilities. The service areas of the three public water supply systems in the watershed—the Milwaukee Water Works, the West Allis Water Utility, and the Cudahy Water Department—and of the one privately-operated system—the Town View Water Co-op in the City of Greenfield—are shown on Map 10. The Milwaukee Water Works and the Cudahy Water Department operate complete and independent water supply systems, whereas the West Allis Water Utility purchases water wholesale from the Milwaukee Water Works. The Milwaukee Water Works provides direct service on a retail basis to water users in the Cities of Milwaukee, Greenfield, and St. Francis and the Village of West Milwaukee. It is of interest to note that all three public water utilities located in the watershed utilize Lake Michigan as a source, while the sole private water utility draws upon the groundwater reservoir.

Electric Power Service and Gas Service: Electric power is available to all portions of the watershed, such power being supplied by the Wisconsin Electric Power Company which is authorized to operate throughout the Kinnickinnic River watershed. Natural gas service is also available to all portions of the watershed. The Wisconsin Gas Company is authorized to provide service to the entire watershed with the exception of those portions of the Cities of Cudahy and St. Francis lying within the watershed which are served by the Wisconsin Natural Gas Company.

[3] *The gross combined sewer service area within the Kinnickinnic River watershed, of 4.54 square miles (2,905 acres), includes the actual area served by a combined sewer system plus small surrounded and contiguous areas not sewered or served by separate sanitary sewers. This approach differs from the net combined sewer service area, which includes only actual site area served by combined sewers, used in SEWRPC Planning Report No. 30, Areawide Water Quality Management Program for Southeastern Wisconsin, 1978; and SEWRPC Technical Report No. 17, Water Quality of Lakes and Streams in Southeastern Wisconsin: 1964-1975, 1978. The net combined sewer service area within the Kinnickinnic River watershed is 3.93 square miles.*

Figure 7

DISTRIBUTION OF URBAN AND RURAL LAND USE IN THE KINNICKINNIC RIVER WATERSHED: 1963 AND 1975



Source: SEWRPC.

Transportation

Highways: As shown on Map 11, the Kinnickinnic River watershed is served by an extensive street and highway system, including 8.3 lineal miles of freeway. The extensive street and highway system serves to provide ease of access to the residential, commercial, and industrial land uses in the watershed, thus supporting those land uses, and the system facilitates rapid movement through the watershed. The street and highway system serving the watershed also is important to the watershed planning program because of associated potential adverse effects on surface water quality. For example, as discussed in Chapter VII of this report, rainfall or snowmelt induced washoff of substances from the urban land surface, including streets and highways, may have a detectable possibly harmful effect on the rivers and streams of the watershed.

Bus Service: The transportation needs of the resident population of the watershed, largely determined by the distribution of residential development in relation to centers of employment, shopping, and other activities in the greater Milwaukee area, together with the configuration of the watershed street and highway system, have resulted in the development of two types of bus service: urban mass transit and intercity bus service. Urban mass transit service within the watershed is provided by the Milwaukee County Transit System, which provides service to the entire watershed. An important feature of urban mass transit service in the watershed is the express commuter service, known as Freeway Flyer service, provided between the Milwaukee central business district and the one terminal located in the suburban portion of the watershed: the S. 27th Street-Target terminal area located in the City of Greenfield at S. 27th Street and W. Layton Avenue. This high speed, nonstop bus service is provided via the existing freeway system, reducing the need for commuting residents of the watershed to drive private automobiles into the central areas of Milwaukee County.

Intercity bus service is provided through the watershed by Wisconsin Coach Lines, Inc., which operates a route connecting the central business district of Milwaukee with Racine and Kenosha, with stops at several locations in the watershed including National Avenue, Chase Avenue, Oklahoma Avenue, and General Mitchell Field.

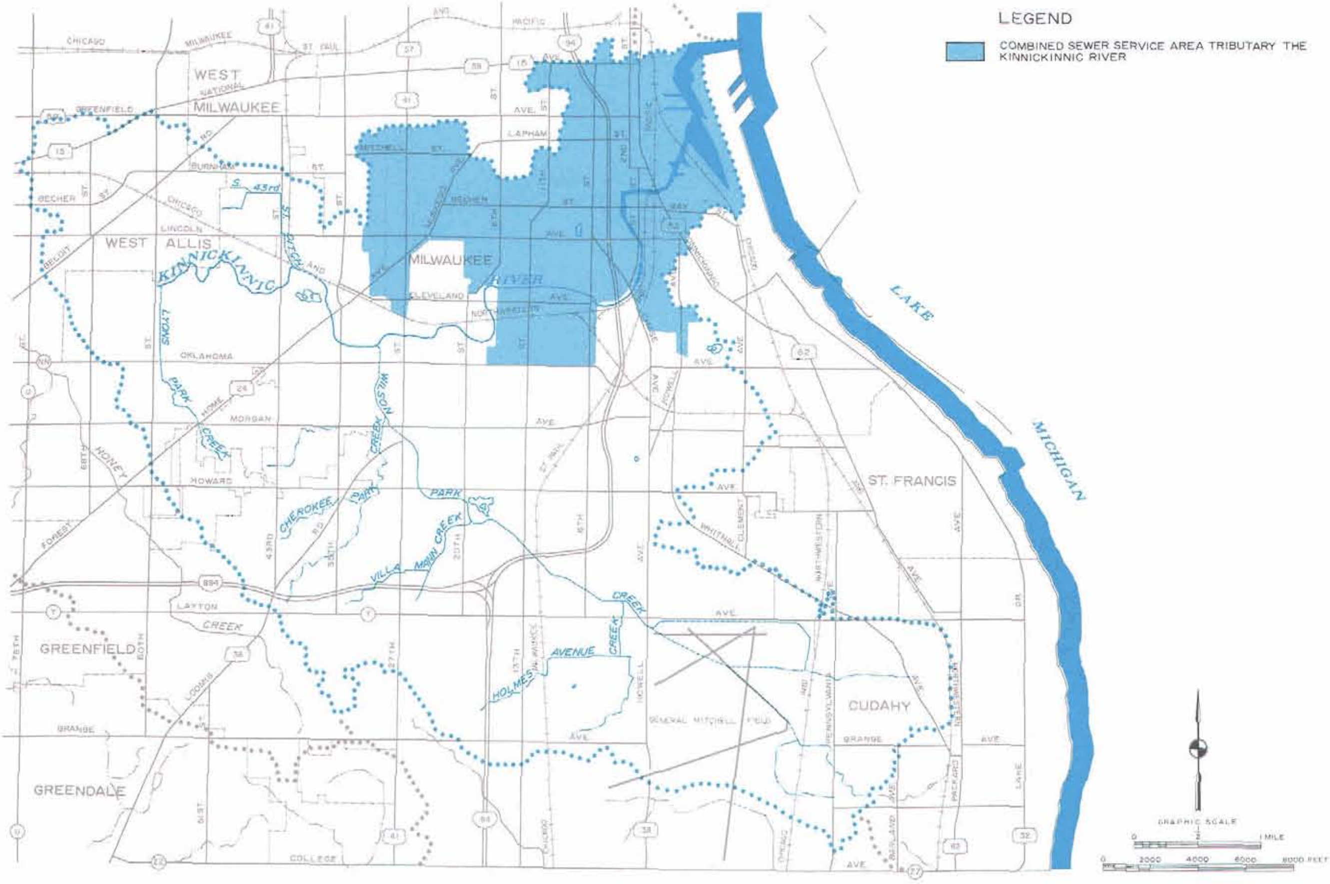
Railroad Service: Railroad service in the watershed is limited to freight hauling, except for scheduled Amtrak passenger service over the lines of the Chicago, Milwaukee, St. Paul & Pacific Railroad Company (Milwaukee Road) between the Union Station in Milwaukee to the north and Sturtevant and Chicago to the south. The Milwaukee Union Station, which is located immediately north of the watershed near the confluence of the Menomonee and Kinnickinnic Rivers, provides the only major rail passenger terminal within the Region.

Extensive freight service is provided to the watershed by the Milwaukee Road and the Chicago & North Western Railroad. As shown on Map 11, railroad lines emanate from the lower Menomonee River industrial valley of the City of Milwaukee and traverse the Kinnickinnic River watershed in east-west and north-south directions.

Commercial Shipping: The main channel of the Kinnickinnic River is navigable by large commercial vessels from its junction with the Milwaukee River to Kinnickinnic Avenue in the City of Milwaukee—a total distance of about 1.28 miles. Port of Milwaukee authority extends farther upstream to the Becher Street bridge—a distance of about 1.67 miles from the confluence of the Kinnickinnic and Milwaukee Rivers—and periodic channel maintenance is conducted to keep this reach of the River open to smaller vessels. As shown on Map 2, the estuary portion of the River forms a relatively complex system of canals and slips and includes the Municipal Mooring Basin. The River and its estuary thus constitute important components of the Great Lakes-St. Lawrence Seaway

Map 9

COMBINED SEWER SERVICE AREA IN THE KINNICKINNIC RIVER WATERSHED: 1977



A 4.54-square-mile portion of the watershed—18 percent of the total area of the basin—is served by a combined sewer system. This system is part of a large contiguous 27-square-mile combined sewer service area within Milwaukee County. During most rainfall and snowmelt events, this large combined sewer service area discharges combined sewage to the Kinnickinnic, Menomonee, and Milwaukee Rivers and to Lake Michigan.

Source: Milwaukee-Metropolitan Sewerage Commissions; City of Milwaukee, Bureau of Engineers; and SEWRPC.

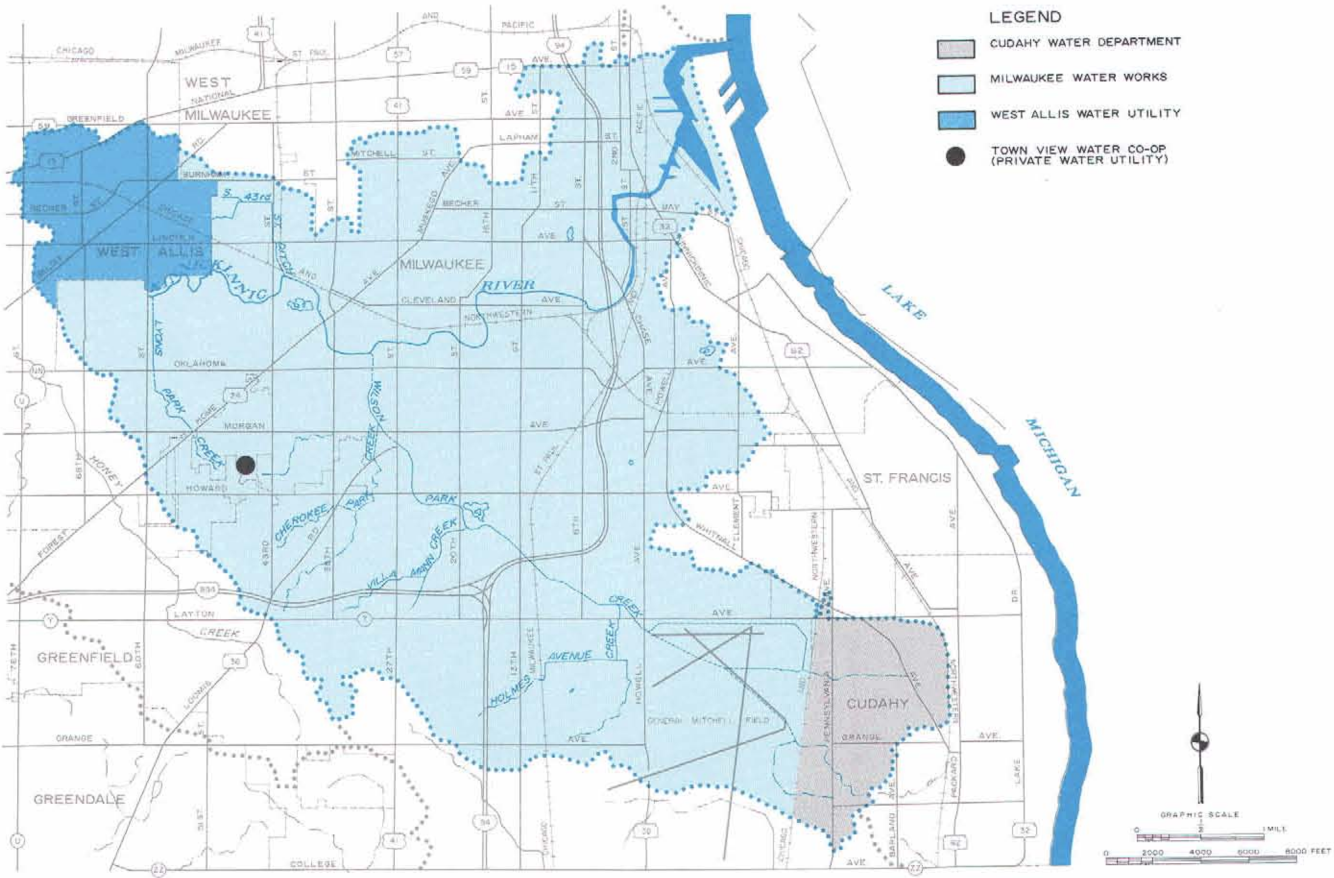
transportation system and of the international Port of Milwaukee. Bulk materials such as coal, salt, liquid cargoes, and scrap metals have traditionally been the primary cargoes handled in the Kinnickinnic River watershed portion of the Port. The large amount of commercial shipping activity within the estuary portion of the watershed, coupled with that in the remainder of the Port of Milwaukee, may be expected to have important economic impacts in the watershed and the Region of which the watershed is an integral part, as well as water quality impacts in the estuary. As indicated in Chapter I, however, the estuary portion of the Kinnickinnic River watershed was excluded from the Kinnickinnic River watershed study analyses because it is the considered opinion of the Commission that the estuary should be studied after, and separately from, the tributary watersheds.

Airport: As shown on Map 11, General Mitchell Field, lying almost entirely within the Kinnickinnic River watershed, is the only airport in the basin. More importantly, General Mitchell Field is the only scheduled air transport airport in the seven-county planning Region, and as such is and may be expected to continue to be an important determining factor in the physical development of both the watershed and the Region of which the watershed is an integral part.

The development of Mitchell Field began in 1926 when the County of Milwaukee transferred airport operations to the present site of Mitchell Field which was then a newly purchased 163 acre tract located in a rural area about six miles south of downtown Milwaukee. The airport was known as the Milwaukee County Airport until 1941—by which time it had grown to 378 acres in size—when the airport was officially renamed General Mitchell Field. By 1976, the airport had expanded to 2,100 acres and is currently served by eight major airlines—North Central, United, Eastern, Northwest Orient, Hughes Airwest, Southern, Braniff, and Ozark. A total of 2,556,720 passengers were handled on 76,914 air carrier flights in 1976, and total aircraft operations approximated 229,000.

Map 10

PUBLIC WATER SUPPLY SERVICE AREAS IN THE KINNICKINNIC RIVER WATERSHED: 1977



Public water supply systems serve essentially the entire area and the population of the Kinnickinnic River watershed. The Milwaukee Water Works provides, on a retail basis, water supply services to those portions of the watershed lying within the Cities of Milwaukee, Greenfield, and St. Francis, and the Village of West Milwaukee. The Milwaukee Water Works provides water on a wholesale basis to the West Allis Water Utility which in turn provides water supply to water users in that portion of the watershed. The City of Cudahy operates a complete water supply system serving the entire portion of the City of Cudahy lying within the watershed. The three public water utilities located within the watershed utilize Lake Michigan as a source and the one remaining private water utility draws upon the groundwater reservoir.

Source: SEWRPC.

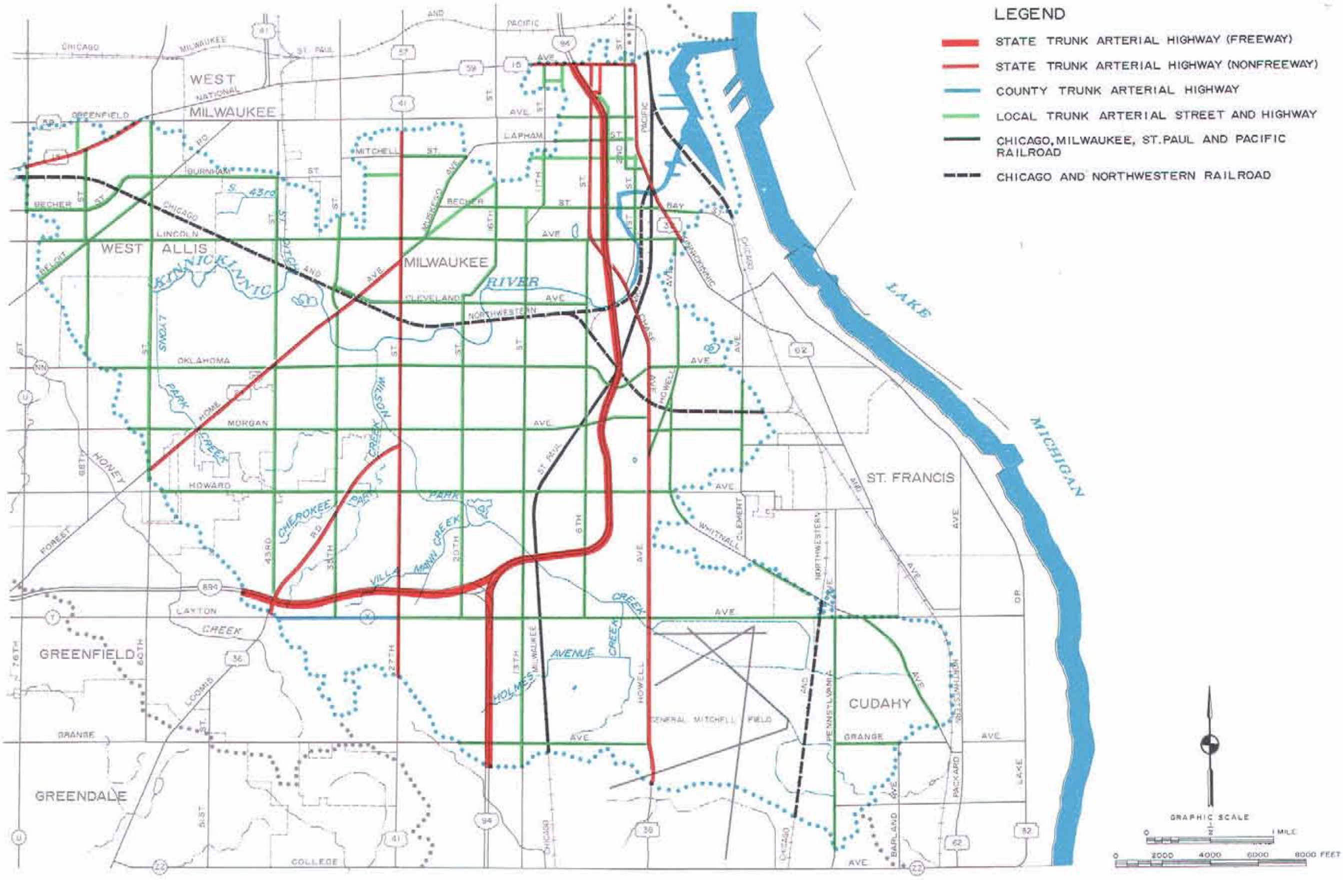
Future recommendations concerning the development of the airport and its environs are bound to concern residents of the watershed since the airport is almost entirely contained within the basin and is almost completely surrounded by residential, commercial, and industrial development. Existing airport operation-related problems, such as aircraft noise, number of operations, automobile and truck traffic, and airport expansion are sure to be aggravated since total passenger enplanement is projected to increase three-fold by 1990 and aircraft operations about 40 percent. SEWRPC Planning Report No. 21, A Regional Airport System Plan for Southeastern Wisconsin, December 1975, recommends that this airport continue to serve as the sole scheduled air transport facility in the Region through the turn of the century. Major improvements to the airport recommended in the cited plan include major passenger terminal renovation, new cargo terminal construction, extension of runways and acquisition of 92 acres of additional land for clear zone protection and the elimination of land use conflicts in the most severe noise impact areas.

DESCRIPTION OF THE WATERSHED: NATURAL RESOURCES BASE

The natural resource base is a primary determinant of the development potential of a watershed and of its ability to provide a pleasant and habitable environment for all forms of life. The principal elements of the natural resource base are climate, physiography, geology, soils, vegetation, water resources, and fish and wildlife resources. Without a proper understanding and recognition of elements comprising the natural resource base and of their interrelationships, human

Map 11

ARTERIAL STREET AND HIGHWAY AND TRUNKLINE RAILROAD FACILITIES
IN THE KINNICKINNIC RIVER WATERSHED: 1972



The Kinnickinnic River watershed is served by a well-developed surface transportation system, with a particularly good network of all-weather streets and highways. Passenger transportation is primarily by highway, with goods movement by both rail and highway. The freeway system permits rapid movement by automobile through the watershed, and the extensive street and highway system provides easy access to the residential, commercial, and industrial portions of the basin. The Chicago, Milwaukee, St. Paul & Pacific Railroad traverses the watershed in a north-south direction and the Chicago & North Western Railroad traverses the basin in an east-west direction.

Source: SEWRPC.

use and alteration of the natural environment proceed at the risk of excessive costs in terms of both monetary expenditures and destruction of nonrenewable or slowly renewable resources. In this age of high resource demand, urban expansion, and rapidly changing technology, it is especially important that the natural resource base be a primary consideration in any areawide planning effort, since these aspects of contemporary civilization make the underlying and sustaining resource base highly vulnerable to misuse and destruction.

This portion of this chapter identifies and describes the significant elements of the natural resource base of the watershed; indicates and quantifies the spatial distribution and extent of those resources; characterizes, where possible, the quality of each component element of the natural resource base; and seeks to identify those elements and characteristics of the natural resource base which must be considered in the watershed planning process. While all the aforementioned components of the natural resource base are described in this chapter in order to provide an overview of the watershed natural resource base, some are discussed in more detail, as needed, in later chapters. For example, this chapter includes an overview of the surface water resources of the watershed, while the findings of a hydrologic-hydraulic inventory are discussed in Chapter V, the results of a historic flooding inventory are set forth in Chapter VI, and the findings of water quality surveys are described in Chapter VII.

Climate[4]

General Climatic Conditions: The midcontinental location of the Southeastern Wisconsin Region, far removed from the moderating effect of the oceans, gives the Region and the watershed a typical continental type climate characterized primarily by a continuous progression of markedly different seasons and a large range in annual temperature. Low temperatures during winter are intensified by prevailing frigid northwesterly winds, while summer high temperatures are reinforced by the warm southwesterly winds common during that season.

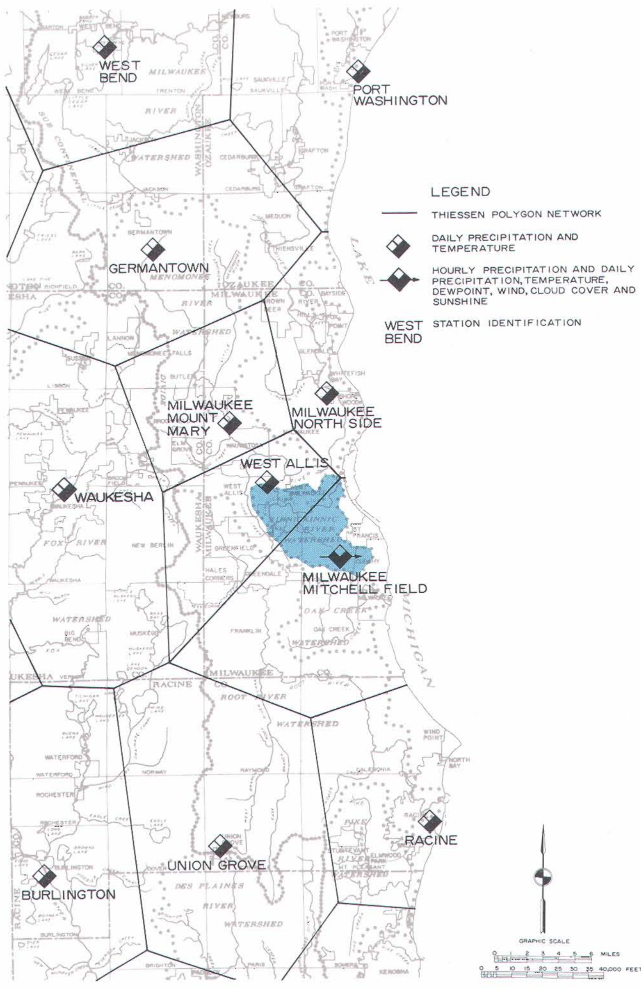
The Region and the watershed are positioned astride cyclonic storm tracks along which low pressure centers move from the west and southwest. The Region and the watershed also lie in the path of high pressure centers moving in a generally southeasterly direction. This location at the confluence of major migratory air masses results in the watershed as a whole being influenced by a continuously changing pattern of different air masses, and results in frequent weather changes being superimposed on the aforementioned large annual range in weather characteristics, particularly in winter and spring when distinct weather changes normally occur every three or five days. These temporal weather changes consist of marked variations in temperatures, type and amount of precipitation, relative humidity, wind speed and direction, and cloud cover.

In addition to these distinct temporal variations in weather, the watershed—in spite of its relatively small size—exhibits spatial variations in weather due primarily to its proximity to Lake Michigan, particularly during the spring, summer, and fall seasons when the temperature differential between the lake water and the land air masses tends to be the greatest. During these periods, the presence of the lake tends to moderate the climate of the eastern border of the seven-county Southeastern Wisconsin planning region in general, and of portions of Kinnickinnic River watershed in particular. It is common, for example, for midday summer temperatures in shoreline areas to drop abruptly to a temperature level 10°F lower than inland areas because of cooling lake breezes generated by air rising from the warmer land surfaces. This Lake Michigan temperature influence is, however, generally limited to that portion of the watershed lying within a few miles of the shoreline.

The location of 11 meteorological stations in and near the Kinnickinnic River watershed as well as the types of precipitation recording equipment and the availability of temperature and other meteorological data are shown on Map 12 and Table 7. Additional information about selected stations is presented in Chapter VIII. The National Weather Service station at Mitchell Field is located in the southeastern corner of the watershed; the West Allis station is located just outside of and within 0.25 mile of the northwesterly limits of the basin, and the other nine meteorologic stations are located outside of the watershed in or on the fringes of the Milwaukee metropolitan area. Selected data from the meteorologic stations in and near the watershed were used in the development of the following discussion of basin temperature, precipitation, snow cover, frost depth, evaporation, wind and sky cover characteristics.

Map 12

METEOROLOGICAL STATIONS OF THE NATIONAL WEATHER SERVICE IN OR NEAR THE KINNICKINNIC RIVER WATERSHED: 1977



The Thiessen polygon network constructed for the 11 National Weather Service observation stations shown above was used to associate land areas with specific meteorological data. This was a necessary requirement for characterizing the meteorologic conditions in the Kinnickinnic River watershed and for operating the water resources simulation model used to calculate streamflow and streamwater quality.

Source: National Weather Service and SEWRPC.

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[4] *Unless otherwise indicated, climatic and weather descriptions and data presented here are based on information extracted from various periodic publications of the National Weather Service, U. S. Department of Commerce, formerly known as the Weather Bureau, U. S. Department of Commerce.*

Table 7

NATIONAL WEATHER SERVICE METEOROLOGICAL STATIONS IN OR NEAR THE KINNICKINNIC RIVER WATERSHED: 1977

Station Identification				Location		
Name	National Weather Service Number	Within Watershed	Outside of Watershed	County	City or Village	Current Location
Germantown	3058	--	X	Washington	Village of Germantown	Germantown Sewage Treatment Plant
Milwaukee-Mount Mary	5474	--	X	Milwaukee	City of Milwaukee	Mount Mary College
West Allis	9046	--	X	Milwaukee	City of West Allis	Allis Chalmers Company
Waukesha	8937	--	X	Waukesha	City of Waukesha	Waukesha Water Utility
Milwaukee-North Side	5477	--	X	Milwaukee	City of Milwaukee	WISN-TV Station Tower
Milwaukee-Mitchell Field	5479	X	--	Milwaukee	City of Milwaukee	Terminal Building Mitchell Field
Port Washington	6764	--	X	Ozaukee	City of Port Washington	Wisconsin Electric Power Company
West Bend	9050	--	X	Washington	City of West Bend	Private Residence
Burlington	1205	--	X	Walworth	City of Burlington	Burlington Sewage Treatment Plant
Union Grove	8723	--	X	Racine	Village of Union Grove	Union Grove Sewage Treatment Plant
Racine	6922	--	X	Racine	City of Racine	Water Pollution Control Center

Source: National Weather Service and SEWRPC.

Temperature: Watershed temperatures, which exhibit a large annual range, are relevant to the watershed planning. Seasonal temperatures determine the kinds and intensities of the recreational uses to which surface waters and adjacent riverine lands may be put, and consequently, the periods over which the highest levels of water quality should be maintained. More importantly, aerobic and anaerobic biochemical processes fundamental to self-purification of streams are temperature dependent, since reaction rates approximately double with each 20°F rise in temperature within the temperature range normally encountered in nature. The supply of oxygen available for such processes is a function of oxygen solubility in water, or the maximum concentration of oxygen that can be retained in solution, which is highly dependent on temperature. For example, a stream at or near freezing temperatures can hold about 15 mg/l of dissolved oxygen, but the surface waters of that same stream on a hot 80°F day will have the dissolved oxygen solubility reduced by almost one-half. The summer period is, therefore, critical and limiting in both natural and artificially induced aerobic processes, since oxygen demands are at their annual maximum due to accelerated reaction rates, while the oxygen supply is at its annual minimum because of solubility limitations associated with those high temperatures.

Data for three selected air temperature observation stations in or near the Kinnickinnic River watershed—Milwaukee at Mitchell Field, West Allis, and Germantown—are presented in Table 8. Monthly temperature data for the three stations are presented graphically in Figure 8. Air temperature and precipitation data used to develop the tables and figures presented in this and the subsequent sections of this chapter are for various periods of record ranging from 16 years to 136 years. Coincident periods of record were not used because of the widely varying periods of historic record available. Although noncoincident periods of record were used, the monthly and annual summary data presented in this chapter are judged to be sufficiently accurate to portray the spatial and temporal variations in watershed temperature and precipitation characteristics. These data indicate the temporal variations, and in some instances the spatial variations, in temperature and precipitation which may be expected to occur within or near the

Table 8

AIR TEMPERATURE CHARACTERISTICS AT SELECTED LOCATIONS IN OR NEAR THE KINNICKINNIC RIVER WATERSHED

	Location									Watershed Summary		
	Milwaukee (Mitchell Field) (1940-1976)			West Allis (1951-1976)			Germantown (1944-1976)					
Month	Average Daily Maximum[a]	Average Daily Minimum[a]	Mean[b]	Average Daily Maximum[a]	Average Daily Minimum[a]	Mean[b]	Average Daily Maximum[a]	Average Daily Minimum[a]	Mean[b]	Average Daily Maximum[c]	Average Daily Minimum[c]	Mean
January	27.7	12.7	20.2	28.1	12.9	20.5	27.6	9.7	18.6	27.9	12.8	20.4
February . . .	30.9	16.4	23.7	32.2	17.4	24.8	31.3	13.2	22.2	31.6	16.9	24.3
March	39.6	25.1	32.3	40.8	26.2	33.5	41.0	23.0	32.0	40.2	25.7	32.9
April.	53.4	35.8	44.6	55.4	37.7	46.6	55.6	34.2	44.9	54.4	36.8	45.6
May	64.0	44.4	54.2	67.3	47.1	57.2	67.0	43.0	55.0	65.2	45.3	55.3
June	75.3	55.1	65.2	78.7	57.8	68.3	77.2	53.3	65.2	77.0	56.5	66.8
July	80.2	61.2	70.7	83.0	63.1	73.1	81.9	57.9	69.9	81.6	62.2	71.9
August	79.0	60.7	69.9	81.3	62.7	72.0	80.9	57.1	69.0	80.2	61.7	71.0
September . .	71.1	52.6	61.8	72.5	54.4	63.5	72.5	49.2	60.9	71.8	53.5	62.7
October. . . .	60.9	42.7	51.8	61.7	44.4	53.0	62.2	40.2	51.2	61.3	43.6	52.5
November . .	44.9	30.2	37.5	45.9	31.5	38.7	45.5	28.2	36.8	45.4	30.9	38.2
December . .	32.4	18.4	25.4	33.3	19.8	26.5	32.2	15.7	23.9	32.9	19.1	26.0
Year	55.0	37.9	46.5	56.7	39.6	48.2	56.2	35.4	45.8	55.9	38.8	47.4

[a] *The monthly average daily maximum temperature and the monthly average daily minimum temperature are obtained by using daily measurements to compile an average for each month in the indicated period of record; the results are then averaged for all months in the period of record.*

[b] *The mean monthly temperature is the average of the average daily maximum temperature and daily minimum temperature for each month.*

[c] *Average of values for the Milwaukee and West Allis stations.*

Source: National Weather Service and SEWRPC.

watershed. The temperature data also illustrate how watershed air temperatures lag approximately one month behind summer and winter solstices during the annual cycle, with the result that July is the warmest month in the watershed and January the coldest.

Summer air temperatures throughout the watershed, as reflected by monthly means at the Milwaukee and West Allis stations for July and August, are in the 70°F to 73°F range. Average daily maximum temperatures within the watershed for these two summer months are in the 79°F to 83°F range, whereas average daily minimum temperatures vary from 61°F to 63°F. With respect to minimum daily temperatures, the meteorological station network is not sufficient to reflect all the effects of topography. During nighttime hours, cold air, because of its greater density, flows into low lying areas. Because of this phenomenon, the average daily minimum temperatures in these topographically low areas, particularly during the summer months, will be less than those recorded by the meteorological stations.

Winter temperatures for the watershed, as measured by monthly means for January and February, are in the range of 20°F to 25°F. Average daily maximum temperatures within the watershed for these two winter months vary from 28°F to 32°F, whereas average daily minimum temperatures are in the 13°F to 17°F range.

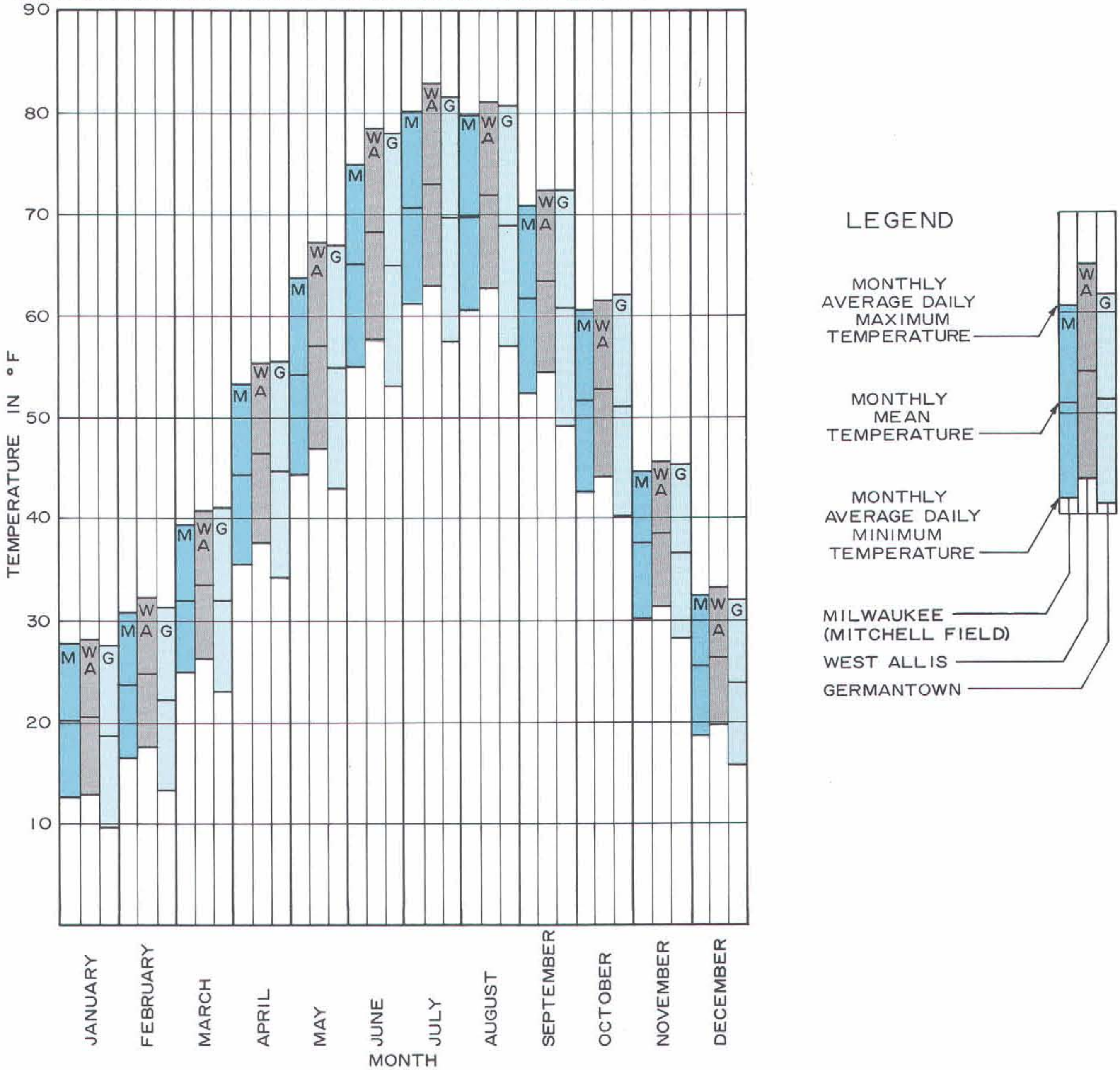
A comparison of temperature data for the Mitchell Field and West Allis stations, which are located on the eastern and western ends of the Kinnickinnic River watersheds, respectively, suggests that this basin is positioned so that the eastern edge of the watershed has lakeshore temperature characteristics whereas the western edge of the basin has inland temperature characteristics. As shown in Table 8 and Figure 8, the Mitchell Field station, which is located about 3.5 miles from the Lake Michigan shoreline, exhibits average daily maximum temperatures during the late spring and throughout summer that are about 2°F to 3°F lower—because of the cooling effect of Lake Michigan—than those recorded at the West Allis station, which is located about six miles from Lake Michigan. The temperature differential that exists across the watershed, which may influence the occurrence of precipitation as rainfall or snow and may affect snowmelt and evaporation rates, is incorporated in the water resource simulation, as discussed in Chapter VIII of this report, by using the input of meteorologic data from both the Mitchell Field and West Allis stations.

A comparison of air temperature data for the West Allis and Germantown stations presented in Table 8 and Figure 8 strongly suggests the existence of an "urban heat island effect." Large urban complexes have been observed to exhibit higher air temperatures than surrounding rural areas. This temperature differential is greatest during the evening hours of clear days and is partly attributable to the numerous heat sources within an urban environment. Another factor is the more gradual loss of this heat to the atmosphere because of the dense pattern of the urban structures emitting the heat in that they radiate heat towards each other rather than into the open atmosphere as in rural areas, and because of the presence of atmospheric contaminants which form a barrier to nighttime radiation from the earth back to the atmosphere.

For all months of the year, average daily minimum temperatures for the West Allis station, which is located in a highly urbanized area, are 3° to 5°F higher than

Figure 8

AIR TEMPERATURE CHARACTERISTICS AT SELECTED LOCATIONS IN OR NEAR THE KINNICKINNIC RIVER WATERSHED



Source: National Weather Service and SEWRPC.

average daily minimum temperatures at Germantown, which is located in a rural area. Although Germantown temperatures would be expected to be slightly lower than West Allis temperatures because of the latitudinal effect—the Germantown station is located about 15 miles north of the West Allis station—the temperature differential is most pronounced for average minimum daily temperatures, and is too large to be entirely attributable to differences in latitude or topography.

The urban heat island effect is reflected in the water resource system simulation conducted under the Kinnickinnic River watershed planning program in that only temperature data characteristic of this urban basin were used as input to the model. One consequence of the heat island effect is an increase in precipitation and cloudiness that is convectively produced as a result of air rising from the warmer urban areas. Such effects, which are probably present throughout the Kinnickinnic River watershed, are reflected in the water resource system simulation in that the precipitation data used in that analysis is for urban stations in and near the watershed.

Extreme high and low temperatures for the watershed, based on 30 years or more of historic records at observation stations within or near the basin, range from a high of about 105°F to a low of about - 25°F. The growing season, which is defined as the number of days between the last 32°F freeze in spring and the first in the fall, averages about 180 days for the watershed. The last 32°F frost in the spring normally occurs near the end of April whereas the first freeze in the fall usually occurs during the latter half of October.

Precipitation: Precipitation within the watershed takes the form of rain, sleet, hail, and snow, and ranges from gentle showers of trace quantities to destructive thunderstorms, as well as major rainfall-snowmelt events causing property damage, inundation of poorly drained areas, and stream flooding. Existing sewerage system problems such as overflows from combined sewers are the direct result of even small precipitation events. Rainfall events may also cause separate sanitary sewerage systems to surcharge and back up into basements and overflow into surface watercourses, and may require sewage treatment plants to bypass large volumes of partially treated or untreated sewage in excess of the hydraulic capacity of the plants. Such surcharging of separate sanitary sewerage systems is caused by the entry of excessive quantities of rain, snowmelt, and groundwater into the sanitary sewers via manholes, building sewers, building downspouts, and foundation drain connections, and by infiltration through faulty sewer pipe joints, manhole structures, and cracked pipes.

Total precipitation as well as snowfall data for three observation stations in or near the Kinnickinnic River watershed—Milwaukee at Mitchell Field, West Allis, and Germantown—are presented in Table 9 and the location of each is shown on Map 12. Monthly total precipitation

Table 9

PRECIPITATION CHARACTERISTICS AT SELECTED LOCATIONS IN AND NEAR THE KINNICKINNIC RIVER WATERSHED

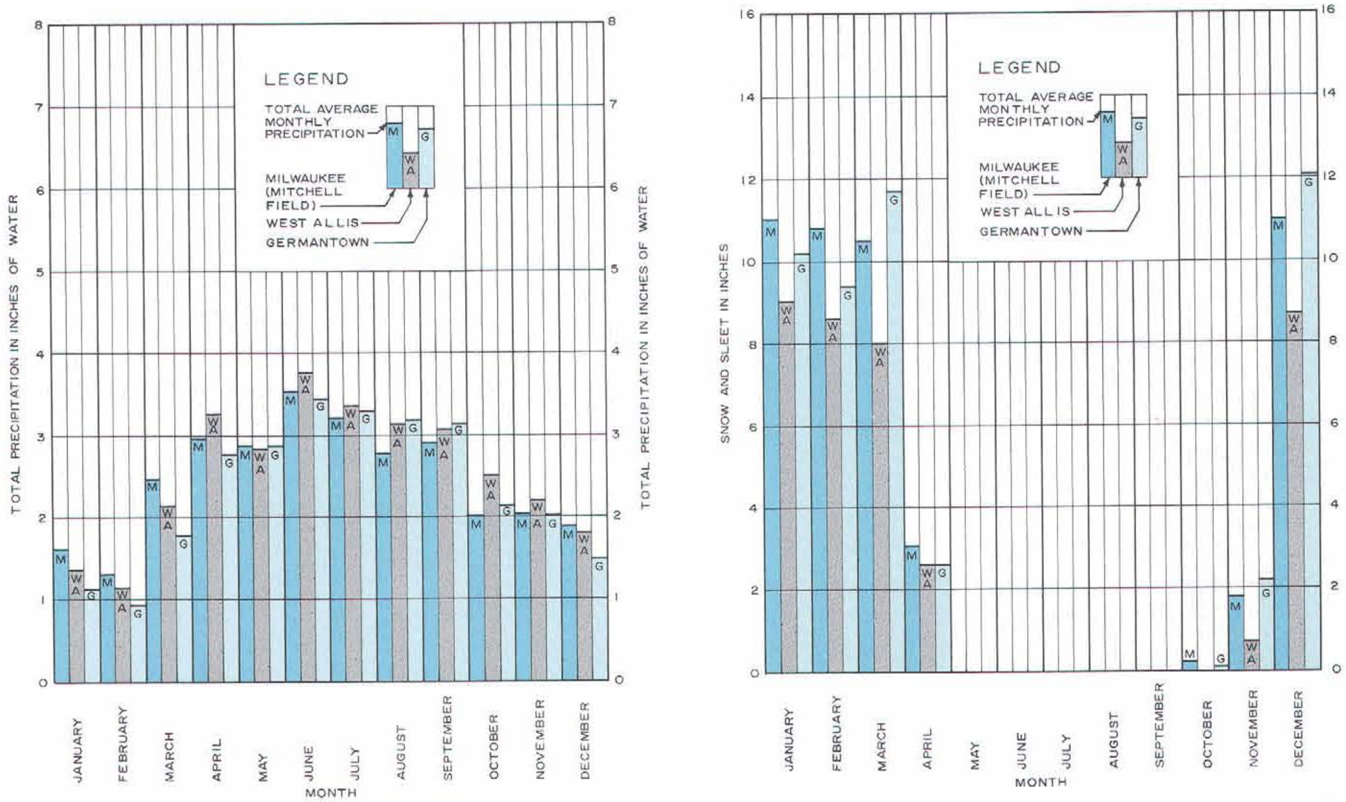
	Location						Watershed Summary			
	Milwaukee-Mitchell Field		West Allis		Germantown				Average Based on the Thiessen Polygon Method	
Month	Average Total Precipitation (1940-1976)	Average Snow and Sleet (1961-1976)	Average Total Precipitation (1951-1976)	Average Snow and Sleet (1961-1974)	Average Total Precipitation (1945-1976)	Average Snow and Sleet (1961-1976)	Average Total Precipitation[a]	Average Snow and Sleet[a]	Total Precipitation	Snow and Sleet
January	1.62	11.0	1.38	9.1	1.13	10.2	1.50	10.0	1.53	10.3
February . . .	1.31	10.8	1.15	8.6	0.92	9.4	1.23	9.7	1.25	10.0
March	2.48	10.5	2.16	8.0	1.79	11.7	2.32	9.3	2.36	9.5
April.	2.97	3.1	3.28	2.6	2.77	2.6	3.12	2.8	3.09	2.9
May	2.89		2.85	0.0	2.88	0.0	2.87	Trace	2.87	Trace
June	3.58	0.0	3.73	0.0	3.45	0.0	3.66	0.0	3.64	0.0
July	3.21	0.0	3.37	0.0	3.30	0.0	3.29	0.0	3.27	0.0
August	2.79	0.0	3.14	0.0	3.19	0.0	2.96	0.0	2.92	0.0
September . .	2.91	0.0	3.07	0.0	3.14	Trace	2.99	0.0	2.97	0.0
October. . . .	2.01	0.2	2.52	Trace	2.15	0.1	2.26	0.1	2.21	0.1
November . .	2.03	1.8	2.20	0.7	2.01	2.2	2.12	1.3	2.10	1.4
December . .	1.88	11.0	1.82	8.7	1.50	12.1	1.85	9.8	1.86	10.1
Year	29.68	48.4	30.67	37.7	28.23	48.3	30.17	43.0	30.07	44.3

[a]*Average of values for the Milwaukee and West Allis stations.*

Source: National Weather Service and SEWRPC.

Figure 9

PRECIPITATION CHARACTERISTICS AT SELECTED LOCATIONS IN OR NEAR THE KINNICKINNIC RIVER WATERSHED



Source: National Weather Service and SEWRPC.

and snowfall observations for the three stations are presented graphically in Figure 9. The data illustrate the temporal variations in the type and amount of precipitation that normally occurs within or near the watershed.

The average annual total precipitation in the watershed and immediate surroundings, based on a numerical average of data for the Mitchell Field and West Allis stations, is 30.2 inches, expressed as water equivalent, while the average annual snow and sleet measured as snow and sleet is 43.0 inches. The average annual total precipitation for the watershed itself as determined by the Thiessen Polygon Network method is 30.1 inches, while the average annual accumulation of snow and sleet is 44.3 inches.

Average total monthly precipitation for the watershed, based on the Thiessen Polygon Network method, ranges from a low of 1.25 inches in February to a high of 3.64 inches in June. The principal snowfall months are December, January, February, and March, when average monthly snowfalls are 10.1, 10.3, 10.0, and 9.9 inches, respectively, and during which time 91.0 percent of the average annual snowfall may be expected to occur. Snowfall is the predominant form of precipitation during these months, totaling approximately 60 percent of the total precipitation expressed as water equivalent. Approximately 18 inches, or 60 percent of the average annual precipitation, normally occurs during the late April through mid-October growing season, primarily as rainfall. Assuming that 10 inches of measured snowfall is equivalent to one inch of water, the average annual snowfall of 44.3 inches is equivalent to 4.4 inches of water, and therefore only 15 percent of the average annual total precipitation occurs as snowfall. It is of interest to note that approximately one-half of the 30.1 inch average annual precipitation leaves the watershed as streamflow; the remaining one-half being lost from the watershed primarily as evapotranspiration.[5]

A comparison of precipitation data for the Mitchell Field and West Allis stations, which are located, respectively, in the eastern and western portions of the Kinnickinnic River watershed, suggests that the eastern edge of the watershed experiences higher average seasonal snow and sleet accumulations than does the western edge of the

[5]*Determined using the hydrologic-hydraulic model described in Chapter VIII.*

basin. As shown in Table 9 and Figure 9, the Mitchell Field station, which is located about 3.5 miles from the Lake Michigan shoreline, exhibits an average seasonal snowfall of 48.4 inches which is 10.7 inches higher than that recorded at the West Allis station, which is located about six miles from Lake Michigan. The occurrence of somewhat higher seasonal snowfall amounts along the Lake Michigan shore is attributed to the availability of more moisture in the air mass immediately above the lake.

Extreme precipitation event data through 1976 for four long-term stations—Milwaukee at Mitchell Field, Waukesha, Racine, and West Bend—are presented in Table 10. Inasmuch as these long-term records are for stations located in or reasonably near to the Kinnickinnic River watershed, data from those stations may be considered representative of the extreme precipitation events that have occurred within the watershed.

Based on the tabulated data, annual precipitation within the watershed and the immediate surroundings has varied from a low of approximately 17 inches, or about 58 percent of the area average, to a high of approximately 50 inches, or about 68 percent above the average. Annual seasonal snowfall has varied from a low of approximately five inches, or about 12 percent of the area average, to a high of approximately 109 inches, or about 170 percent above the average. The maximum monthly precipitation at the four stations is 13.17 inches, recorded at West Bend in August of 1924, and the maximum monthly

Table 10

EXTREME PRECIPITATION EVENTS FOR SELECTED LONG-TERM STATIONS IN AND NEAR THE KINNICKINNIC RIVER WATERHSHED

Observation Station		Period of Precipitation Records Except Where Indicated	Total Precipitation (Water Equivalent)											
			Maximum Annual		Minimum Annual		Maximum Monthly			Maximum Daily			
Name	County	Otherwise	Amount	Year	Amount	Year	Amount	Month	Year	Amount	Day	Month	Year
Milwaukee	Milwaukee	1870-1976	50.36[a]	1876	18.69[a]	1901	10.03	June	1917	5.76[b]	22-23	June	1917
Racine	Racine	1895-1976	48.33	1954	17.75	1910	10.98	May	1933	4.00	11	September	1933
Waukesha	Waukesha	1892-1976	43.57	1938	17.30	1901	11.41	July	1952	5.09	18	July	1952
West Bend	Washington	1922-1976	40.52	1938	19.72	1901	13.17[f]	August	1924	7.58[g]	4	August	1924

Observation Station		Snowfall										
		Maximum Annual		Minimum Annual		Maximum Monthly			Maximum Daily			
Name	County	Amount	Year	Amount	Year	Amount	Month	Year	Amount	Day	Month	Year
Milwaukee	Milwaukee	109.0[c]	1885-1886	11.0[c]	1884-1885	52.6	January	1918	20.3[d]	4-5	February	1924
Racine	Racine	85.0	1897-1898	5.0[e]	1901-1902	38.0	February	1898	30.0[d]	19-20	February	1898
Waukesha	Waukesha	83.0[e]	1917-1918	9.1	1967-1968	56.0	January	1918	20.0[d]	5-6	January	1918
West Bend	Washington	86.5	1935-1936	19.6	1967-1968	38.0	January	1943	21.0	10-11	December	1970

[a] *Based on the period 1841-1976.*

[b] *Maximum precipitation for a 24-hour period.*

[c] *Maximum and minimum snowfalls for a winter season.*

[d] *Maximum snowfall for a 24 hour period.*

[e] *Estimated from incomplete records.*

[f] *Based on the period 1895-1959 as reported in "A Survey Report for Flood Control on the Milwaukee River and Tributaries," U. S. Army Engineers District, Chicago, Corps of Engineers, November 1964.*

Source: Wisconsin Statistical Reporting Service, National Weather Service, U. S. Corps of Engineers, and SEWRPC.

snowfall is 56 inches, measured at Waukesha in January 1918. The maximum 24-hour rainfall is 7.58 inches as recorded on August 4, 1924 at West Bend, while the maximum 24-hour snowfall is 30 inches measured at Racine on February 19 and 20, 1898.

Snow Cover: The likelihood of snow cover and the depth of snow on the ground are important precipitation-related factors that influence the planning, design, construction, and maintenance of public utilities. Snow cover, particularly early in the winter season, significantly influences the depth and duration of frozen ground, which in turn affects engineered works involving extensive excavation and underground construction. Accumulated snow depth at a particular time and place is primarily dependent on antecedent snowfall, rainfall, and temperature characteristics, and the amount of solar radiation. Rainfall is relatively unimportant as a melting agent but can, because of compaction effects, significantly affect the depth of snow cover on the ground.

Snow depth as measured at Milwaukee for the 70-year period from 1900 through 1969 and published in "Snow and Frost in Wisconsin," a 1970 Wisconsin Statistical Reporting Service report, is summarized and presented in Table 11. It should be emphasized that the tabulated data pertain to snow depth on the ground as measured at the place and time of observation, and are not a direct measure of average snowfall. Recognizing that snowfall and temperatures, and therefore snow accumulation on the ground, vary spatially within the watershed, the Milwaukee area data presented in Table 11 should be considered only as an approximation of conditions throughout the watershed. As indicated by the data, snow cover is most likely during the months of December, January, and February, during which at least a 0.40 probability exists of having one inch or more of snow cover at Milwaukee. Furthermore, during January and the first half of February, at least a 0.25 probability exists of having five or more inches of snow on the ground. During March, the month in which severe spring snowmelt-

Table 11

SNOW COVER PROBABILITIES AT MILWAUKEE BASED ON DATA FOR THE PERIOD 1900-1970

Date		Snow Cover[a]									
		1.0 Inch or More		5.0 Inches or More		10.0 Inches or More		15.0 Inches or More		Average (inches)	
Month	Day	Number of Occurrences[b]	Probability of Occurrence[c]	Number of Occurrences[b]	Probability of Occurrence[c]	Number of Occurrences[b]	Probability of Occurrence[c]	Number of Occurrences[b]	Probability of Occurrence[c]	Per Occurrence[d]	Overall[e]
November	15	5	0.07	0	0.00	0	0.00	0	0.00	1.2	0.09
	30	12	0.17	1	0.01	1	0.01	0	0.00	2.8	0.49
December	15	33	0.47	10	0.14	0	0.00	0	0.00	3.3	1.54
	31	32	0.46	9	0.13	1	0.01	0	0.00	3.6	1.66
January	15	43	0.61	17	0.24	4	0.06	2	0.03	4.9	2.94
	31	48	0.69	22	0.31	9	0.13	4	0.06	6.2	4.26
February	15	44	0.63	23	0.33	7	0.10	3	0.04	6.0	3.69
	28	27	0.39	8	0.11	3	0.04	1	0.01	4.5	1.69
March	15	23	0.33	6	0.09	4	0.06	0	0.00	3.9	1.21
	31	5	0.07	1	0.01	1	0.01	0	0.00	3.4	0.24

[a] *Data pertains to snow depth on the ground as it was measured at the time and place of observation, and is not a direct measure of average snowfall.*

[b] *Number of occurrences is the number of times during the 70 year period of record when measurements revealed that the indicated snow depth was equaled or exceeded on the indicated date.*

[c] *Probability of occurrence of a given snow depth and date is computed by dividing the number of occurrences by 70, and is defined as the probability that the indicated snow cover will be reached or exceeded on the indicated date.*

[d] *Average snow cover per occurrence is defined as the sum of all snow cover measurements in inches for the indicated date divided by the number of occurrences for that date; that is, the number of times in which 1.0 inch or more of snow cover was recorded.*

[e] *Overall average snow cover is defined as the sum of all snow cover measurements in inches for the indicated date divided by 70; that is, the number of observation times.*

Source: Wisconsin Statistical Reporting Service, National Weather Service, and SEWRPC.

rainfall flood events are most likely to occur, at least a 0.30 probability exists of having one inch or more of snow on the ground during the first half of the month, while the probability of having that much snow cover diminishes to 0.07 by the end of the month.

The aforementioned table facilitates an estimation of the probability that a given snow cover will exist or be exceeded at any given time, and should, therefore, be useful in planning winter outdoor work and construction activities as well as in estimating runoff for hydrologic purposes. There is, for example, only a 0.07 probability of having one or more inches of snow cover on November 15 of any year, whereas there is a much higher probability, 0.61, of having that much snow cover on January 15.

Frost Depth: Ground frost or frozen ground refers to that condition in which the ground contains variable amounts of water in the form of ice. Frost influences hydrologic processes, particularly the proportion of rainfall or snowmelt that will run off the land directly to sewerage systems and to surface watercourses in contrast to that which will enter and be temporarily detained in the soil. Anticipated frost conditions influence the design of engineered works in that structures and facilities are designed either to prevent the accumulation of water and, therefore, the formation of damaging frost as in the case of pavements and retaining walls, or the structures and facilities are designed to be partially or completely located below the frost susceptible zone in the soil, as in the case of foundations and water mains. For example, in order to avoid or minimize the danger of structural damage, foundation footings must be placed at a sufficient depth in the ground to be below that zone in which the soil may be expected to contract, expand, or shift due to frost actions. A similar consideration exists in the design and construction of sanitary sewers.

Snow cover is a primary determinant of the depth of frost penetration and of the duration of frozen ground. The thermal conductivity of snow cover is less than one-fifth that of moist soil, so that heat loss from the soil to the cold atmosphere is greatly inhibited by an insulating snow cover. An early, major snowfall that is retained on the ground as a substantial snow cover will inhibit or prevent frost development in unfrozen ground and may even result in a reduction or elimination of frost in already frozen ground. If an early, significant snow cover is maintained by additional regular snowfall throughout the winter season, frozen ground may not develop at all or, at most, a relatively small frost penetration will occur. Frost depth is also dependent on vegetal cover and soil type. Assuming similar soil types, for example, frost will penetrate more deeply into bare, unprotected soil than into soil covered with an insulating layer of sod.

Frost conditions for the Region are available on a bimonthly basis for the months of November to April as shown in Table 12 and are based upon data for an eight-year period of record extending from 1961 through 1968, as set forth in the report "Snow and Frost in Wisconsin," published in 1970 by the Wisconsin Statistical Reporting Service. These data are provided for representative locations on a weekly basis by funeral directors and cemetery officials. Since cemetery soils are normally overlain by an insulating layer of turf, the frost depths shown in Table 12 should be considered minimum values. Frost depths in excess of four feet have been observed in southeastern Wisconsin. During the period that frost depth observations have been made in southeastern Wisconsin, one of the deepest regionwide frost penetrations occurred in early March 1963, when 25 to 30 inches of frost occurred throughout the planning region. Frost depths of over three feet were observed throughout the Region in January and February of 1977. The Milwaukee and West Allis City Engineers reported over five feet of frost beneath some city streets in January and February of 1977.

The data indicate that frozen ground is likely to exist throughout the watershed for approximately four months each winter season, extending from late November through March, with more than six inches of frost normally occurring during January, February, and the first half of March. Historical data indicate that the most severe frost conditions normally occur in February, when 15 or more inches may be expected.

Evaporation: Evaporation is the natural process in which water is transformed from the liquid or solid state to the vapor state and returned to the atmosphere. Total

Table 12

AVERAGE FROST DEPTH IN THE KINNICKINNIC RIVER WATERSHED NOVEMBER TO APRIL

Month and Day	Nominal Frost Depth (inches)[a]
November 30	1
December 15	3
December 31	3
January 15.	9
January 31.	12
February 15.	15
February 28.	15
March 15.	12
March 31	6
April 15.	1

[a] *Based on 1960-1968 frost depth data for cemeteries as reported by funeral directors and cemetery officials. Since cemeteries have soils that are overlain by an insulating layer of turf, the frost depths should be considered as minimum values.*

Source: Wisconsin Statistical Reporting Service, "Snow and Frost in Wisconsin," June 1970.

evaporation includes evaporation from water and snow surfaces and directly from the soil, and also includes evaporation of precipitation intercepted on or transpired by vegetation. The magnitude and annual variation in evaporation from water surfaces and the relation of the evaporation to precipitation is important because of the key role of this process in the hydrologic cycle of the Kinnickinnic River watershed.

Limited evaporation data available for the watershed and immediate surroundings indicate an average annual evaporation from a water surface of about 29 inches, with about three-quarters of this, or 23.6 inches, occurring during the six-month May through October period. As indicated earlier in this chapter and summarized in Table 9, the average annual precipitation for the watershed is about 30.1 inches, that is, approximately equal to the average annual evaporation. During the aforementioned six-month May through October period, watershed precipitation is about 17.9 inches, and therefore evaporation from a water surface may be expected to exceed precipitation by about 5.7 inches during this period.

Wind: Prevailing winds in the Region follow a clockwise pattern in terms of the prevailing direction over the seasons of the year, being northwesterly in the late fall and winter, northeasterly in the spring, and southwesterly in the summer and early fall. Wind velocities in the Kinnickinnic River watershed may be expected to be less than five miles per hour about 15 percent of the time, between 5 and 15 miles per hour about 60 percent of the time, and in excess of 15 miles per hour about 25 percent of the time.

Daylight and Sky Cover: The annual variation in the time of sunrise and sunset and the daily hours of sunlight for the watershed are presented in Figure 10. Expected sky cover information, in the form of the expected percent of clear, partly cloudy, and cloudy days each month, also is summarized in Figure 10. These daylight and sky cover data have some value in planning outdoor construction and maintenance work, and are also useful in analyzing and explaining diurnal changes in observed surface water quality. For example, marked changes in measured stream dissolved oxygen levels are normally correlated with the transition from daytime to nighttime conditions, when photosynthetic oxygen production by algae and aquatic plants is replaced by oxygen utilization through respiration by those algae and aquatic plants. As illustrated in Figure 10, the duration of daylight ranges from a minimum of 9.0 hours on about December 22, the winter solstice, to a maximum of 15.4 hours on about June 21, the summer solstice.

Mean monthly sky cover for the sunrise to sunset period varies somewhat during the year. The smallest amount of daytime sky cover may be expected to occur during the four-month July through October period, when the mean monthly sky cover is at or slightly above 0.5. Clouds or other obscuring phenomena are most prevalent during the five months of November through March, when the mean monthly daytime sky cover is about 0.7. The tendency for maximum average sky cover to occur in the winter and for minimum average sky cover to occur in the summer is also illustrated by examining the expected relative number of days classified as clear, partly cloudy, and cloudy for months in each of those seasons. During the summer months, as shown in Figure 10, about one-third of the days may be expected to be categorized as clear, one-third as partly cloudy, and one-third as cloudy. Greater sky cover occurs in the winter, however, when over one-half of the days are classified as cloudy, with the remainder being approximately equally divided between partly cloudy and clear.

Physiography

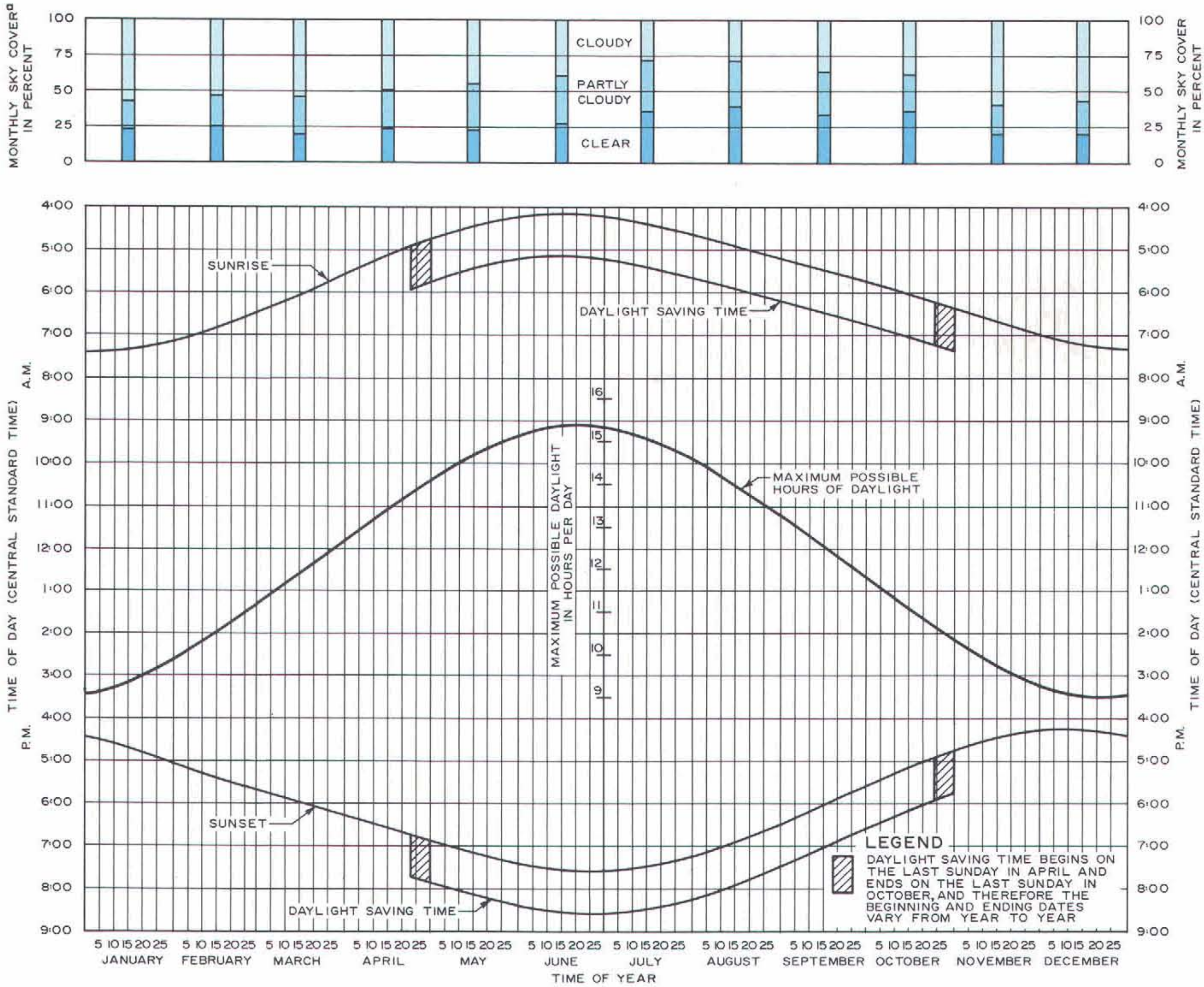
The 24.78 square mile Kinnickinnic River watershed is an irregularly shaped basin with its major axis oriented in an approximately northwest-southeast direction. Its length—measured from the northwest to the southwest extremity of the basin—is approximately 8.5 miles, and its maximum width, which occurs approximately midway between the northwest and southeast extremities of the basin, is about 5.5 miles.

Topographic and Physiographic Features: Watershed topography or variation in elevation, is shown on Map 13. Watershed physiographic features, or surficial land forms, have been determined largely by the underlying bedrock and the overlying glacial deposits of the watershed. The Niagara cuesta on which the watershed lies is a gently eastward sloping bedrock surface. The topography in this section is asymmetrical as shown on Map 13, with the northeastern portions of the watershed being generally lower in elevation—approximately 200 feet—than the southwestern portions. Glacial deposits overlying the bedrock formations form the surface topography of the watershed consisting primarily of gently sloping ground moraine—heterogeneous material deposited on the glacial ice. Surface elevations within the watershed range from a high of approximately 800 feet above National Geodetic Vertical Datum (Mean Sea Level Datum) near the intersection of W. Edgerton Avenue and S. 37th Street in the City of Greenfield to approximately 580 feet above National Geodetic Vertical Datum in the harbor area, a maximum relief of 220 feet. The areas of greatest local relief are located along the southwestern edge of the watershed.

Topography is an important consideration in watershed planning since it is one of the most important factors determining the hydrologic response of a watershed to rainfall and rainfall-snowmelt events, and since topographic considerations enter into the selection of sites and routes for public utilities and facilities such as sewerage and water supply systems, flood control facilities and highways. Some type of large scale mapping is available for the entire watershed (see Map 14). Of the total 24.78 square mile watershed area, 2.32 square miles, representing about 9.4 percent of the watershed, is covered by large-scale topographic mapping prepared to SEWRPC standards. For the remaining area, other large-scale topographic mapping and sanitary and storm sewer maps with or without street grade elevations are available. The scale, contour interval, date, and source of mapping and

Figure 10

SUNRISE, SUNSET, AND SKY COVER IN THE KINNICKINNIC RIVER WATERSHED



[a]BASED ON MILWAUKEE SKY COVER DATA. THESE MONTHLY DATA ARE SIMILAR TO THOSE OBSERVED AT MADISON AND AT GREEN BAY, WHICH SUGGESTS THAT THERE IS VERY LITTLE VARIATION IN THIS MONTHLY DATA FOR THE LARGE GEOGRAPHIC REGION RELATIVE TO THE KINNICKINNIC RIVER WATERSHED, REPRESENTED BY THESE THREE NATIONAL WEATHER SERVICE STATIONS. THEREFORE, THE MILWAUKEE DAYLIGHT AND SKY COVER MONTHLY DATA MAY BE CONSIDERED APPLICABLE TO THE WATERSHED. SKY COVER CONSISTS OF CLOUDS OR OBSCURRING PHENOMENA, AND IS EXPRESSED IN TENTHS. A DAY IS CLASSIFIED AS CLEAR IF THE SKY COVER DURING THE DAYLIGHT PERIOD IS 0-0.3, PARTLY CLOUDY IF THE SKY COVER IS 0.4-0.7, AND CLOUDY IF THE SKY COVER IS 0.8-1.0. MONTHLY SKY COVER INDICATES, BY MONTH, THE PERCENT OF DAYS THAT HISTORICALLY HAVE BEEN CLEAR, PARTLY CLOUDY, OR CLOUDY.

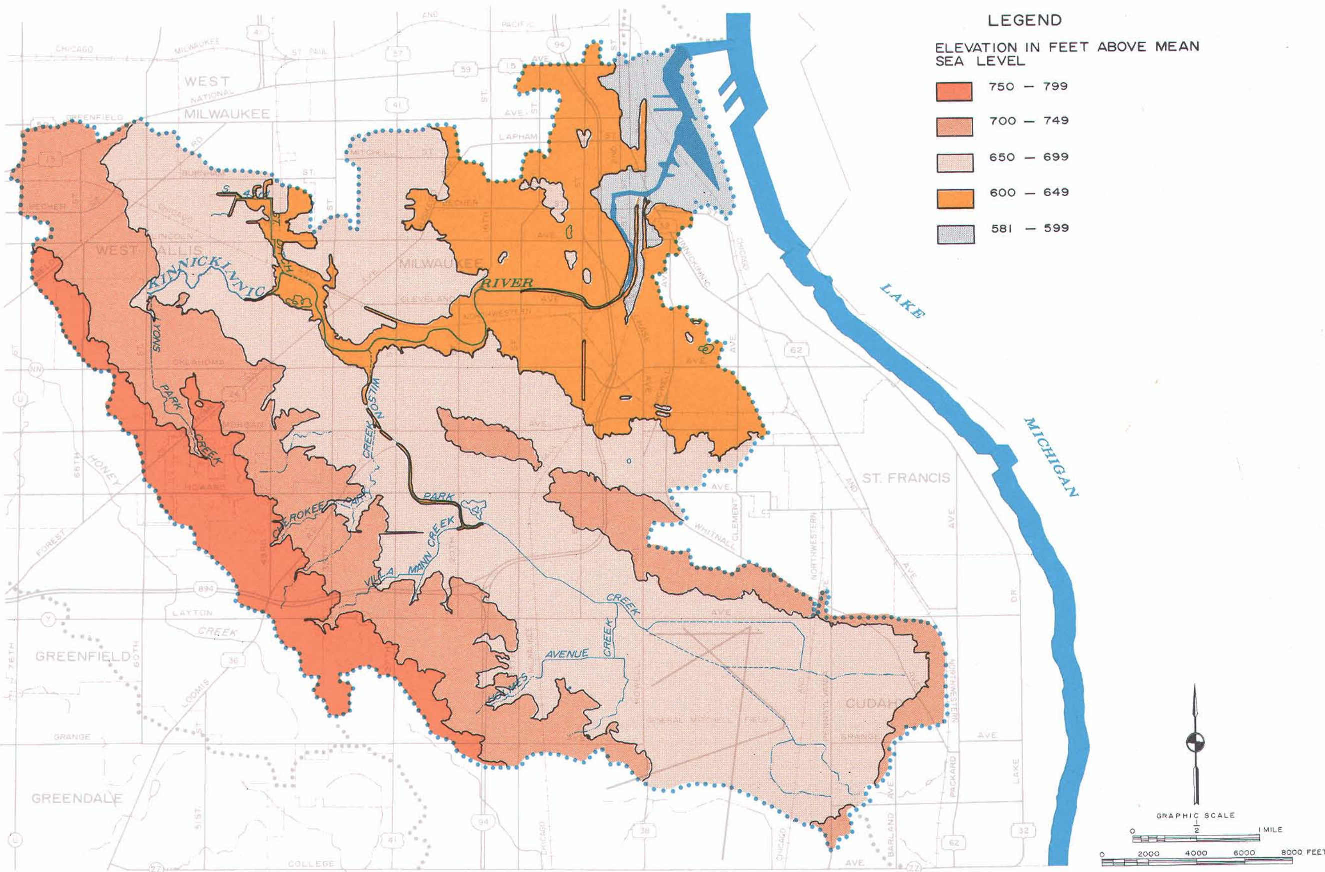
Source: Adapted by SEWRPC from National Weather Service and U. S. Naval Observatory Data.

other selected information are presented in Table 13. The above mapping, together with 1" = 400' scale aerial photographs were used during the watershed planning process and should be equally valuable during implementation of the Kinnickinnic River watershed plan.

Surface Drainage: The Kinnickinnic River watershed drains in a generally northerly and easterly direction, discharging to Lake Michigan. Certain water quality requirements are imposed on the stream system of the watershed as a result of that system being tributary to the Great Lakes. The Kinnickinnic River watershed adjoins the Menomonee River watershed on the north and west, the Oak Creek watershed on the south, and lands that drain directly to Lake Michigan on the east. A comprehensive watershed plan has been completed and adopted by the Commission or the Menomonee River watershed.

Map 13

TOPOGRAPHIC CHARACTERISTICS OF THE KINNICKINNIC RIVER WATERSHED



Glacial deposits superimposed on underlying bedrock establish the overall topography of the Kinnickinnic River watershed. The watershed land surface generally slopes downward from southwest to northeast, with the northeastern portions of the basin lying about 200 feet below the southwestern edge. Surface elevations in the watershed range from a high of approximately 800 feet above National Geodetic Vertical Datum (mean sea level datum) near the intersection of W. Edgerton Avenue and S. 37th Street in the City of Greenfield to a low of approximately 580 feet above National Geodetic Vertical Datum in the harbor area—a maximum relief of 220 feet.

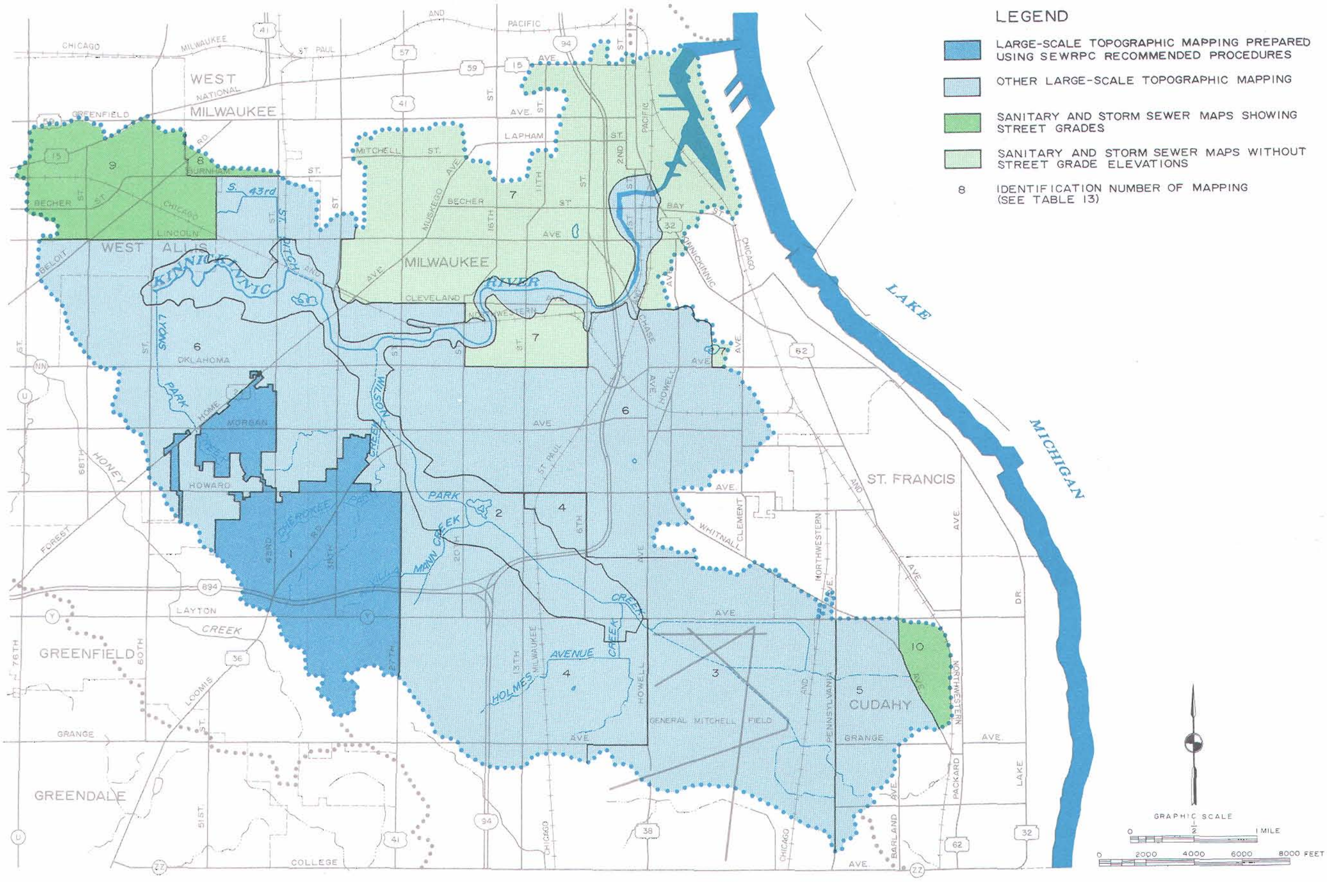
Source: SEWRPC.

Surface drainage within the watershed is very diverse with respect to channel cross-sectional shape, channel slope, degree of stream sinuosity, and floodland shape and width. The heterogeneous character of the surface drainage system is due partly to the natural effects of recent glaciation superimposed on the bedrock and partly due to the extensive channel modifications and other results of urbanization that are evident throughout the basin.

The Kinnickinnic River begins its 8.05 mile route to Lake Michigan from its point of origin as a surface stream at a storm sewer outfall located at S. 60th Street immediately south of W. Kinnickinnic River Park Drive in the City of Milwaukee. From this source the Kinnickinnic River flows in a generally easterly direction until about S. 4th Street where it begins to flow in a north-northeasterly direction to its confluence with the Milwaukee River near the Lake Michigan shoreline.

Map 14

AVAILABILITY OF LARGE-SCALE TOPOGRAPHIC MAPPING IN THE KINNICKINNIC RIVER WATERSHED: 1976



Some type of large-scale mapping is available for the entire watershed. Large-scale topographic maps prepared to SEWRPC standards are available for about 2.3 square miles, or about 9 percent, of the watershed area. The large-scale mapping was used in a variety of ways during preparation of the watershed plan, including to provide input to the hydrologic-hydraulic simulation modeling effort as well as sites for alternative water-related public facilities and utilities. The extensive amount of available large-scale mapping should be valuable during the plan implementation process.

Source: SEWRPC.

The entire length of the Kinnickinnic River lies within the City of Milwaukee with the exception of a 0.06 mile reach between S. 51st Street extended and S. 52nd Street extended and a 0.08 mile reach between S. 54th Street extended and S. 55th Street extended located in the City of West Allis. Wilson Park Creek, the largest tributary to the Kinnickinnic River, begins its 6.12 mile route to the Kinnickinnic River from its point of origin at S. Whitnall Avenue in the City of Cudahy, where it is also known as the Edgerton Ditch. From there it flows in a northwesterly direction with most of its length being contained within the City of Milwaukee, and joins the Kinnickinnic River at about S. 30th Street. Several other streams, each with unique characteristics, are tributary to the Kinnickinnic River or Wilson Park Creek, including Lyons Park Creek and the S. 43rd Street Ditch which are tributary to the Kinnickinnic River and Cherokee Park Creek, Villa Mann Creek, and Holmes Avenue Creek, all of which are tributary to Wilson Park Creek.

Table 13

SELECTED INFORMATION PERTAINING TO LARGE-SCALE MAPPING IN THE KINNICKINNIC RIVER WATERSHED: 1976

Identification Number on Map 14	Civil Division City, Village, or Town	Type of Mapping	Scale	Contour Interval (feet)	Mapping Using SEWRPC Recommended Procedures[a]	Mapping Agency or Firm	Agency or Community for Which Mapping Was Originally Prepared	Date of Photography or Field Work	Date of Map Preparation
1	City of Greenfield	Topographic	1" = 100'	2'	Yes	J. C. Zimmerman Engineering Corporation	City of Greenfield	1975	1976
2	Cities of Milwaukee and West Allis, Village of West Milwaukee	Topographic	1" = 200'	2'	No	Abrams Aerial Survey Corporation	Department of the Interior, U. S. Geological Survey	1975	1976
3	Cities of Cudahy, Milwaukee and St. Francis	Topographic	1" = 100'	1' - 2'	No	Alster and Associates Incorporated	Milwaukee County Airport Department	1966	1966
4	City of Milwaukee	Topographic	1" = 100'	2'	No	Abrams Aerial Survey Corporation	City of Milwaukee, Bureau of Engineering	1956	1957
5	City of Cudahy	Topographic	1" = 100'	2'	No	Chicago Aerial Survey	City of Cudahy	1958	1958
6	Cities of Milwaukee, West Allis and Village of West Milwauee	Topographic	1" = 200'	5'	No	Milwaukee-Metropolitan Sewerage Commissions	Milwaukee-Metropolitan Sewerage Commissions	1922	1932
7	City of Milwaukee	Storm and Sanitary Sewer	1" = 100'	--	No	City of Milwaukee, Bureau of Engineering	City of Milwaukee, Bureau of Engineering	1968	1968
8	Village of West Milwaukee	Storm and Sanitary Sewer	1" = 150'	--	No	Steinhagen and Steinhagen Civil Engineers	Village of West Milwaukee	1958	1958
9	City of West Allis	Storm and Sanitary Sewer	1" = 200'	--	No	City of West Allis	City of West Allis	1968	1968
10	City of Cudahy	Storm and Sanitary Sewer	1" = 200'	--	No	City of Cudahy	City of Cudahy	1962	1962

[a]*SEWRPC-Recommended Procedures are described in SEWRPC Technical Report No. 7, Horizontal and Vertical Survey Control in Southeastern Wisconsin.*

Source: SEWRPC.

Geology—A Stratigraphic and Historical Overview[6]

The geology of the Kinnickinnic River watershed is a complex system of various layers and ages of rock formations. The type and extent of the various bedrock formations underlying the watershed was determined primarily by the environments in which the sediments forming the various rock layers were deposited. The surface of this varied system of rock layers was, moreover, eroded prior to being buried by a blanket of glacial deposits consisting of unconsolidated sand, silt, clay, gravel, and boulders. The bedrock formations underlying the Kinnickinnic River watershed consist of, in ascending order, predominantly crystalline rocks of the Precambrian Era, Cambrian through Silurian Period sedimentary rocks of the Paleozoic Era, and unconsolidated surficial deposits. Only the glacial deposits are exposed in the watershed, there being no known bedrock outcrops in the basin.

Table 14, which summarizes the stratigraphy of the Kinnickinnic River watershed, indicates that the unconsolidated surficial deposits have a thickness of 100 to 250 feet and that the underlying dolomite, shale, and sandstone bedrock attains a combined thickness in excess of 1,900 feet. Bedrock layers slope downward in an easterly direction at about 40 feet per mile (about 0.75 feet per 100 feet). The relationship between the geologic units and the three aquifer systems underlying the watershed is also set forth in Table 14.

Precambrian Rock Units: Precambrian crystalline rocks thousands of feet thick form the basement on which younger rocks were deposited. Little is known of their

[6]*This summary of watershed geology is based on data and information presented in the following published reports:*

- *William J. Drescher, Frederick C. Dreher, and Paul N. Brown, "Water Resources of the Milwaukee Area, Wisconsin," U. S. Geological Survey Circular 247, Washington, D.C., 1953, 42 pp.*
- *F. C. Foley, W. C. Walton, and W. J. Drescher, "Ground-Water Conditions in the Milwaukee-Waukesha Area, Wisconsin," U. S. Geological Survey Water-Supply Paper 1229, Washington, D. C., 1953, 96 pp.*
- *J. H. Green and R. D. Hutchinson, "Ground-Water Pumpage and Water Level Changes in the Milwaukee-Waukesha Area, Wisconsin, 1950-61," U. S. Geological Survey Water-Supply Paper 1809-I, Washington, D. C., 1965, 19 pp.*
- *Martha J. Ketelle, "Hydrogeologic Considerations in Liquid Waste Disposal, With a Case Study in Southeastern Wisconsin," SEWRPC Technical Record, Vol. 3, No. 3, September 1971, 39 pp.*
- *Earl L. Skinner and Ronald G. Borman, "Water Resources of Wisconsin-Lake Michigan Basin," Hydrologic Investigations Atlas HA-432, U. S. Geological Survey, Washington, D. C., 1973.*
- *U. S. Geological Survey, Wisconsin Geological and Natural History Survey, and SEWRPC, Digital Computer Model of the Sandstone Aquifer in Southeastern Wisconsin, April 1976, 42 pp.*

Table 14

STRATIGRAPHY OF THE KINNICKINNIC RIVER WATERSHED

System	Geologic Unit[a]	Nominal Thickness or Thickness Range (feet)	Dominant Lithology	Hydrologic Unit[b]
Quaternary. . .	Holocene and Pleistocene Deposits	100-250	Clay, silt, sand, and gravel and boulders. Possibly locally stratified.	Sand and gravel aquifers (unconfined)
Silurian	Dolomite Undifferentiated	300	Dolomite	Dolomite Aquifer (unconfined)
Ordovician . . .	Maquoketa Shale Undifferentiated	200	Shale	Confining bed
	Galena Dolomite, Decorah Formation, and Platteville Formation, Undifferentiated	250	Dolomite	Sandstone Aquifer (confined)
	St. Peter Sandstone	250	Sandstone	
Cambrian. . . .	Eau Claire Sandstone	200	Sandstone, siltstone and shale	
	Mount Simon Sandstone	700+	Sandstone	
Precambrian . .	Undifferentiated	(thousands of feet)	Crystalline rocks including granite and quartzite.	--

[a] *Each geologic unit underlies or covers the entire watershed with the exception of holocene deposits which are found only in topographically low areas such as in streams and marshes.*

[b] *The combination of the unconfined sand and gravel and dolomite aquifers is sometimes referred to as the shallow aquifer whereas the confined sandstone aquifer is sometimes referred to as the deep aquifer.*

Source: U. S. Geological Survey and SEWRPC.

origin, but in wells near the watershed that reach the Precambrian basement, the rock types include quartzite and granite. The Precambrian rocks were extensively eroded to an uneven surface before the overlying sedimentary formations were deposited. Layered sedimentary rocks overlying the Precambrian rocks consist primarily of sandstone, shale, and dolomite. These rocks were deposited during the Cambrian, Ordovician, and Silurian geologic time periods, in seas that covered much of the present North American continent.

Cambrian Rock Units: Cambrian rocks in the watershed are primarily sandstone, but contain some siltstone and shale. The two Cambrian rock units are the Mount Simon sandstone, which was deposited on the Precambrian surface, and the Eau Claire sandstone. The two units are present throughout the watershed. The Eau Claire sandstone has a thickness of about 200 feet whereas the Mount Simon sandstone has a thickness in excess of 700 feet, with the total thickness being unknown because of the absence of fully penetrating wells or other bore holes.

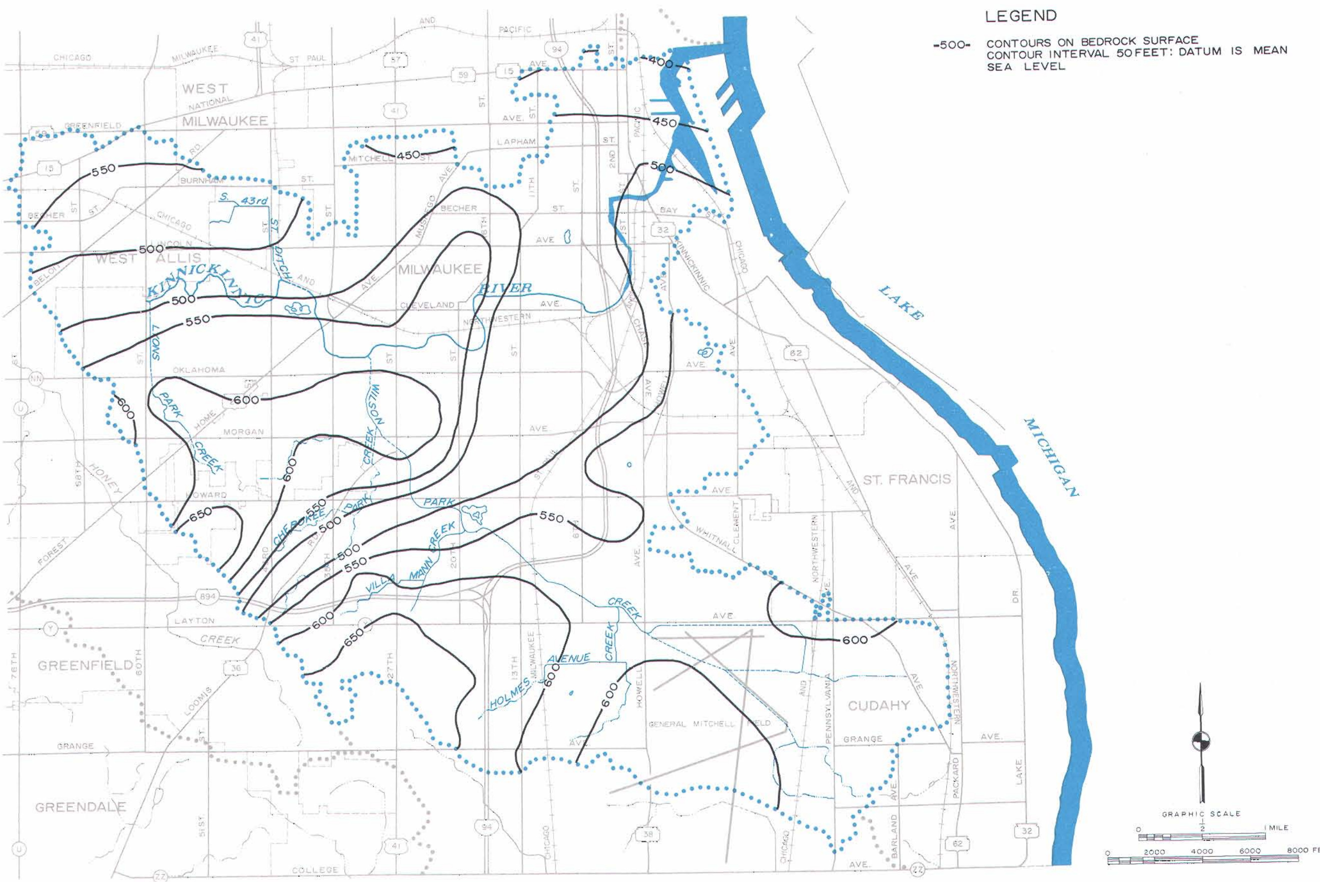
Ordovician Rock Units: Ordovician rocks in the watershed consist of sandstone, dolomite, and shale. The St. Peter sandstone, which was deposited on an erosion surface cut into the underlying Cambrian formations, has a relatively uniform thickness of about 250 feet over the watershed. The Platteville formation, Decorah formation, and Galena dolomite, which were deposited in succession on top of the St. Peter sandstone but are not differentiated in the watershed, have a combined thickness of approximately 250 feet. Above these is the relatively impermeable Maquoketa shale, which has a thickness of about 200 feet throughout the watershed.

Silurian Rock Units: Silurian rocks consisting of undifferentiated dolomite strata and having a thickness of about 300 feet overlie the Maquoketa shale. They form the bedrock beneath the glacial deposits in all of the watershed. As shown on Map 15, which depicts the topography of the surface of the bedrock, the Silurian dolomite was eroded prior to deposition of the glacial till so as to exhibit an overall downward slope in a northeasterly direction—a feature similar to that of the present surface topography of the watershed.

Quaternary Deposits: Unconsolidated deposits of boulders, gravel, sand, silt, and clay overlie the sedimentary rocks. These were deposited during the Pleistocene age by continental glaciers that last covered the watershed about 11,000 years ago. The deposits can be classified according to their origin into till and stratified drift. Till, a heterogeneous mixture of clay, silt, sand, gravel, and boulders, was deposited from ice without the sorting action of water. Most of the watershed is overlain by till in the form of ground moraine. Stratified drift consists primarily of sand and gravel that were sorted and deposited as outwash by glacial meltwater. Local deposits of stratified drift may exist in the watershed in the form of outwash sand and gravel. As shown on Map 16, the thickness of the unconsolidated deposits in the Kinnickinnic River watershed is variable ranging from 100 to 250 feet.

Map 15

TOPOGRAPHY OF THE SURFACE OF THE BEDROCK IN THE KINNICKINNIC RIVER WATERSHED

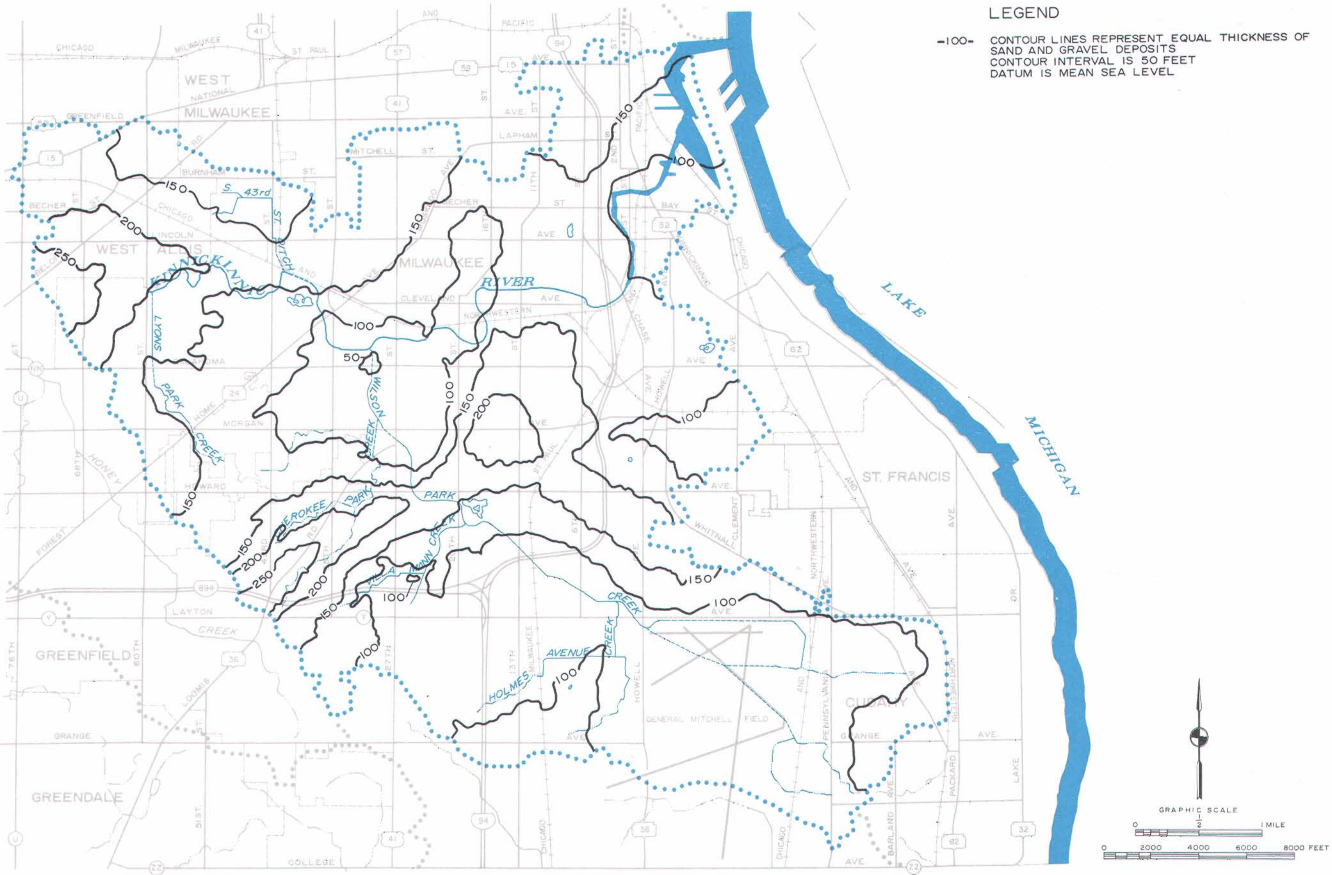


The surface of both the bedrock and the dolomite aquifer is located from 100 to 250 feet beneath the ground surface of the Kinnickinnic River watershed. This bedrock surface dips generally downward in a northeasterly direction across the watershed at about 40 feet per mile. Topographic variations on the surface of the bedrock probably reflect preglacial water and wind erosion. The relatively impermeable Maquoketa shale is positioned immediately below the dolomite unit, whereas unconsolidated glacial till, drift, and alluvial deposits lie immediately above the unit.

Source: U. S. Geological Survey.

Map 16

THICKNESS OF GLACIAL DEPOSITS IN THE KINNICKINNIC RIVER WATERSHED



The thickness of the glacial deposits which form the surface of the watershed and which are composed of clay, silt, sand, gravel, and boulders is available throughout the basin. Thickness varies from a low of about 100 feet, which occurs in the center of the watershed and along its eastern and southern extremities, to a maximum of about 250 feet, which occurs at several points along the western edge of the basin. The thickness of glacial deposits is an important factor in the planning for and design of subsurface utilities and facilities because the thickness determines whether such facilities will be constructed above or within the underlying bedrock.

Source: U. S. Geological Survey and SEWRPC.

Holocene materials consist of recent alluvium and marsh deposits. They occur only along streams and in marshy areas and constitute a very small fraction of the unconsolidated deposits covering the watershed land surface.

Abandoned Sand and Gravel Pits and Quarries: Inactive sand and gravel deposits and dolomite quarries, and more particularly the excavations left as a result of the mining operations, have the potential to serve a variety of needs in the ever-expanding urban area. The depressions may serve initially as solid waste disposal sites and, upon filling, serve residential, commercial, or industrial land uses. Lakes and ponds developed in the depressions left by sand, and gravel and dolomite operations could complement contiguous public recreational areas or private residential, commercial, or industrial development. Those depressions that are in an urban setting may also serve as storm water detention ponds. Carefully selected inactive sand and gravel pits and dolomite quarries could also be preserved, in whole or in part, as scientific sites, oriented to the study of glacial and bedrock geology, or as historic sites intended to inform visitors of the commercial activities of early inhabitants.

There are no active sand and gravel pits in dolomite quarries in the Kinnickinnic River watershed. There is only one known abandoned sand pit on the east side of S. Pennsylvania Avenue at E. Morris Avenue extended in the City of Cudahy.

Soils

The nature of the soils within the Kinnickinnic River watershed has been determined primarily by the interaction of the parent glacial deposits covering the Region with topography, climate, plants, animals, and time. Within each soil profile, the effects of these soil forming factors are reflected in the transformation of soil material in place, chemical removal of soil components by leaching or physical removal by wind or water erosion, additions by chemical precipitation or by physical deposition, and transfer of some soil components from one part of the soil profile to another.

Soil forming factors, particularly topography and the nature of the parent glacial materials, exhibit wide spatial variations in southeastern Wisconsin, and therefore hundreds of different soil types have developed within the Kinnickinnic River watershed and the Region. In order to assess the significance of these unusually diverse soil types to sound regional development, the Commission in 1963 negotiated a cooperative agreement with the U. S. Soil Conservation Service under which detailed operational soil surveys were completed for most of the Region. The results of the soil survey have been published in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin. The regional soil survey has not only resulted in the mapping of soils within the Region in great detail and provided data on the physical, chemical, and biological properties of the soils, but has also provided interpretations of the soil properties for planning, engineering, agricultural, and resource conservation purposes.

Because of the highly urbanized character of the watershed, detailed soils data are available for only six square miles, or about 24 percent of the total area of the watershed, that portion of the watershed lying south of Layton Avenue. The principal use of the detailed soils data in the Kinnickinnic River watershed planning program was in the preparation of input parameters for hydrologic modeling. This limited use of soils data in the Kinnickinnic River watershed planning program differs from earlier studies of other watersheds having large amounts of land in rural use. In the other watershed studies the soils data were not only used extensively in the hydrologic and hydraulic simulation modeling but also in the identification of areas having limitations for urban development utilizing onsite waste disposal systems and public sanitary sewer service, identification of prime agricultural lands, and delineation of primary environmental corridors. Because of the absence of soils data for the urbanized areas of the watershed, the nature of the underlying soils as needed for hydrologic modeling purposes was deduced from the character of the soils and the physiography of contiguous areas for which detailed soils data were available.

Water Resources

Surface water resources, consisting of streams and associated floodlands, form the singularly most important element of the natural resource base of the watershed. Their contribution to the economic development, recreational activity, and aesthetic quality of the watershed is immeasurable. The groundwater resources of the Kinnickinnic River watershed are hydraulically connected to the surface water resources, inasmuch as they provide the base flow of streams. The groundwater resources, along with Lake Michigan, constitute the major sources of supply for domestic, municipal, and industrial water users. Indeed, together with the abatement of flooding, the protection, enhancement, and proper development of these invaluable water resources constitute the basis for mounting the Kinnickinnic River watershed study.

Surface Water Resources: None of the 100 major lakes—that is, lakes of 50 acres or more in surface area in southeastern Wisconsin—is located in the Kinnickinnic River watershed. The absence in the heavily populated Kinnickinnic River watershed of lakes capable of supporting reasonable recreational use with little degradation of the resource is significant in that it means that recreational pressures will be more heavily exerted on the watershed stream system and on streams and lakes in adjacent watersheds. There are several small offstream ponds in the watershed, the largest of which are in Milwaukee County parklands and consist of the Jackson Park Pond (8.1 acres in area), the Kosciuszko Park Pond (2.9 acres), the Wilson Park Pond (8.8 acres), the Humboldt Park Pond (4.6 acres), the Saveland Park Pond (0.5 acres) and the Holler Park Pond (0.3 acres). The largest privately owned pond is at the former Tuckaway Country Club (0.6 acres). The lack of large inland lakes and attendant recreational opportunities is offset by the proximity of the watershed to Lake Michigan, an enormous body of fresh water with great recreational potential.

Streams: One of the most interesting, variable, and occasionally unpredictable features of the watershed is its river and stream system with its ever changing, sometimes widely fluctuating, discharges and stages. The stream system of the watershed receives a relatively uniform flow of water from the shallow groundwater reservoir underlying the watershed. This groundwater discharge constitutes the baseflow of the streams. The streams also periodically receive surface water runoff from rainfall and snowmelt. This runoff, superimposed on the baseflow, sometimes causes the streams to leave their channels and occupy the adjacent floodplains. The volume of water drained annually from the watershed by the stream system is equivalent to about 14.8[7] inches of water spread over the watershed, amounting to about one-half of the average annual precipitation.

Perennial streams are defined herein as those streams which maintain at least a small continuous flow throughout the year except under unusual drought conditions. Within the watershed there are 18.12 lineal miles of such perennial streams, as listed in Table 15. The detailed study of portions of the perennial stream system within the watershed comprises an important element of the watershed planning effort, and subsequent chapters of this report will develop and describe the important interrelationships between the stream system and other natural and man-made elements of the watershed.

Floodlands: The natural floodplain of a river is a wide, flat to gently sloping area contiguous with and usually lying on both sides of the channel. The floodplain, which

[7] *Determined using the hydrologic-hydraulic model described in Chapter VIII.*

Table 15

PERENNIAL STREAMS IN THE KINNICKINNIC RIVER WATERSHED

Perennial Stream	Tributary to:	Upstream End	Length[a] (miles)	Community or Communities in Which Stream is Located
Kinnickinnic River.	Milwaukee River	S. 60th Street	8.05	Cities of Milwaukee and West Allis
Wilson Park Creek	Kinnickinnic River	End of Channelization in General Mitchell Field	5.25	City of Milwaukee
Lyons Park Creek	Kinnickinnic River	W. Forest Home Avenue (STH 24)	1.31	City of Milwaukee
West Milwaukee Ditch . .	Kinnickinnic River	S. 50th Street Extended	1.10	City of Milwaukee, Village of West Milwaukee
Villa Mann Creek.	Wilson Park Creek	W. Armour Avenue Extended	1.24	Cities of Greenfield and Milwaukee
Holmes Avenue Creek . .	Wilson Park Creek	W. Edgerton Avenue Extended	1.17	City of Milwaukee
Total	--	--	18.12	--

[a] *Total perennial stream length as determined from U. S. Geological Survey quadrangle maps supplemented with field surveys by the SEWRPC staff.*

Source: SEWRPC.

is normally bounded on its outer edges by higher topography, is gradually formed over a long period of time by the river during flood stage as that river meanders in the floodplain, continuously eroding material from concave banks of meander loops while depositing it on the convex banks. A river or stream may be expected to occupy and flow on its floodplain on the average of approximately once every two years, and therefore the floodplain should be considered as an integral part of a natural stream system.

How much of the natural floodplain will be occupied by any given flood will depend upon the severity of that flood, and more particularly, upon its elevation or stage. Thus, an infinite number of outer limits of the natural floodplain may be delineated, each related to a specified flood recurrence interval. The Southeastern Wisconsin Regional Planning Commission recommends, therefore, that the natural floodplains of a river or stream be more specifically defined as those corresponding to a flood having a recurrence interval of 100 years, with the natural floodlands being defined as consisting of the river channel plus the 100-year floodplain.

A floodway is that designated portion of the regulatory floodlands required to convey the 100-year recurrence interval flood discharge. The floodway, which includes the channel, is that portion of the floodlands not suited for human habitation. All fill, structures, and other development that would impair floodwater conveyance by adversely increasing flood stages or velocities, or would itself be subject to flood damage, should be prohibited in the floodway.

The floodplain fringe is that portion of the regulatory floodplain lying outside of the floodway. Floodwater depths and velocities are small in this regulatory area relative to the floodway and, therefore, in a developed urban area further development may be permitted, although restricted and regulated so as to minimize flood damage. Because the regulatory floodway may result in increases in the stage of the regulatory flood relative to that which would occur under natural conditions, the floodplain fringe may include at its edges areas that would not be subject to inundation under natural conditions, but would be subject to inundation under regulatory floodway conditions.

The delineation of the natural floodlands in rural or largely undeveloped watersheds is extremely important to sound planning and development. Flood hazard delineations have many practical uses including identification of areas not well suited to urban development but possible prime locations for needed park and open space areas, identification of flood hazard areas possibly requiring structural or nonstructural floodland management measures, delineation of hazard areas for flood insurance purposes, and provision of stage and probability data needed to quantify flood damages in monetary terms.

Even though the Kinnickinnic River watershed is largely urbanized and, therefore, there is minimal opportunity to use flood hazard delineation and related data to identify park and open space areas, the flood hazard delineations developed under the Kinnickinnic River watershed planning program were extremely valuable for the other applications identified above. The flood hazard delineation procedures are described in Chapter VIII, whereas the various applications of the flood hazard data are discussed in Chapter XII.

Groundwater Resources: The Kinnickinnic River watershed is richly endowed with groundwater resources. Although groundwater is the source of water supply for some industries, the domestic water supply for essentially all of the 165,000 people who reside in the watershed is provided by Lake Michigan. Gradual discharge from the groundwater reservoir supplies the baseflow to the Kinnickinnic River and its tributaries.

The amount of groundwater stored in the rocks directly beneath the Kinnickinnic River basin is enormous, and is estimated to exceed four million acre-feet, a quantity sufficient to cover the entire watershed to a depth in excess of 250 feet. Unlike the surface water system of the Kinnickinnic River watershed, which is largely independent of the surface water systems of adjacent watersheds, groundwater located directly below the watershed is an integral part of the groundwater system that lies beneath southeastern Wisconsin. Therefore, proposed groundwater withdrawals within the Kinnickinnic River watershed must be evaluated with regard to their impact on the regional groundwater system.

Rock units that yield water in usable amounts to pumped wells and in important amounts to lakes and streams are called aquifers. The aquifers beneath the watershed differ widely in water yield capabilities and extend to great depths, probably attaining a thickness in excess of 2,200 feet in the lower portion of the watershed. Three major aquifers exist in the Kinnickinnic River watershed. These are, in order from land surface downward: 1) the sand and gravel deposits in the glacial drift; 2) the shallow dolomite strata in the underlying bedrock; and 3) the Cambrian and Ordovician strata, composed of sandstone, dolomite, siltstone, and shale. Because of their relative nearness to the land surface, the first two aquifers are sometimes called the "shallow aquifers" and the latter the "deep aquifer." Wells tapping these aquifers are referred to as shallow or deep wells, respectively.

The occurrence, distribution, movement, use, and quality of groundwater resources and their relationship with surface water resources and other elements of the planning study are discussed in subsequent chapters of this report.

Wildlife and Wildlife Habitat

Various forms of wildlife are desirable in highly urbanized areas such as the Kinnickinnic River watershed because of their aesthetic values, their importance in the ecological system, their educational value, and their enhancement of certain recreational activities. The location, extent, and quality of wildlife habitat areas and the type of wildlife characteristic of those areas are, therefore, important determinants of the overall quality of the environment in the watershed.

The complete spectrum of wildlife species originally native to the watershed has, along with its habitat, undergone tremendous alteration since settlement of the watershed by Europeans. The change is the direct result of an extreme conversion of the basic environment, beginning with the clearing of forests and prairie and the draining of wetlands and ending with extensive urbanization. This process, which began in the early nineteenth century when European settlers began to develop the watershed, still operates today although it functions at a decreasing rate as measured by the conversion of land from rural to urban land uses in recent decades. Many of these land use changes and the cultural activities subsequently superimposed on those changes have proceeded with little explicit concern for wildlife and their habitat. The resiliency of wildlife to such impact is truly remarkable, but a tremendous toll has been taken. Inexorably the minimum life requirements have disappeared over much of the watershed and, as a result, only remnants remain to continue a precarious existence. The wildlife and wildlife habitat loss is only part of a much greater loss of diversity that is characteristic of some urbanizing areas.

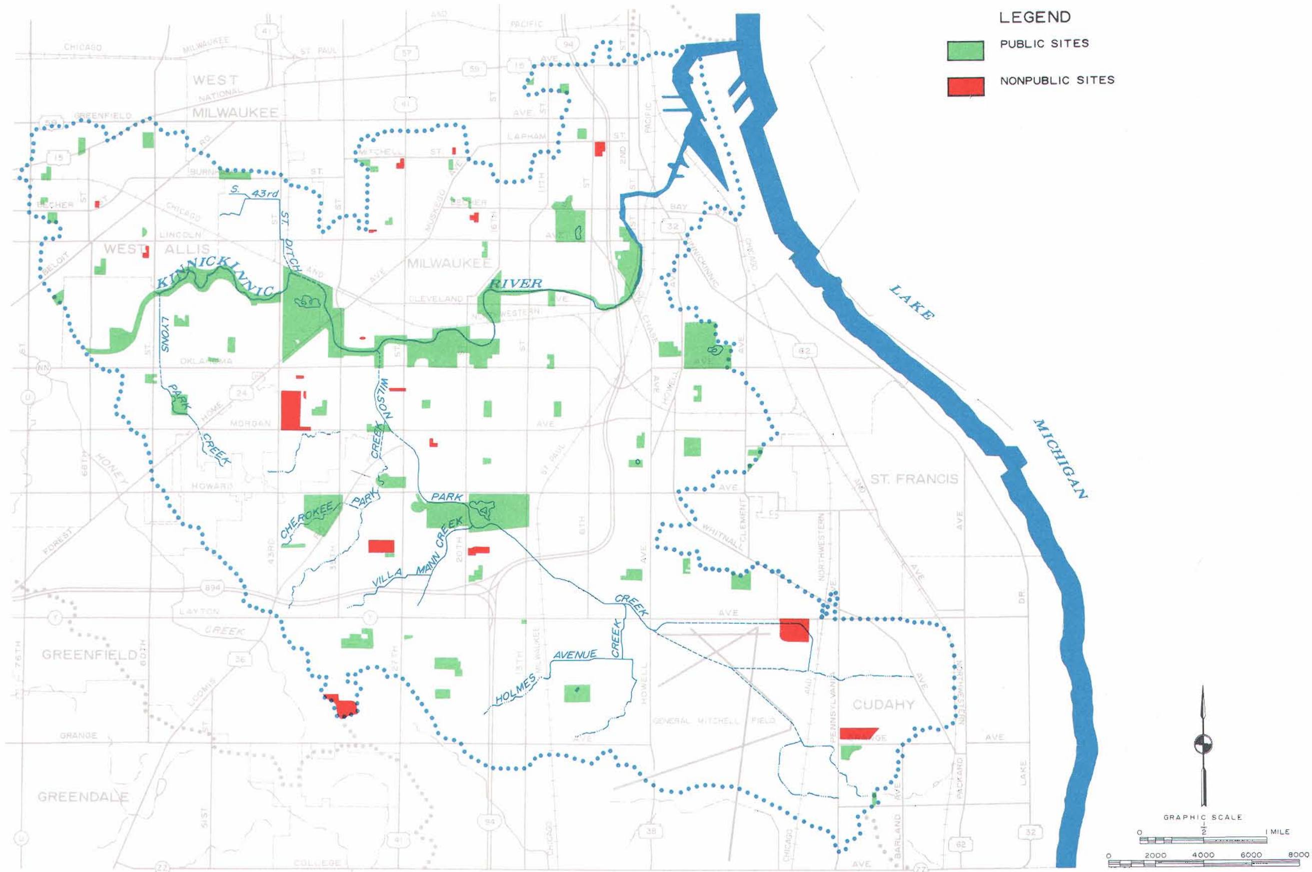
Habitat: The precise areal extent of any particular wildlife habitat is indeterminable. While the wildlife within a given habitat may concentrate most of their activities in a particular wooded area or in and along a given stream reach that constitutes the principal element in the habitat and can be delineated with some precision, even in an urban area their normal range may extend into contiguous surrounding open space and residential areas, the extent of which cannot be precisely delineated.

The remnant wildlife habitat areas in the Kinnickinnic River watershed are concentrated in and around existing park and related open space sites as shown on Map 17 and in other open space areas in the basin. Moderate quality wildlife habitat—considerable disturbance and low plant and animal diversity—exists in the Milwaukee County parklands located along the Kinnickinnic River, particularly the 2.55-mile-long reach bounded at the upstream end by S. 60th Street and at the downstream end by S. 35th Street. Although portions of this area have been changed from a strictly natural state by park development and use, this continuous, linear portion of the watershed exhibits reasonably good plant and animal diversity. Other moderate quality wildlife habitats exist in the watershed in the larger County parks such as Humboldt Park, Wilson Park, and Cherokee Park. Low quality wildlife habitats—remnant or markedly deteriorated former wildlife habitat area—are also found in the watershed. Examples include the open space lands along Wilson Park Creek and the area along the Kinnickinnic River downstream of S. 6th Street.

Wildlife: The watershed remnant wildlife population consists of amphibians and reptiles, birds, mammals, and fish. Examples of amphibians still likely to be found in

Map 17

EXISTING PARK, OUTDOOR RECREATION, AND RELATED OPEN SPACE SITES IN THE KINNICKINNIC RIVER WATERSHED: 1973



A total of 97 park, outdoor recreation, and related open space sites encompassing 1,113 acres exist in the Kinnickinnic River watershed. About 89 percent of this land is owned by public entities such as the county, cities, and school systems. The remainder of park, outdoor recreation, and related open space sites are owned by nonpublic entities such as parochial schools and private clubs. About 75 percent of the publicly owned land is within the Milwaukee County park system.

Source: SEWRPC.

the watershed include frogs, toads, and salamanders, whereas turtles and snakes are examples of reptiles likely to be found, although only infrequently, in this basin.

A large number of birds, ranging in size from large gamebirds to small song birds, are found in the Kinnickinnic River watershed. Gamebirds which are occasionally found in the watershed include the pheasant, ducks, and coots. Hawks and owls function as major rodent predators within the ecosystem whereas swallows, whip-poor-wills, woodpeckers, and nuthatches, as well as several other species of birds found in the watershed, serve as major insect predators. In addition to their ecological roles, birds such as robins, orioles, cardinals, blue jays, and mourning doves serve as subjects for birdwatchers and photographers. Not all birds are viewed as an asset from an ecological, economic, or aesthetic point of view. As a result of urbanization, and therefore the loss of natural habitat, conditions have become less compatible for the more desirable bird species. English sparrows, starlings, grackles, and pigeons have replaced the more desirable birds in most areas of the watershed because of their tolerance for urban conditions.

Mammals likely to be common to fairly common in the watershed include cottontail rabbit, gray squirrel, bats, muskrat, weasel, raccoon, skunk, oppossom, mice, and rats. Bats, despite their appearance and nocturnal habits, generally have a positive impact on the urban environment in that they are major insect predators, often consuming up to one-third their weight in insects a night. Some of the mammals likely to be found in the Kinnickinnic River watershed, particularly rats and mice, may serve as carriers of diseases.

Concluding Statement: Wildlife and Their Habitat: As a result of urban activity and the associated decrease in woodlands, wetlands, and other natural areas, wildlife habitat in the Kinnickinnic River watershed has been almost eliminated. The habitat that remains consists primarily of Milwaukee County Parklands and other open space lands. Most of the remaining habitat has been modified or has deteriorated as a result of advancing urban development.

As a consequence of the decrease in wildlife habitat, the wildlife population within the watershed has decreased. The fish, amphibian, reptile, bird, and animal species once abundant to the watershed have diminished in type and quantity. Certain wildlife species, such as some songbirds, have the capacity to exist in a small island of undeveloped land within the urban complex or to adapt to the urban landscape, but this characteristic is not generally shared by most wildlife.

The most important consideration in maintaining and even increasing the existing remnants of wildlife in the watershed lies in providing a land use pattern within the watershed that preserves the remaining good habitat and perhaps creates additional habitat. It is also necessary to constantly remember that all wildlife species are dependent in one way or another on each other. This means that the loss of habitat for one species has an adverse effect on certain other species, even though the required habitat for these other species remains.

Park, Outdoor Recreation, and Related Open Space Sites

Existing Sites: An inventory of the existing parks, outdoor recreation areas, and related open space sites was conducted within the Region and the watershed during 1973, under the regional park outdoor recreation and related open space planning program of the Commission. This inventory indicated a total of 98 existing park, outdoor recreation, and related open space sites within the watershed, totaling 1,113 acres (1.74 square mile), or about 7 percent of the total area of the watershed.[8] The

[8] *The 1.74 square miles of "existing park, outdoor recreation and related open space sites" in the watershed as inventoried in 1973 under the Commission's regional park, outdoor recreation, and related open space planning program is 0.48 square miles, or 38 percent, greater than the 1.26 square miles of "park and recreation" land inventoried in 1975 under the Commission's continuing land use-transportation study. This difference is primarily attributed to an ownership-based definition of park, recreation, and open space used in the former inventory, contrasted with a land use-oriented definition of park and recreation in the latter inventory. For example, a parking lot owned by a county and contained within a county park was considered part of a park, recreation, and open space site in the 1973 park and recreation study inventory, but was not, because of the primary use being parking as opposed to recreation, so included in the 1975 land use inventory.*

Table 16

EXISTING PARK, OUTDOOR RECREATION, AND RELATED OPEN SPACE SITES WITHIN THE KINNICKINNIC RIVER WATERSHED: 1973

Ownership	Number of		Percent of Public		Percent of Nonpublic		Percent of Total	
	Sites	Acres	Sites	Acreage	Sites	Acreage	Sites	Acreage
Public								
County	20	745	25.0	75.1	--	--	20.4	66.9
City	21	69	26.3	7.0	--	--	21.4	6.2
School District	39	178	48.7	17.9	--	--	39.8	16.0
Subtotal	80	992	100.0	100.0	--	--	81.6	89.1
Nonpublic								
Organizational	14	60	--	--	77.8	49.6	14.3	5.4
Commercial	3	46	--	--	16.7	38.0	3.1	4.1
Private (restricted)	1	15	--	--	5.5	12.4	1.0	1.4
Subtotal	18	121	--	--	100.0	100.0	18.4	10.9
Total	98	1,113	--	--	--	--	100.0	100.0

Source: SEWRPC.

distribution of these sites by ownership is shown in Table 16. The spatial distribution of existing parks, outdoor recreation areas, and related open spaces is shown on Map 17, while Figure 11 illustrates the relative size of such areas to the watershed as a whole and also facilitates a comparison of public and private holdings.

Of the total 98 sites, and 1,113 acres of existing park, outdoor recreation, and related open space in the watershed, public ownership accounts for 80 sites covering 992 acres, or 89 percent of the total acreage. Nonpublic ownership accounts for the remaining 18 sites encompassing 121 acres, or 11 percent of the total acreage. Of the 992 acres of park, outdoor recreation, and related open space sites in public ownership, about 75 percent is owned by Milwaukee County, and most of that consists of parkway lands along the Kinnickinnic River.

The nonpublic recreation sites, consisting of private, organizational, and commercially operated recreational lands, account for about 19 percent of the number of sites in the watershed but only 11 percent of the acreage. About 50 percent of the nonpublic acreage, or 60 acres, is owned by organizations such as parochial schools and private clubs. About 38 acres are operated on a profit-making commercial basis.

Potential Sites: According to an inventory of potential outdoor recreation and related open space sites which was also conducted within the Region during 1974 under the Commission's regional park, outdoor recreation, and related open space planning program, no potential recreation and related open space sites exist in the heavily urbanized Kinnickinnic River watershed. It may, however, be possible to expand existing neighborhood parks or riverine area parkways to better meet the outdoor recreational needs of watershed residents.

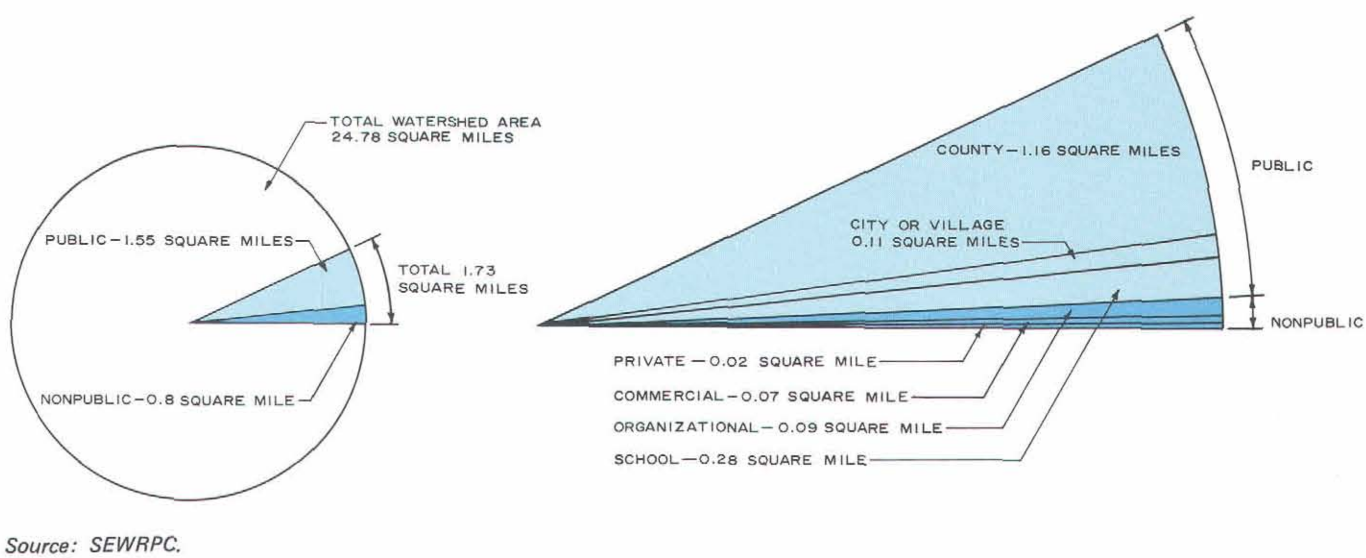
Environmental Corridors

The Corridor Concept: One of the most important tasks completed under the regional planning effort to date has been the identification and delineation of those areas of the Region in which concentrations of recreational, aesthetic, ecological, and cultural resources occur and which, therefore, should be preserved and protected. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and natural beauty of the Region.

1. Lakes, rivers, and streams and their associated floodlands.
2. Wetlands.
3. Woodlands.
4. Wildlife habitat areas.
5. Rugged terrain and high-relief topography.
6. Significant geological formations and physiographic features.
7. Wet or poorly drained soils.

Figure 11

AREAL EXTENT OF EXISTING PARK, OUTDOOR RECREATION, AND RELATED OPEN SPACE SITES IN THE KINNICKINNIC RIVER WATERSHED BY OWNERSHIP: 1973



Source: SEWRPC.

Although the foregoing elements comprise the integral parts of the natural resource base, there are four additional elements which, although not a part of the natural resource base per se, are closely related to or centered on that base and are a determining factor in identifying and delineating areas with scenic, recreational, and historic value. These additional elements are:

1. Existing outdoor recreation sites.

2. Potential outdoor recreation and related open space sites.

3. Historic sites and structures.

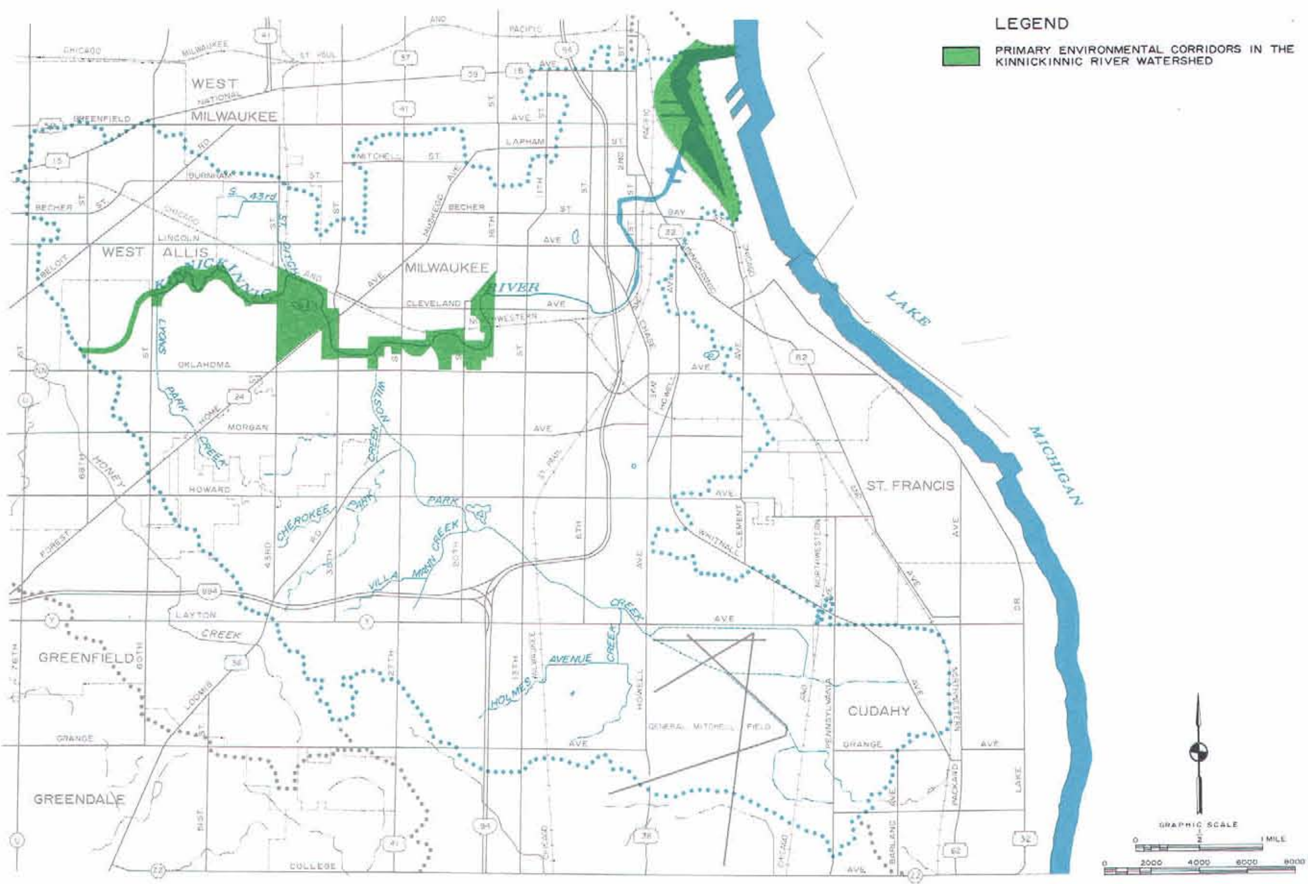
4. Significant scenic areas and vistas.

The delineation of these natural resource and natural resource-related elements on a map of the Region results in an essentially lineal pattern encompassed in narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors are defined as those areas which generally encompass three or more of the aforementioned 11 environmental elements, whereas secondary environmental corridors are contiguous areas exhibiting one or two of the 11 necessary elements.

Watershed Environmental Corridors: The primary environmental corridors existing within the Kinnickinnic River watershed were delineated by the Commission in 1964 during preparation of the initial land use plan for the Region. The corridor delineation has since been refined as a result of the land use plan reevaluation which analyzed the changing land uses within the net primary environmental corridors. As shown on Map 18, the primary environmental corridors of the Kinnickinnic River watershed, most of which lie along the Kinnickinnic River, were found to occupy approximately 558 gross acres, or about 3 percent of the total area of

Map 18

PRIMARY ENVIRONMENTAL CORRIDORS IN THE KINNICKINNIC RIVER WATERSHED: 1970



Primary corridors encompass, by definition, almost all of the remaining woodlands and habitat areas, almost all of the streams and associated undeveloped floodlands, and many of the significant topographic, geologic, and historic features of a watershed. What remains of the ecologic, aesthetic, recreational, and cultural resources of the Kinnickinnic River watershed is concentrated in the indicated primary environmental corridors. The preservation of these corridors in compatible open space uses—and perhaps even the restoration of portions of the corridor—is essential to maintain the quality of the urban environment that dominates the watershed.

Source: SEWRPC.

the watershed. The gross primary environmental corridor area is defined as including all land uses, both urban and rural, whereas the net primary environmental corridor area is defined as the gross corridor acreage minus the noncompatible urban land use acreages in the corridor. Net corridor areas consist of recreation land use, agricultural and related land uses, water, wetlands and woodlands uses, and other open space land uses. Net primary corridor areas in the watershed total nearly 412 acres, or 2.5 percent of the watershed area.

A very narrow gross environmental corridor consisting of lake, beach, and bluff exists along the entire length of the Lake Michigan shoreline in the Region. A portion of that corridor crosses the watershed near the outlet. Although certainly not a "natural area," this eastern extremity of the watershed is considered a part of the lakeshore corridor because of a combination of existing conditions or factors including its role as a link in a continuous lakeshore corridor, the scenic vistas to the east, public access, and places of historic significance. Furthermore, because of recreational boating and fishing opportunities available on Lake Michigan and in the outer harbor, there is the potential to create urban-oriented "green areas" contiguous with the lakeshore and within the designated corridor.

The primary environmental corridor lands along the Kinnickinnic River are largely coincident with the public parks and parkways of the Milwaukee County park system and are available for general recreational use. This corridor connects to the west with the primary environmental corridor of the Menomonee River watershed.

The preservation of the primary environmental corridors from further encroachment of degradation is one of the principal objectives of the adopted regional land use plan upon which the Kinnickinnic River in the watershed plan is based. The net primary environmental corridor along the Kinnickinnic River in the watershed is considered permanently preserved, at least as to areal extent, because of the public ownership.

SUMMARY

The Kinnickinnic River watershed is a complex of natural and man-made features that interact to provide a changing environment for human life. Future changes in the watershed ecosystem and the favorable or unfavorable impact of those changes on the quality of life within the watershed will be largely determined by human actions. The Kinnickinnic River watershed planning program seeks to rationally direct those actions so as to favorably affect the overall quality of life in the watershed. This chapter describes the natural resource base and man-made features of the watershed, thereby establishing a factual base upon which the watershed planning process may be built.

The man-made features of the watershed include its political boundaries, its land use pattern, its public utility network, and its transportation system. These features along with the resident population and the economic activities within the watershed may be thought of as the socioeconomic base of the watershed.

The 24.78 square mile Kinnickinnic River watershed comprises 1 percent of the Southeastern Wisconsin Planning Region and is the second smallest of the 11 distinct watersheds located wholly or partly within the Region. This highly urbanized basin is located entirely within Milwaukee County and in portions of five cities—Cudahy, Greenfield, Milwaukee, St. Francis, and West Allis—and one village—West Milwaukee.

The Metropolitan Sewerage District of the County of Milwaukee, with its service area encompassing the entire Kinnickinnic River watershed, has important responsibilities providing sanitary sewer service and sewage treatment for water pollution control and for drainage and flood control within the basin.

The 1975 resident population of the watershed was estimated at about 165,000 persons, or 16 percent of the population of Milwaukee County and about 9 percent of the total population of the Region. From 1900 to 1960, Kinnickinnic River watershed population growth rates generally have paralleled those of the City of Milwaukee, Milwaukee County, and the Region. However, from 1960 to 1975, the watershed decreased in population at rates similar to those of the City of Milwaukee, while the regional population continued to increase. Population densities range from less than 350 persons per gross square mile in scattered portions of the basin to a maximum of 22,000 persons per square mile in highly urbanized northern portions of the watershed. Median age in the watershed exceeds that for the Region, whereas household size and household income are below that for the Region indicating that older, smaller family units with below average incomes reside in the watershed in contrast with younger, larger family units having above average incomes which reside in the new urban areas on the fringes of the Milwaukee Metropolitan area.

Total employment in the watershed in eight major industrial groups is estimated at 77,000, with 45 percent of that employment being in the manufacturing sector. The principal type of manufacturing is electrical machinery, which accounts for one-third of all manufacturing within the basin.

The sheltered harbor provided by the confluence of three rivers attracted early European settlers in the 1830's and has since been an important factor in the cities' and watershed's commerce. Urbanization has generally occurred in expanding, concentric rings emanating outward from the historic urban centers near the confluence of the Kinnickinnic, Menomonee, and Milwaukee Rivers. Urbanization proceeded very rapidly until about 1963 at which time 84 percent of the watershed was categorized as urban development. During the 1963 to 1975 period, additional urban development occurred in the watershed but at a rate less than that experienced earlier.

As of 1975, 24 square miles, or 92 percent of the watershed area, were urban as opposed to rural in land use. The dominant land use in the watershed is residential, which encompasses 8.9 square miles, or 35 percent of the watershed area, and the transportation-communication-utility facility category which encompasses over 9.1 square miles, or 36 percent of the watershed area.

The watershed's public utility base is composed of its sanitary sewerage systems, water supply systems, electric power service, and gas service. Adequate supplies of both electric power and natural gas are available or could be readily provided to all areas of the watershed. The watershed is completely served by public sanitary sewerage facilities in that sanitary sewage from the entire basin is collected and transmitted for treatment and disposal to the Jones Island and South Shore treatment plants located outside of the watershed on the shore of Lake Michigan. A 4.54 square mile portion of the watershed—18 percent of the total area of the basin—is served by a combined sewer system that is part of a large contiguous 27 square mile combined sewer service area in Milwaukee County. Public water supply systems serve the entire Kinnickinnic River watershed. The Milwaukee Water Works provides direct service on a retail basis to water users in the Cities of Milwaukee, Greenfield, and St. Francis and the Village of West Milwaukee and provides wholesale service to the West Allis Water Utility. The Cudahy Water Department operates a complete and independent water supply system. These three public water utilities utilize Lake Michigan as a source.

The watershed is well served by an extensive all-weather street and highway system, including 8.3 lineal miles of freeway. Two types of bus service are available in the watershed: urban mass transit and intercity bus service. Urban mass transit service is provided to the entire watershed. Railroad service in the watershed is limited to freight hauling, except for scheduled Amtrack passenger service over lines of the Milwaukee, St. Paul & Pacific Railroad Company (Milwaukee Road) between Union Station, lying north of the watershed in Milwaukee, and Chicago to the south. An active commercial shipping operation, handling bulk materials such as coal, salt, liquid cargoes, and scrap metals exists along the 1.67 mile Kinnickinnic River reach downstream of Becher Street in the City of Milwaukee. Most of General Mitchell Field, the only scheduled air transport airport in the seven-county planning region, lies within the basin. The development at Mitchell Field began in 1926 and by 1976 the airport had grown to 2,100 acres and is currently served by eight major airlines—North Central, United, Eastern, Northwest Orient, Hughes Airwest, Southern, Braniff, and Ozark.

The natural resource base of the watershed is a composite of climate, physiography, geology, soils, water resources, and fish and wildlife resources. Inasmuch as the underlying and sustaining natural resource base is highly vulnerable to misuse and destruction, management of the remnants of that resource base must be a primary consideration in the Kinnickinnic River watershed planning effort.

Because of its midcontinental location, far removed from the moderating effect of the oceans, the Kinnickinnic River watershed has a climate characterized by a progression of markedly different seasons. An essentially continuous pattern of distinct weather changes occurring at about three day intervals is superimposed on the seasonal pattern. Air temperatures in the watershed range from a daily average of about 20°F in January to 72°F in July. Watershed temperature extremes have ranged from a low of about - 25°F to a high of approximately 105°F. The eastern portion of the watershed exhibits lakeshore temperature characteristics such as summer average daily maximum temperatures 2°F to 3°F lower than those experienced in the western portion of the basin which exhibits inland temperature characteristics.

Average annual precipitation within the watershed is 30.1 inches expressed as water equivalent, and average monthly amounts range from a low of 1.25 inches in February to a high of 3.64 inches in June. The average annual amount of snow and sleet expressed as snow and sleet is 44.3 inches which, when converted to its water equivalent, constitutes 15 percent of the total annual precipitation. About 91 percent of the annual snowfall occurs in the four months of December, January, February, and March. Annual total precipitation in the vicinity of the watershed has varied from a low of 17 inches to a high of 50 inches. Snowfall has, relative to the annual average, historically exhibited a wider variation than total precipitation, with the annual snowfall ranging from a low of five inches to a high of approximately 109 inches. As a result of its proximity to Lake Michigan, the eastern part of the watershed experiences an average of about 10.7 inches more seasonal snow and sleet accumulations than does the western part of the watershed.

With respect to snow cover, there is a 0.25 probability of having five or more inches of snow on the ground during January and the first half of February. A minimum of six or more inches of frozen ground normally exists in the watershed during January, February, and the first half of March. Annual potential evaporation in the watershed is about 29 inches and is approximately equal, both annually and seasonally, to precipitation. Prevailing winds follow a clockwise pattern in terms of prevailing direction over the seasons of the year, being northwesterly in the late fall and winter, northeasterly in the spring, and southwesterly in the summer and early fall.

Daylight in the watershed ranges from a minimum of 9.0 hours on about December 22nd to a maximum of 15.4 hours on about June 21st. The smallest amount of daytime sky cover occurs from July through October, when the mean monthly daytime sky cover is approximately 0.5, whereas a sky cover of about 0.7 may be expected from November through March.

Watershed topography and physiographic features have been largely determined by the underlying bedrock and overlying glacial deposits. The last of the four major stages of glaciation occurred about 11,000 years ago and was the most influential in sculpturing the watershed land surface. Watershed topography is asymmetrical, with the northeastern border of the watershed being lower—about 200 feet—than the southwestern edge of the basin. Surface elevations within the watershed range from a high of approximately 800 feet above National Geodetic Vertical Datum at a point in the City of Greenfield in the southwest section of the watershed to a low of approximately 580 feet above National Geodetic Datum level in the harbor area—a maximum relief of 220 feet.

Surface drainage within the watershed is very diverse with respect to channel cross-sectional shape, channel slope, degree of stream sinuosity, and floodland shape and width. The heterogeneous character of the surface drainage system is due partly to the natural effect of glacial drift and partly to the extensive channel modifications and other results of urbanization that are evident throughout the basin.

The geology of the Kinnickinnic River watershed is a complex system of various layers and ages of rock formations. These formations slope gently down toward the east, and consist of, in ascending order, predominantly Precambrian crystalline rocks—granite and quartzite; Cambrian through Silurian sedimentary rocks—sandstone, siltstone, dolomite, and shale; and unconsolidated surficial deposits—clay, silt, sand, gravel, and boulders.

Streams and associated floodlands comprise the most important elements of the natural resource base of the watershed, primarily because of the associated aesthetic, recreational, and economic values. There are 18.12 lineal miles of perennial streams within the watershed, and inasmuch as there are no major lakes of 50 acres or more in size in the watershed, these streams along with ponds located in Milwaukee County parks constitute the watershed's surface water resources. Although the delineation of floodlands along the watershed stream system is extremely important to sound planning and development, precise floodland delineations were not, until the conduct of this study, available for the Kinnickinnic River watershed.

Extensive groundwater resources underlie the Kinnickinnic River watershed and are an integral part of the much larger groundwater system that lies beneath the Southeastern Wisconsin Planning Region. The aquifers lying beneath the watershed, which attain a combined thickness in excess of 2,000 feet, may be subdivided so as to identify three distinct groundwater sources. In order from the land surface downward they are the sand and gravel deposits in glacial drift, the shallow dolomite strata in the underlying bedrock, and the deeper bedrock strata composed of sandstone, dolomite, siltstone, and shale. The combined groundwater reservoirs are the source of water supply for some industries while the gradual discharge from the groundwater reservoir supplies the baseflow to the Kinnickinnic River and its tributaries.

As a result of urban activity and the associated decrease in woodlands, wetlands, and other natural areas, wildlife and their habitat have been almost eliminated in the Kinnickinnic River watershed. The habitat that remains consists primarily of Milwaukee County park lands and other scattered small, open space areas. The remaining wildlife resources are particularly significant to the urban Kinnickinnic River watershed because of the recreational, educational, and aesthetic values and because of the element of naturalness and diversity that they impart to the urban environment.

There is a total of 98 park, outdoor recreation, and related open space sites within the watershed, totaling 1,113 acres, or about 7 percent of the watershed area. A watershedwide inventory revealed the existence of no significant potential recreation and related open space sites.

The delineation of selected natural resource and natural resource-related elements on a watershed map produces an essentially lineal pattern encompassed in narrow, elongated areas which have been termed environmental corridors by the Southeastern Wisconsin Regional Planning Commission. As of 1970, gross primary environmental corridors occupied approximately 558 acres, or 3 percent of the watershed area. The preservation of the remaining primary environmental corridors in a natural state or in park and related open space uses is essential to maintain a high level of environmental quality in the Kinnickinnic River watershed.

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Chapter IV

ANTICIPATED GROWTH AND CHANGE IN THE WATERSHED

INTRODUCTION

In any 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 land and water resources in a planning area is determined primarily by the size and spatial distribution of future population and employment levels. 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 in events at regional and local levels. In the preparation of a comprehensive watershed plan, therefore, future population and economic activity levels must be forecast. These forecasts can then be converted to future demand for land and water resources within the watershed, and a land and water use plan can be prepared to meet this demand.

POPULATION AND ECONOMIC ACTIVITY

Forecasts of future population and economic activity within the Kinnickinnic River watershed must consider the setting of the watershed within the urbanizing southeastern Wisconsin Region. As described in SEWRPC Planning Report No. 25, A Regional Land Use Plan and A Regional Transportation Plan for Southeastern Wisconsin—2000, Volume Two, Alternative and Recommended Plans, an overall regional population forecast was prepared. Individual population forecasts then were developed for each of the seven counties comprising the Region. Specific assumptions about migration, fertility, and mortality were developed for each county, based upon historic trends in that county and assumptions about future trends. From the county forecasts, local analysis areas designated by the Commission were allocated a forecast population. The population forecast for the Kinnickinnic River watershed was prepared using these planning analysis area forecasts as allocated on a quarter section basis through the regional land use planning process.

Forecasts also must reflect the geographic and political features, the present pattern of historic trends, and the distribution of the population and economic activity within the watershed. As indicated in Chapter III, the City of Milwaukee contains about three-fourths of the watershed area and over 78 percent of the present watershed population. Population growth and changes for the remainder of the watershed are strongly influenced by the City of Milwaukee. Similarly, economic activity in the entire watershed is heavily dependent upon employment in the City of Milwaukee and the Milwaukee urbanized area.

Population Forecast

Population forecasts for the Region and for the Kinnickinnic River watershed have been prepared by the Commission to the year 2000. These forecasts are based upon economic as well as demographic studies and upon analysis using several independent methods.[1] Given a continuation of existing trends in population and employment growth and change, the population of the Region may be expected, as shown in Table 17 and Figure 12, to reach a year 2000 level of approximately 2.22 million persons, an increase of about 460,000 persons, or about 25 percent, over the 1970 level of about 1.76 million persons.

As also indicated in Table 17 and Figure 12, the population of the Kinnickinnic River watershed increased steadily from a level of about 104,000 persons in 1920 to about 178,000 persons in 1960, an increase over the 40-year period of about 70 percent. From 1960 to 1975 the population of the watershed decreased from a level of about 178,000 persons in 1960 to about 165,000 persons in 1975, a decrease of about 7 percent over the 15-year period. This level may be expected to decline further by about 5,000 persons to about 160,000 persons by 2000, or about 3 percent below the 1975 population.

A review of the historic relationship between population growth in the watershed and population growth in the Southeastern Wisconsin Region indicates this forecast decline in population to be reasonable. Historically, the watershed has held a declining percentage of the total regional population, decreasing from 13 percent in 1920 to 10 percent in 1970, and it is forecast to decrease further to 7 percent by 2000. This decline in the total regional population located within the Kinnickinnic River watershed reflects the change of migratory patterns from high rates of net in-migration to high rates of net out-migration in the older central communities of the metropolitan area, combined with declining birth rates.

Economic Forecast

Economic activity, considered primarily in terms of employment opportunities, is not linked functionally to watershed patterns within southeastern Wisconsin. Rather, the forces from which economic activity originates and is sustained can come as much or more from outside the watershed as from within the watershed. Employment in Milwaukee County and the watershed is expected to increase during the next three decades but at a rate less than that of the Region as a whole, reflecting a continued decentralization of economic activity from the established urban areas of the Region to suburban and rural locations. As shown on Table 18, employment opportunities within the watershed may be expected to increase by only about 9 percent, or 7,000 jobs, over the next approximately three decades, from about 77,000 jobs in 1972 to 84,000 in 2000. This contrasts with the 36 percent increase in employment that is forecast for the Region as a whole.

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[1] *See SEWRPC Planning Report No. 25, A Regional Land Use Plan and A Regional Transportation Plan for Southeastern Wisconsin—2000, Volume II, Alternative and Recommended Plan, May 1977.*

Table 17

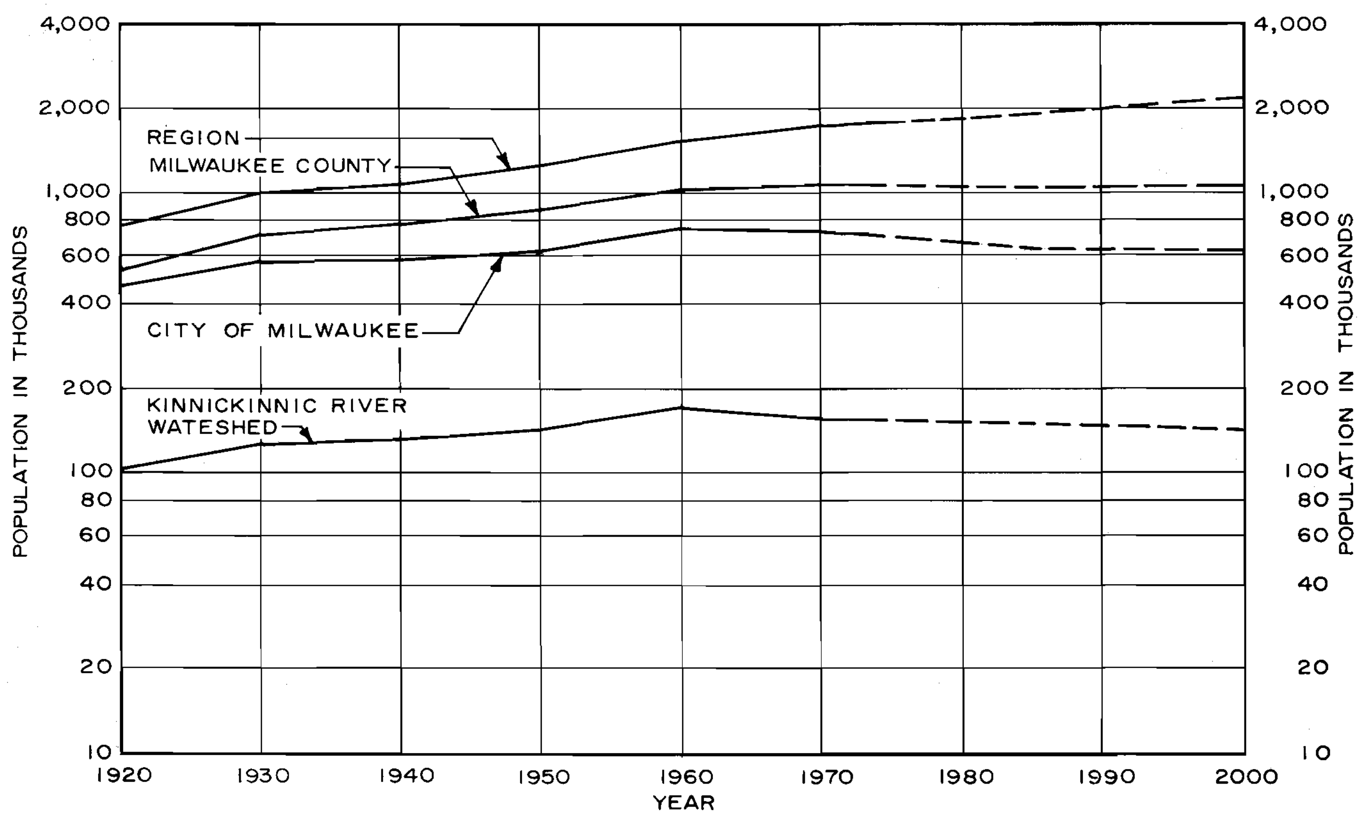
POPULATION TRENDS AND FORECASTS FOR THE REGION, MILWAUKEE COUNTY, THE CITY OF MILWAUKEE, AND THE KINNICKINNIC RIVER WATERSHED: SELECTED YEARS 1920-2000

Year	Southeastern Wisconsin Region	Milwaukee County	City of Milwaukee	Kinnickinnic River Watershed	Watershed Population as Percentage of Regional Population
1920	783,681	539,449	457,157	104,256	13
1930	1,006,118	725,263	578,249	135,645	13
1940	1,067,699	766,885	587,472	139,689	13
1950	1,240,618	871,047	637,392	153,286	12
1960	1,573,620	1,036,041	741,324	177,598	11
1970	1,756,086	1,054,249	717,372	173,914	10
1985	1,954,100	1,015,000	656,000	164,900	8
2000	2,219,300	1,049,600	636,400	159,500	7
1970-2000 Percent Change	26.4	- 0.4	- 11.3	- 8.3	--

Source: U. S. Bureau of the Census and SEWRPC.

Figure 12

POPULATION TRENDS AND FORECASTS FOR THE REGION, MILWAUKEE COUNTY, THE CITY OF MILWAUKEE, AND THE KINNICKINNIC RIVER WATERSHED: 1920-2000



Source: U. S. Bureau of the Census and SEWRPC.

Table 18

EXISTING AND FORECAST EMPLOYMENT WITHIN THE KINNICKINNIC RIVER WATERSHED AND THE REGION: 1972 AND 2000

Area	Estimated 1972 Employment	Forecast 2000 Employment	Change 1972 to 2000	
			Absolute	Percent
Kinnickinnic River Watershed	77,000	84,000	7,000	9.0
Southeastern Wisconsin Region	749,000	1,015,900	266,900	35.6

Source: SEWRPC.

LAND USE DEMAND

The land use pattern and the supporting transportation and utility systems must be planned to meet not only existing demands but the anticipated demand at some future point in time. In land use, transportation, and water resource planning, all require forecasts of population and employment as a basis for plan preparation.

Although the population forecast for the watershed for the year 2000 reflects a net decrease in population due to high rates of out-migration and declining birth rates, some population redistribution within the watershed can nevertheless be expected. The forecast resident watershed population of 160,000 persons in the plan design year may therefore be expected to require the conversion of some additional land from rural to urban use within the watershed.

As discussed in Chapter III, the Kinnickinnic River watershed is almost entirely urbanized, reflecting the historic growth and expansion of the Milwaukee urbanized area. Considering future population and employment demands on the watershed, it would indicate that the remaining "unused" open lands would be virtually fully developed within the next two to three decades.

SUMMARY

The population of the Kinnickinnic River watershed is expected to decrease from the 1975 level of about 165,000 persons to a 2000 level of about 160,000 persons, a decrease of about 5,000 persons, or 3 percent. Over the 28-year period from 1972 to 2000, the number of jobs within the watershed may be expected to increase by about 7,000, or about 9 percent, from about 77,000 in 1972 to about 84,000 in 2000.

Although the population forecast for the watershed for the year 2000 reflects a net decrease in population due to high rates of out-migration and declining birth rates, some population redistribution within the watershed can be expected. This will require the conversion of some land from rural to urban uses. Since the Kinnickinnic River watershed is almost entirely urbanized, most remaining "unused" open lands would be developed by the year 2000.

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Chapter V

HYDROLOGY AND HYDRAULICS

INTRODUCTION

Hydrology may be defined as the study of the physical behavior of the water resource from its occurrence as precipitation to its entry into streams and lakes or its return to the atmosphere via evapotranspiration. In accordance with this definition, an inventory and analysis of the hydrology of a watershed may include consideration of precipitation, evapotranspiration, and other elements of the hydrologic budget; examination of such factors as soil types and land use that affect rainfall-runoff relationships; review of stream gaging records to ascertain the volume and timing of that portion of the precipitation that ultimately reaches the surface water system of the watershed as runoff; and determination of the volume of water that moves to and from and is contained within the aquifers lying beneath the watershed.

Hydraulics may be defined as the study of those factors that affect the physical behavior of water as it flows within stream channels and associated natural floodlands; under and over bridges, culverts and dams; through lakes and other impoundments; and within the aquifer system of the watershed. In accordance with this definition, an inventory and analysis of the hydraulics of a watershed may include examination of the length, slope, flow resistance, and other characteristics of both natural and modified stream reaches within the watershed; determination of the hydraulic significance of the numerous and varied hydraulic structures—bridges, culverts, dams, channelized sections—located throughout the stream system; and determination of the flow characteristics of the aquifers underlying the watershed.

Comprehensive planning for the wise use and development of the land and water resources of the Kinnickinnic River watershed requires knowledge and understanding of the relationships existing among the many natural and man-made features that together comprise the hydrologic-hydraulic system of the watershed. The objective of this chapter is to present a description of the Kinnickinnic River watershed hydrologic-hydraulic system and its behavioral characteristics pertinent to comprehensive watershed planning. An understanding of this system is important to the Kinnickinnic River watershed planning program inasmuch as the system and the processes that occur there form the framework within which all the water resource and water resource-related problems of the watershed must be analyzed and resolved. Because of the interdependence of land use and surface and groundwater quality and quantity, any planned modification to, or development of, one element of the hydrologic-hydraulic system must consider the potential effects on all other elements of the system. Only by considering the hydrologic-hydraulic system as a whole can a sound, comprehensive watershed plan be prepared and the water-related problems of the basin be ultimately abated.

Digital computer simulation was used in the Kinnickinnic River watershed study to accomplish the necessary integrated analysis of the watershed hydrologic-hydraulic system. The primary purpose of inventorying and analyzing the hydrologic and hydraulic data and information as presented in this chapter was to provide the input required by the hydrologic-hydraulic simulation model.

HYDROLOGY OF THE WATERSHED

The Hydrologic Cycle

The quantity and quality of water at a particular location within the Kinnickinnic River watershed may vary greatly from time to time. These variations may occur rapidly or slowly and may occur in the atmosphere, on the land, in the surface waters, or in the groundwater of the watershed. Moreover, these variations may involve water in all its states-solid, liquid, and vapor. This continuous, unsteady pattern of circulation of the water resource from the atmosphere to and under the land surface and, by various processes, back to the atmosphere, is known as the hydrologic cycle.

Precipitation is the primary source of all water in the Kinnickinnic River watershed. Part of the precipitation runs directly off the land surface into stream channels and is ultimately discharged from the watershed; part is temporarily retained in snow packs, ponds, and depressions in the soil or on vegetation, and is subsequently transpired or evaporated, while the remainder is retained in the soil or passed through the soil into a zone of saturation or groundwater reservoir. Some water is retained in the groundwater system; but in the absence of groundwater development, much eventually returns to the surface as seepage or spring discharge into ponds and surface channels. This discharge constitutes the entire natural flow of surface streams in the Kinnickinnic River watershed during extended periods of dry weather.

With the exception of the groundwater in the deep sandstone aquifer underlying the watershed, all of the water on the land surface and underlying the Kinnickinnic River basin generally remains an active part of the hydrologic system. In the deep aquifer, water is held in storage beneath the nearly water-tight Maquoketa shale formation and is, therefore, taken into the hydrologic cycle in only a very limited way. Since the deep aquifer recharge area lies entirely west of the Kinnickinnic River watershed, artificial movement through wells and minor amounts of leakage through the shale beds provide the only connection between this water and the surface water and shallow groundwater resources of the watershed.

The Water Budget: Quantification of the Hydrologic Cycle

A quantitative statement of the hydrologic cycle, termed the water budget, is commonly used to equate the total gain, loss, and change in storage of the water resource in a watershed over a given time period. Water is gained by a basin from precipitation and subsurface inflow, while water loss occurs as a result of evaporation, transpiration, and surface and subsurface outflow. A change in surface and groundwater storage results from an imbalance between inflow and outflow. The complete hydrologic budget applicable to a watershed for any time interval may be expressed by the equation:

$$P - GW - E - T - R = S$$

in which the individual terms are volumes expressed in inches of water over the entire area of the watershed and are defined as follows:

- P = precipitation on the watershed
- GW = net inflow or outflow of groundwater from the aquifer beneath the watershed
- E = evaporation from the watershed[1]
- T = transpiration from the watershed[1]
- R = runoff from the watershed measured as streamflow
- S = net change in total surface and groundwater storage

Quantitative data, however, are normally available for only a few of the elements in the hydrologic budget. Quantitative measurements, or estimates, compiled for the Kinnickinnic River watershed include precipitation, streamflow, evaporation, and groundwater levels; but the records of each of these phenomena are incomplete or of a relatively short duration. It is necessary, therefore, to express the hydrologic budget on an average annual water-year basis in a simplified form which includes the significant components of the hydrologic cycle but excludes those components for which sufficient data are not available. A water-year time frame—October 1 of a given year through September 30 of the following year—is used because the beginning and end of that period normally correspond to low and stable streamflows and groundwater levels; moreover, since water in the deep sandstone aquifer is taken into the hydrologic cycle in only a very limited way, a hydrologic budget for the Kinnickinnic River watershed can be developed considering only the surface and shallow groundwater supplies.

[1]*Evaporation is the process by which water is transformed from the liquid or solid state to the vapor state and returned to the atmosphere. Transpiration is the process by which water in the liquid state moves up through plants, is transformed to the vapor state, and returned to the atmosphere. Evapotranspiration is the sum of the two processes.*

In its simplest form, then, the long-term hydrologic budget for the Kinnickinnic River watershed may be expressed by the equation:

$$ET = P - R$$

where evaporation and transpiration have been combined into one variable, ET, denoting evapotranspiration, and where net groundwater flow out of the watershed has been assumed to be zero, as has the net change in the total surface and groundwater stored within the watershed. Because of seasonal variations in the behavior of the phases of the hydrologic cycle, this simplified equation is not generally valid for time durations of less than a year.

As stated in Chapter III of this report, the average annual precipitation over the watershed is 30.1 inches. Streamflow records of sufficient duration are not available for the Kinnickinnic River watershed to determine the average annual runoff although a continuous recorder streamflow gage was placed in operation in the watershed at the S. 7th Street crossing of the Kinnickinnic River on September 13, 1976, as a part of this watershed study. The average volume of water drained annually from the watershed by the stream system is estimated to be equal to about 14.8 inches of water spread uniformly over the watershed land surface. This estimated average annual water-year runoff was determined, as described in Chapter VIII of this report, using hydrologic-hydraulic simulation which was based in part on—and was used to extend—the available but short streamflow record developed during the study. Substitution of these values for precipitation and runoff into the simplified hydrologic budget equation indicates an average annual evapotranspiration of 15.3 inches. On an average annual water-year basis, therefore, about 51 percent of the precipitation that falls on the Kinnickinnic River watershed is returned to the atmosphere by the evapotranspiration process while the remaining 49 percent leaves the watershed as streamflow.

Atmospheric Phase of the Hydrologic Cycle

The processes of precipitation and evapotranspiration constitute the atmospheric phase of the hydrologic cycle of the Kinnickinnic River watershed. On a water-year basis, precipitation accounts for essentially all the water entering the watershed while evapotranspiration is the process by which most of the water leaves the watershed.

Precipitation: The average annual total precipitation for the Kinnickinnic River watershed based on a Thiessen polygon network analysis of data from two observation stations located in or near the watershed is 30.1 inches, as described in Chapter III of this report, whereas the average annual snow and sleet fall is 44.3 inches measured as snow and sleet. The location of these two stations—one of which lies within the watershed and the other just outside of it—as well as the types of precipitation-recording equipment and the availability of temperature and other meteorological data are shown on Map 12 and Table 7 in Chapter III. That chapter also discusses the significance of precipitation data in the watershed planning process, and includes information on precipitation-related climatic factors such as temperatures, snow cover, and frost depth. Chapter X discusses the results of various statistical analyses of the basic precipitation data with the results being presented in graphical and tabular form in Appendix B of this report. That Appendix includes point rainfall-intensity-duration-frequency relationships in both graphical and tabular form, point rainfall depth-duration-frequency curves, and depth-duration area curves.

Evapotranspiration: Annual evaporation from water surfaces, such as ponds and streams, within the Kinnickinnic River watershed is about 29 inches and, therefore, approximately equal to the average annual precipitation of 30.1 inches. The average annual evapotranspiration, as calculated in the hydrologic budget for the watershed, is about 15.3 inches. The 14-inch difference between the potential for evaporation from a free water surface and long-term evapotranspiration over the watershed occurs because evapotranspiration from soils and plants, depending upon such factors as land use, temperature, available water, and soil conditions, is normally less than evaporation from free water surfaces.

Surface Water Phase of the Hydrologic Cycle

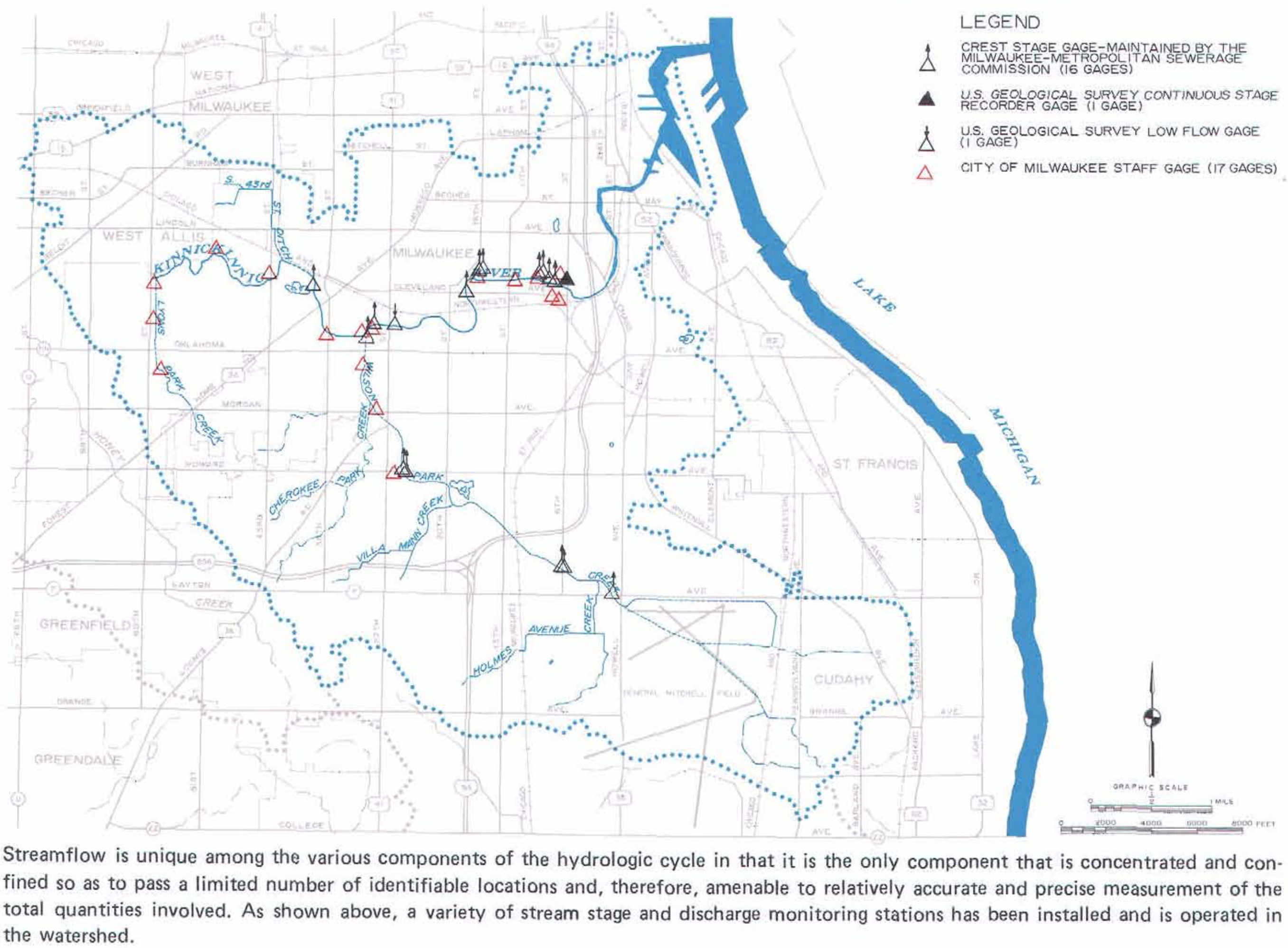
Surface water in the Kinnickinnic River watershed is composed almost entirely of streamflow since, as indicated in Chapter III, there are no major lakes—that is, lakes of 50 acres or more in surface area—located within the watershed. Small offstream ponds, most of which are located in Milwaukee County parklands and which have a combined surface area of 25 acres, comprise the remainder of the surface water.

Monitoring Stations: Streamflow is unique among the components of the hydrologic cycle in that it is the *only component so confined as to pass a finite location* and, therefore, amenable to relatively precise measurement of its total quantity. As shown on Map 19, a variety of stream stage and discharge monitoring stations have been constructed and are operated in the watershed by the U. S. Geological Survey, the Milwaukee-Metropolitan Sewerage Commissions, and the City of Milwaukee.

Streamflow is not measured directly at discharge monitoring stations but is derived from measurements of "stage," that is, of water surface elevation at monitoring

Map 19

STREAM STAGE AND DISCHARGE STATIONS IN THE KINNICKINNIC RIVER WATERSHED



Streamflow is unique among the various components of the hydrologic cycle in that it is the only component that is concentrated and confined so as to pass a limited number of identifiable locations and, therefore, amenable to relatively accurate and precise measurement of the total quantities involved. As shown above, a variety of stream stage and discharge monitoring stations has been installed and is operated in the watershed.

Source: SEWRPC.

stations along a stream. In order to convert a measured stage to its corresponding discharge, a stage-discharge relationship must be developed for each monitoring site. Such relationships are normally constructed by making field measurements of discharge for a wide range of river stages. For each such stage, discharge is determined by partitioning the total flow cross section into subareas, using a meter to measure the flow velocity in such subarea, multiplying velocity times area for each subarea to obtain subarea discharge, and integrating over all subareas to obtain the total discharge. Stage is determined by various types of indicators with the readings taken manually at intervals by an observer or recorded by automatic instruments. Stage indicators are classified according to the method by which the stage is measured and by the manner in which it is read. The principal types are staff gages, crest stage indicators, wire weight gages, and continuous recording gages.[2]

U. S. Geological Survey Stage and Discharge Stations: Some of the streamflow and related monitoring stations are maintained in the watershed stream system by the U. S. Geological Survey (USGS). Results of the observations at these stations are published by the USGS in a series of publications entitled "Water Resources Data for Wisconsin." The USGS in cooperation with the Commission and the Metropolitan Sewerage Commission of the County of Milwaukee has operated a continuous stage recorder gage (USGS Gage No. 4-0871.6, Milwaukee) since September 14, 1976, at the S. 7th Street crossing of the Kinnickinnic River in the City of Milwaukee. This station monitors flow from a 18.1-square-mile drainage area which comprises 73 percent of the total area of the watershed.[3] Even though the period of record is very short, the daily discharge measurements at this gage constitute the only source of continuous data for characterizing streamflow of the Kinnickinnic River watershed. All the other stage and discharge monitoring stations in the watershed are utilized only during either major flood events or unusual drought periods and, therefore, do not provide information about the full spectrum of stream stages and discharges that actually occurs.

A low-flow gage (USGS Gage No. 4-0871.5, Milwaukee) has been maintained by the USGS in cooperation with the Wisconsin Department of Natural Resources since 1962 at the S. 27th Street crossing of the Kinnickinnic River in the City of Milwaukee. This station monitors streamflow from a 17.6-square-mile area comprising 71 percent of the watershed area. Low-flow measurements have been obtained at this site for each of the water years in the period of record except for seven years: 1968, 1970, 1971, 1972, 1973, 1974, and 1975.

Milwaukee-Metropolitan Sewerage Commissions' Crest Stage Gages: A total of 16 crest stage gages were operated in the Kinnickinnic River watershed by the Milwaukee-Metropolitan Sewerage Commissions as of mid-1977. These flood crest monitoring stations were installed in 1967, 1971, and 1975 and, as shown on Map 19, are rather uniformly distributed along the Kinnickinnic River downstream of Jackson Park and along Wilson Park Creek. Ten of the sites are on the Kinnickinnic River and the remaining six are on Wilson Park Creek. In general, one or more flood crest measurements have been made at each of the 16 stations during each of the years for which the stations have been in existence.

Peak flood stage data from these 16 gages were used, as discussed in the report's Chapter VI, "Flood Characteristics and Problems," to develop historic flood stage profiles of the Kinnickinnic River system. In addition to providing quantitative documentation of historic flooding, these flood stage profiles were also used, as discussed in Chapter VIII, "Water Resource Simulation Model," to calibrate the watershed hydrologic-hydraulic simulation model.

City of Milwaukee Staff Gages: A total of 17 staff gages are maintained by the City of Milwaukee in the City of Milwaukee portion of the watershed, as of mid-1977. This network of staff gages is monitored by field personnel during and after flood events. As shown on Map 19, 11 of the monitoring sites are on the Kinnickinnic River, three are located on Wilson Park Creek, and three are on Lyons Park Creek. In general, one or more flood stage measurements have been made at each of the 17 City of Milwaukee stations during each of the years that these stations have been in existence. The flood stages recorded at these staff gages were used, along with the Milwaukee-Metropolitan Sewerage Commission crest stage data, to develop historic flood stage profiles which in turn were used to calibrate the watershed hydrologic-hydraulic simulation model.

Seasonal Distribution of Peak Stages

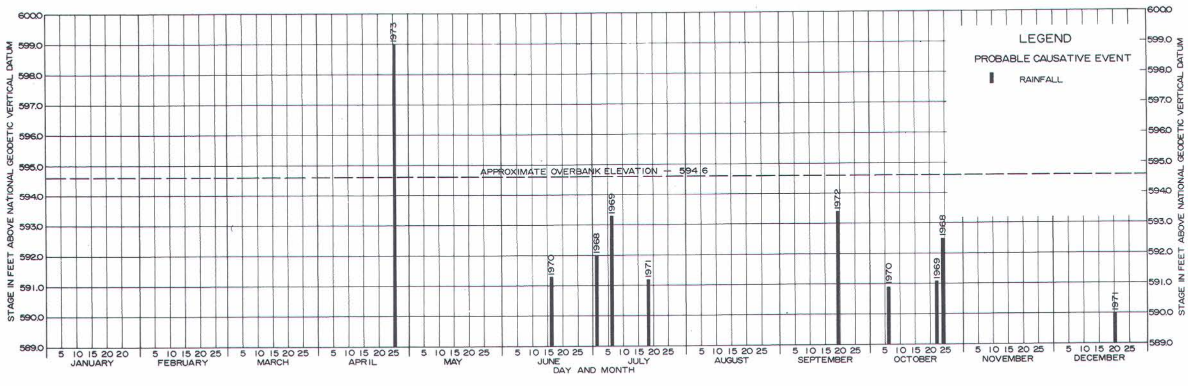
Flood stages for two locations on the Kinnickinnic River and two locations on Wilson Park Creek as recorded by the Milwaukee-Metropolitan Sewerage Commissions are shown in Figure 13. These four locations are representative of the major stream system in the watershed and the stages recorded at these sites indicate the flood events generally occur during the three seasons of spring, summer, and fall. Although not uniformly distributed among three seasons for all locations, the occurrence of events causing high water is not concentrated within

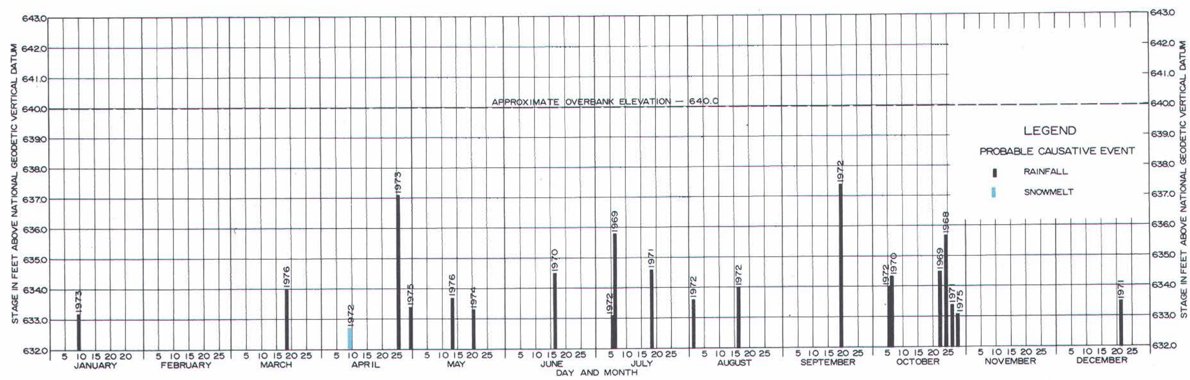
[2] *For a description, including photographs, of the various types of stage indicators see SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume Two, "Inventory Findings and Forecasts," October 1976, pp. 104-109.*

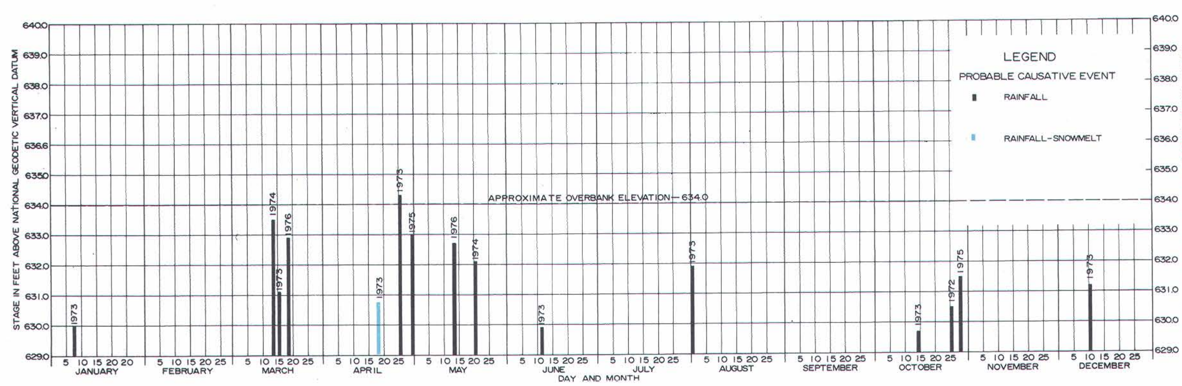
[3] *The area tributary to the gage may exceed 18.1 square miles and increase to as much as 19.9 square miles under severe rainfall and snowmelt conditions. Two subbasins with a combined area of 1.8-square-miles (subbasins KKR-7 and KKR-11 shown on Map 28) served by a combined sewer system lie upstream of the gaging station but, under low runoff conditions, do not discharge to the Kinnickinnic River. However, when rainfall or snowmelt runoff rates exceed the capacity of the combined sewers in this subbasin, some of the flow will be discharged through combined sewer outfalls to the Kinnickinnic River reach upstream of the gaging station.*

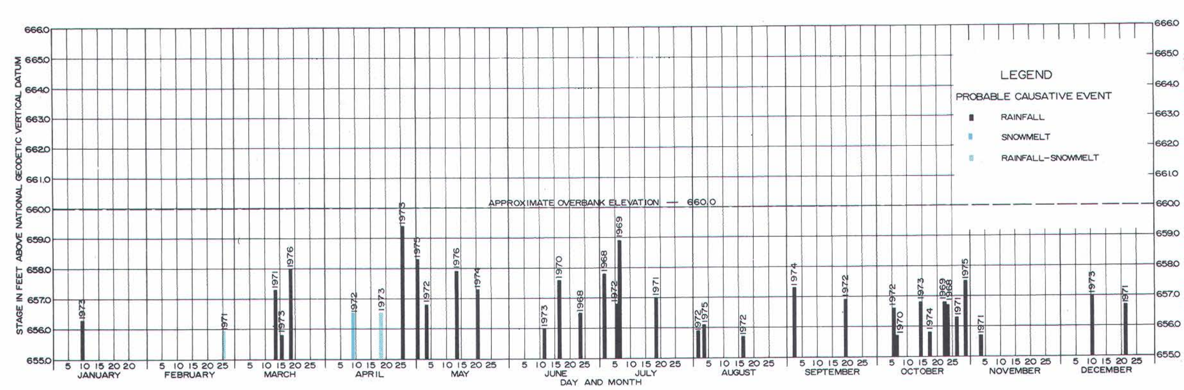
Figure 13

SEASONAL DISTRIBUTION OF RECORDED PEAK STAGES FOR SELECTED LOCATIONS ON THE KINNICKINNIC RIVER AND WILSON PARK CREEK









Source: Milwaukee-Metropolitan Sewerage Commissions and SEWRPC.

any given season. In the case of the Kinnickinnic River at S. 7th Street, two, or 20 percent, of the 10 flood stages recorded from 1967 to 1976 occurred in the spring; four, or 40 percent, in the summer; four, or 40 percent, in the fall; and none in the winter.[4] For the Kinnickinnic River at Jackson Park Drive, six, or 29 percent, of the 21 flood stages recorded from 1967 to 1976 occurred in the spring; six, or 29 percent, in the summer; seven, or 33 percent, in the fall; and only two, or 9 percent, in the winter. For Wilson Park Creek at the confluence with the Kinnickinnic River, four, or 27 percent, of the 15 flood stages recorded from 1972-1976 occurred in the spring; six, or 40 percent, in the summer; one, or 6 percent, in the fall; and four, or 27 percent, in the winter. For Wilson Park Creek at S. 6th Street, 10, or 29 percent, of the 35 flood stages recorded from 1967 to 1976 occurred in the spring; nine, or 26 percent, in the summer; 11, or 31 percent, in the fall; and five, or 14 percent, in the winter.

The seasonal distribution of peak stages as exhibited in the Kinnickinnic River watershed, which is similar to that experienced in the 137-square-mile Menomonee River watershed, is in marked contrast to the seasonal distribution pattern of peak stages and discharges observed at or near the discharge point of the larger 197-square-mile Root River watershed, the 939-square-mile Fox River watershed, and the 694-square-mile Milwaukee River watershed as indicated by completed Commission studies of these basins. In these watersheds, each of which is significantly larger than the Kinnickinnic River and Menomonee River watersheds, the instantaneous peak discharges and the peak flood stages at or near the watershed outlets tend to be concentrated in the late winter and early spring portion of the year. For example, of the 54 annual instantaneous peak discharges that occurred on the Milwaukee River in the 1915-1968 period, 32, or 59 percent, occurred during March or April, as did five of the six largest discharges.

The difference in the seasonal characteristics of peak flood events in the Kinnickinnic and Menomonee River watersheds relative to the Root, Fox, and Milwaukee River watersheds is due primarily to the size difference of these basins and the resulting relative importance of rainfall versus rainfall-snowmelt induced flood events. Although major rainfall events commonly occur in spring, summer, and fall, they have not been the sole causative factor for major floods in the lower reaches of the Root, Fox, and Milwaukee River watersheds. This is because major rainfall events do not occur with sufficient intensity and duration over large enough areas of these watersheds to produce flood peaks of similar magnitude to those that occur as a result of snowmelt or a combination of snowmelt-rainfall condition on these large watersheds. Unlike rainfall, snowmelt does occur over large geographic areas since it is primarily a function of air temperature and snow cover distribution.

As smaller and smaller watersheds, or subwatersheds, are considered, rainfall events assume increased importance as the causative factor for flood events. The Kinnickinnic and the Menomonee River watersheds are sufficiently small that rainfall as opposed to snowmelt or a rainfall-snowmelt combination is the primary cause of major flood events for not only their subwatersheds but also for the entire watershed. As shown in Figure 13, rainfall alone has been responsible for all of the flood stages recorded on the Kinnickinnic River at S. 7th Street from 1967 to 1976; 95 percent of the flood stages recorded on the Kinnickinnic River at Jackson Park Drive from 1967 to 1976; 93 percent of the flood stages recorded on Wilson Park Creek at its confluence with the Kinnickinnic River from 1972 to 1976; and 91 percent of the flood stages recorded on Wilson Park Creek at S. 6th Street from 1967 to 1976.

When rainfall is the dominant cause of flood events, as it is for the Kinnickinnic River watershed and for the Menomonee River watershed, the occurrence of flood stages tends to be more uniformly distributed throughout the year since rainfall-producing thunderstorms commonly occur during the spring, summer, and fall seasons. In summary, then, the Kinnickinnic River does not exhibit a "flood season." Most major flood events in the Kinnickinnic River watershed have been and may be expected to continue to be the result of rainfall activity and, therefore, have occurred and will continue to occur with little warning anytime during the late winter, spring, and summer of the year.

Rainfall-Runoff Response: From the perspective of watershed hydrology and hydraulics, urbanization is the conversion of floodland and nonfloodland areas of a basin from rural to urban uses. The urbanization process, in the absence of compensatory detention storage or other similar structural flood control measures, may increase downstream flood discharges and stages. Increased discharges result from the more extensive areas being covered by impervious surfaces and from the shortened runoff times which usually accompany the conversion of land from rural to urban uses.

The rainfall-runoff relationship is influenced by the degree of imperviousness of the surface in that the proportion of runoff resulting from a given amount of rainfall may be expected to increase as the proportion of impervious surface increases. Since urbanization is normally accompanied by an increase in area covered by impervious surfaces, it follows that urbanization will result in larger volumes of runoff for given rainfall events.

The response time of the watershed or subwatershed varies with the hydraulic resistance characteristics of its surfaces, which in turn are determined largely by land use. Smooth surfaces, such as paved areas and the paved

[4] *For the purpose of this analysis, winter is defined as January through March, spring as April through June, summer as July through September, and fall as October through December.*

channels, gutters, and sewers typical of urban drainage systems, reduce runoff times and reduce the base and increase the peak of runoff hydrographs. In summary, then, the increase in imperviousness and increased efficiency of drainage systems associated with the urbanization process increases runoff volumes and decreases runoff times. These two effects of urbanization are additive with the result that the incremental urbanization can cause large increases in flood volumes, discharges, stages, and areas subject to inundation.

Because of the impact of urbanization, small, intensely urbanized basins, such as the Kinnickinnic River watershed, tend to show a rapid rise in runoff hydrographs subsequent to the beginning of rainfall events relative to the rate of rise of runoff hydrographs in rural basins of similar size. This "flashy" response is evident in the Kinnickinnic River watershed as shown by the rainfall-runoff relationships for two rainfall-runoff events that occurred in the Kinnickinnic River watershed since the establishment in September 1976 of a continuous recording stream gage at the S. 7th Street crossing of the Kinnickinnic River. As indicated on Figure 14, the response time of the 18.1-square-mile portion of the watershed tributary to the Kinnickinnic River at S. 7th Street, as defined by the time from the beginning of a significant rainfall event to the peak discharge of the runoff hydrograph, was less than two hours for the two typical events. The significance of the rapid response of flood flow hydrographs to rainfall events in the Kinnickinnic River watershed is that very little time is available to warn riverine area residents of impending flood damage and disruption.

High Flow Discharge-Frequency Relationships: The most important hydrologic characteristics of floods are the probabilities of frequencies of occurrence, the peak rate of discharge, the volume of runoff, and the duration and timing of the event. "Probability" or "frequency" is defined as the chance of occurrence, in any year, of a flood equaling or exceeding a specified magnitude. Probability may be expressed as a decimal, a fraction, or a percentage. "Recurrence interval" is defined as the average time interval between floods of a given magnitude and is equal to the reciprocal of the probability. For example, a flood that would be equalled or exceeded on the average of once in 100 years would have a recurrence interval of 100 years and a 0.01 probability, or 1 percent, chance of occurring or being exceeded in any year.

Figure 14

TYPICAL RAINFALL-RUNOFF EVENTS FOR THE KINNICKINNIC RIVER WATERSHED

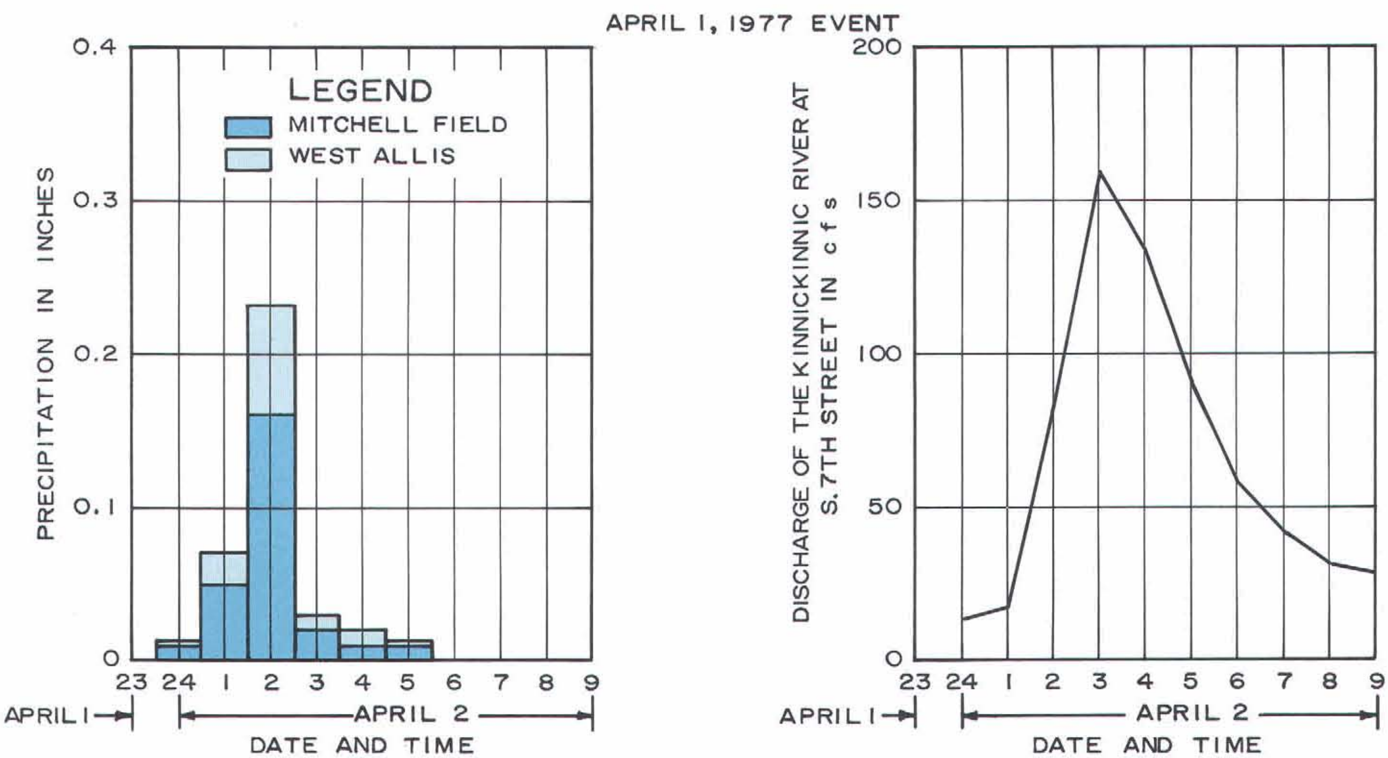
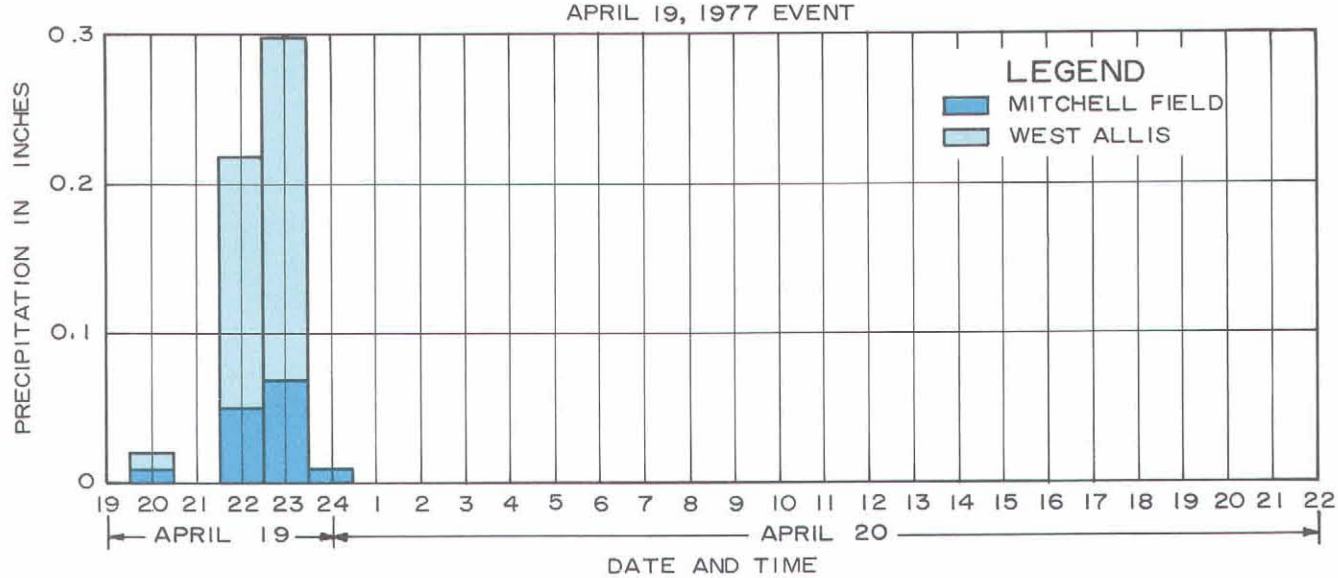
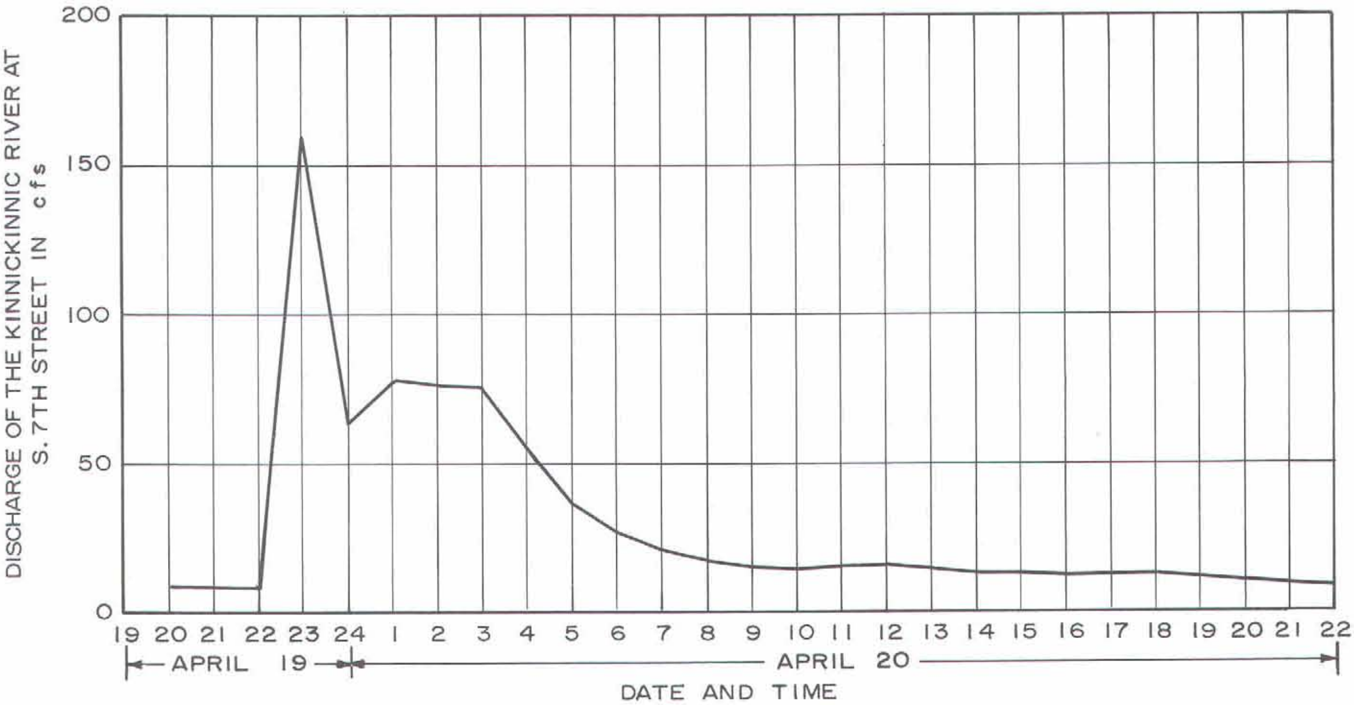


Figure 14 (continued)





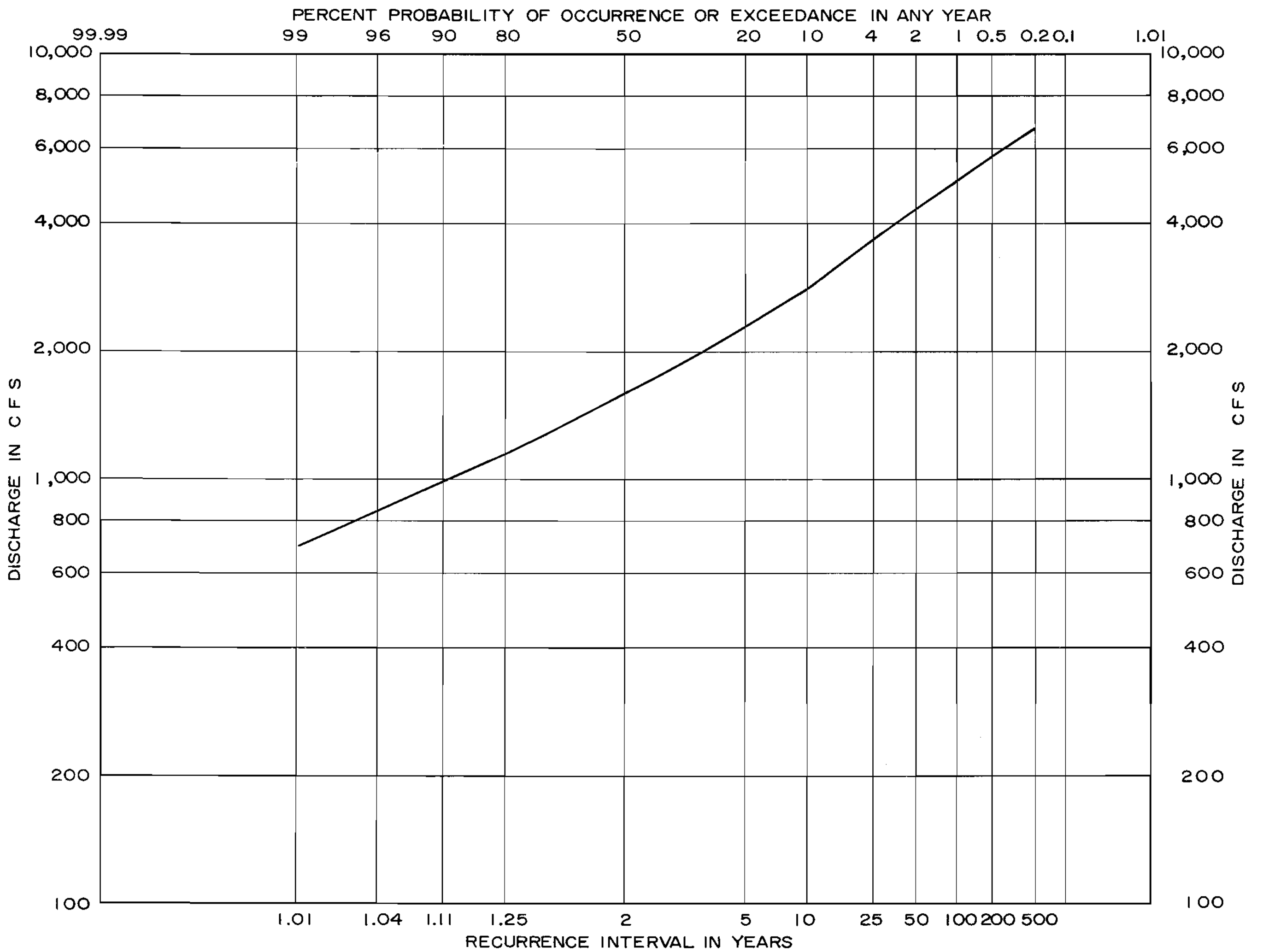
Source: U. S. Geological Survey, National Weather Service, and SEWRPC.

A long and continuous record at river discharge is the best basis for determination for flood discharge-frequency relationships. Discharge records for the Kinnickinnic River at S. 7th Street encompass only the short period since September 1976 and are not, therefore, of sufficient length to provide a direct basis for discharge-frequency analyses. The available short streamflow record, in combination with historic flood stage data throughout the Kinnickinnic River watershed, was adequate, however, for the calibration of the hydrologic-hydraulic model of the watershed system as described in Chapter VIII of this report. Simulated annual instantaneous peak discharges of the Kinnickinnic River at S. 7th Street and for other locations throughout the watershed for the 37 year period from 1940 through 1976 were used to determine one- through 500-year recurrence interval discharges for existing land use and channel-floodplain conditions. Statistical analyses required to compute the discharges corresponding to the desired recurrence intervals were conducted using the log-Pearson Type III method of analysis. That method was used because, as discussed in Chapter II, "Watershed Development Objectives, Principles, and Standards," it is recommended by the U. S. Water Resources Council and is specified for floodplain regulatory purposes by the Wisconsin Department of Natural Resources. A graphical representation of the resulting existing watershed condition discharge-frequency relationship for the Kinnickinnic River at S. 7th Street is shown in Figure 15. The 100-, 50-, and 10-year recurrence interval peak discharges at this location are 5,000, 4,350, and 2,800 cfs, respectively.

Whereas Figure 15 presents the discharge-frequency relationship for instantaneous peak discharges, Figure 16 shows existing condition high flow discharge-frequency relationships for the Kinnickinnic River at S. 7th Street for periods of one, seven, 30, and 120 days. These relationships also were developed using simulated stream flows and the Log-Pearson Type III method of statistical analysis. For a specified discharge, these curves facilitate estimating the probability that a specified high stream flow will be maintained or exceeded for a given period of

Figure 15

DISCHARGE-FREQUENCY RELATIONSHIPS OF THE KINNICKINNIC RIVER AT S. 7TH STREET
EXISTING LAND-USE FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

time during any water year. For example, the probability of maintaining an average flow of 50 cfs or more for a seven-day period in any water year is about 98 percent, while the probability of maintaining that average flow for 30 days is a lower 70 percent, and for 120 days an even lower 7 percent.

Low Flow Discharge-Frequency Relationships

Figure 17 shows low flow discharge-frequency relationships for the Kinnickinnic River at S. 7th Street for periods of one day, seven days, 30 days, and 120 days. Simulated discharges for the 37-year period from 1940 through 1976 were used, in conjunction with the Log-Pearson Type III method of statistical analysis, to develop these relationships.

Low flow discharge-frequency relationships are useful in water quality management aspects of comprehensive watershed studies. For example, the low-flow condition established by the Wisconsin Department of Natural Resources for evaluating compliance with water use objectives and supporting standards is a stream flow equivalent to the average minimum seven-day flow expected to occur once on the average of every 10 years. The seven day-10 year low flow for the Kinnickinnic River at S. 7th Street, as obtained from Figure 17, is 6.3 cfs. However, as shown in Figure 17, the minimum flow possible at S. 7th Street is 5.6 cfs due to the constant nature of the existing upstream industrial discharges.

Flow Duration Analysis

A flow duration curve is defined as a cumulative frequency curve that indicates the percentage of time that specified discharges may be expected to be equalled or exceeded. Figure 18 is a flow duration curve for existing land use-floodland development conditions based on simulated daily stream flows for the Kinnickinnic River at S. 7th Street for the 37 water years from 1940 through

1976. The daily simulated flows, on which the Kinnickinnic River flow duration relationship is based, range from a low of 5.6 cfs from industrial discharges to a high of 1,100 cfs on June 22, 1940. Since the flow duration curve is based on all daily flows in the simulated period, it is an effective means of summarizing streamflow characteristics.

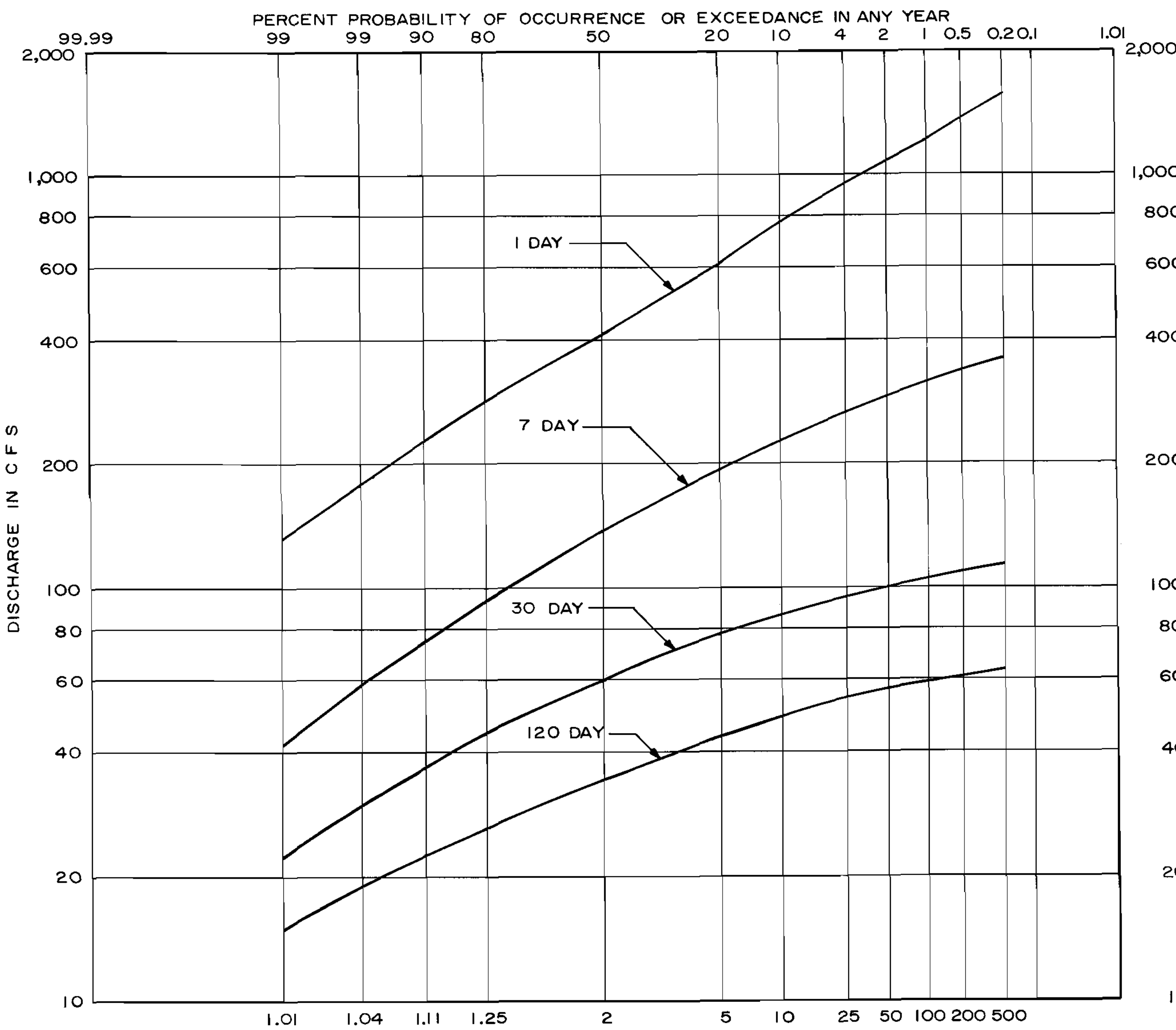
Flow duration curves are most frequently used as an aide in forecasting the availability of specified rates of flow. For example, the flow duration curve for the Kinnickinnic River at S. 7th Street indicates that a daily flow of 10 cfs has been, and may be expected to be, exceeded 95 percent of the time under existing land use-floodland development conditions whereas much higher daily discharges of 50 cfs and 400 cfs have been, and may be expected to be, exceeded only 10 percent and 0.2 percent of the time, respectively.

Groundwater Phase of the Hydrologic Cycle

That part of precipitation that infiltrates into the ground and escapes becoming evapotranspiration or part of the

Figure 16

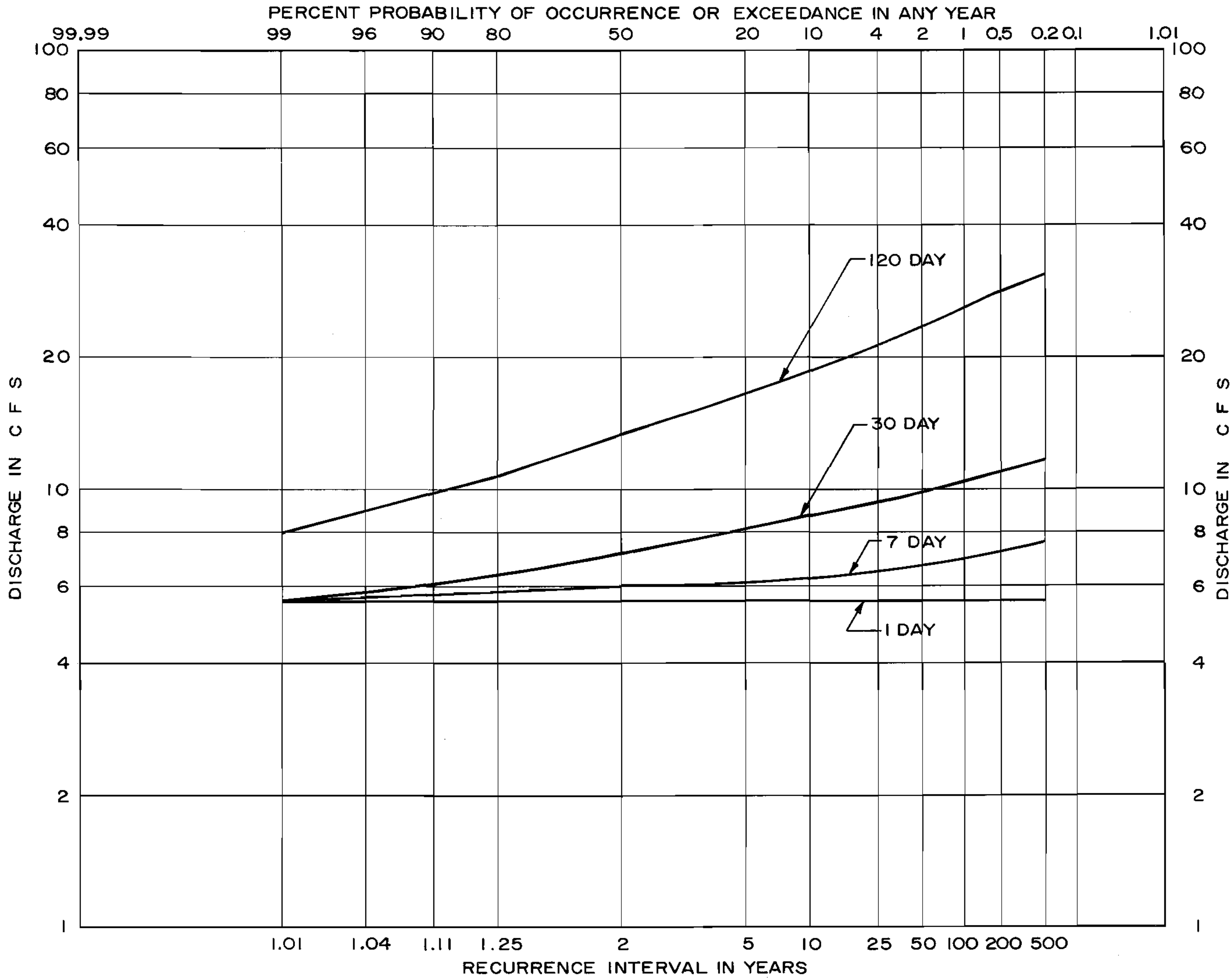
HIGH FLOW DISCHARGE-FREQUENCY RELATIONSHIPS OF THE KINNICKINNIC RIVER AT S. 7TH STREET: EXISTING LAND USE-FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

Figure 17

LOW FLOW DISCHARGE-FREQUENCY RELATIONSHIPS OF THE KINNICKINNIC RIVER AT S. 7TH STREET: EXISTING LAND USE-FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

soil moisture percolates downward until it reaches the zone of saturation and becomes part of the groundwater reservoir. The inventory and analysis of the groundwater resources may be subdivided into two phases: groundwater hydrology and groundwater hydraulics. Groundwater hydrology, as described below, has to do with the vertical and horizontal extent of the significant aquifers[5] underlying the watershed, their relative positions, and the quantities of water contained within them. In contrast, groundwater hydraulics relates to such factors as the flow resistance of the aquifers and the flow patterns associated with those aquifers.

As stated in Chapter I of this report, the Kinnickinnic River watershed planning program is directed to the resolution of existing and possible future surface water quantity problems, that is, flooding problems and surface water pollution problems. However, an overview of groundwater hydrology is presented below inasmuch as it contributes to an understanding of surface water quantity and quality. Groundwater hydraulics is not discussed in this report with the exception of a brief treatment of the potentiometric surface of deep and shallow aquifers.

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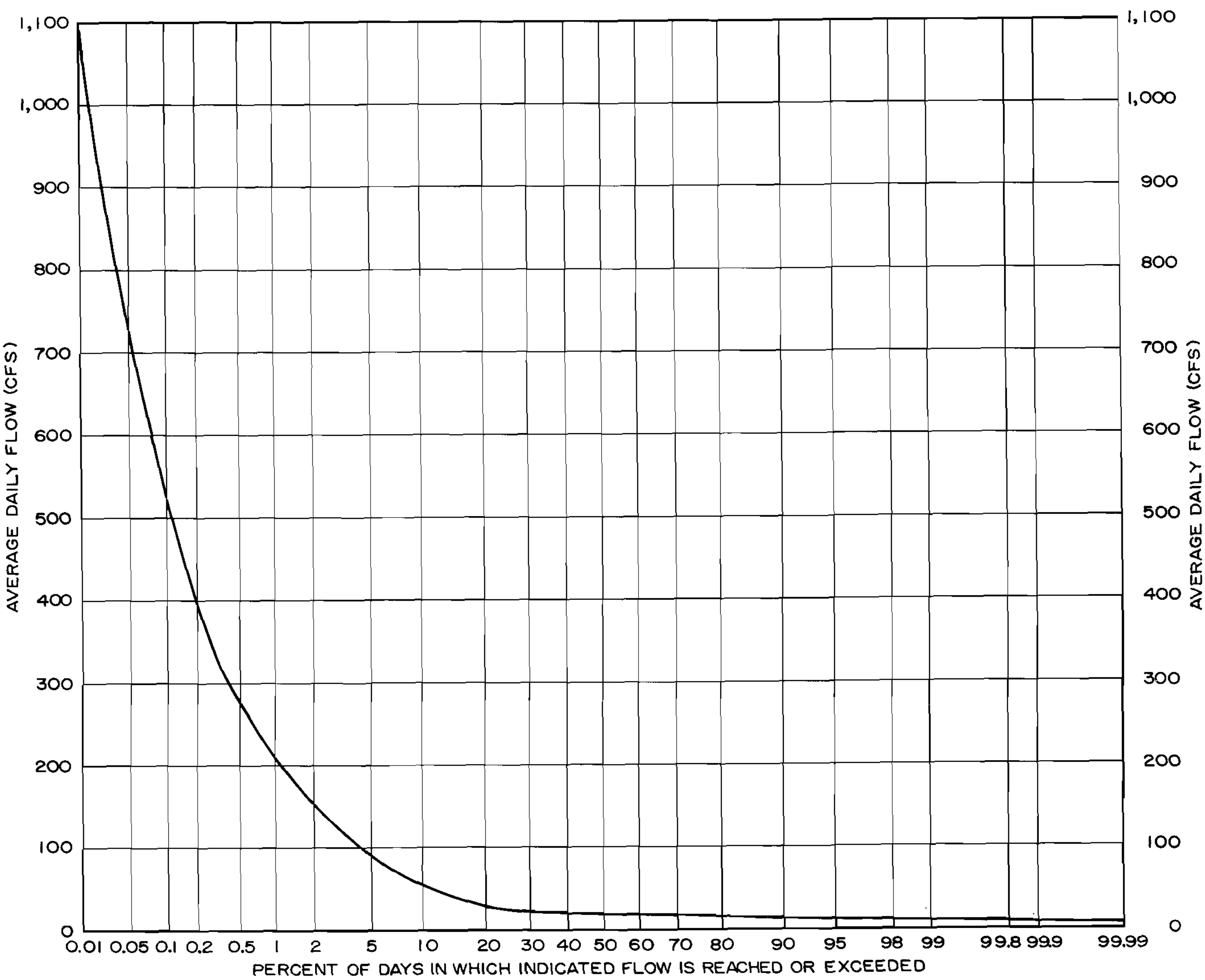
[5] *An aquifer is a porous water-bearing geologic formation. As used here, it is a relative term designating geologic formations, or deposits, that contain significant amounts of groundwater which can be used as a principal source of water supply.*

Figure 18

FLOW DURATION RELATIONSHIPS OF THE KINNICKINNIC RIVER AT S. 7TH STREET
EXISTING LAND USE-FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

Principles of Occurrence

Groundwater in saturated rock occupies the pore spaces and other openings in the rock materials. Similarly, in loose, unconsolidated materials, groundwater occupies the spaces between individual grains of silt, clay, sand, or gravel. In rock, the openings that may be filled with water include those along bedding planes, fractures, faults, joints, and solution cavities. Solution cavities probably are important in the dolomite formations of the Kinnickinnic River watershed. Intergranular pore openings in rocks may be fewer and smaller than those in unconsolidated materials because they are often constricted by cementing material, such as calcite and silica. In rocks such as dolomite, which contain little or no intergranular pore space, the groundwater occupies primarily the factures and crevices that pass through such rocks.

Groundwater occurs under water table conditions whenever the surface of the zone of saturation is at atmospheric pressure. Groundwater occurs under confined or artesian conditions wherever a saturated formation is directly overlain by a relatively impermeable formation which confines the water in the permeable unit under pressure greater than atmospheric pressure. Flow of groundwater from an artesian aquifer is similar to gravity flow from a high elevation reservoir through a pipe distribution system. The static water level in wells tapping artesian aquifers always rises above the top of the artesian aquifer. Discharge from artesian aquifers is controlled by the confining stratum, and most of the recharge of the artesian aquifer occurs where the confining stratum is missing. Uncased wells provide conduits for the movement of groundwater between aquifers in a multiaquifer system, such as that present in the Kinnickinnic River watershed, both upward under artesian head and downward under gravity flow conditions. Flowing wells result if the static water level at the well is higher than the land surface. Flow continues until that water level is lowered below the land surface.

Groundwater is released from storage in water table and artesian aquifers as the result of different physical processes. In a water table aquifer, groundwater is released to wells by gravity drainage of the aquifer pore spaces. In an artesian aquifer, water is released to the well as the result of compression of the aquifer and expansion of groundwater. An aquifer consisting of tightly packed, well sorted spherical particles of sand may contain up to 40 percent water by volume—about three gallons per cubic foot of aquifer. Given sufficient time, about one-half of this volume of water may be drained by gravity from a water table aquifer with the other half adhering to the aquifer against the force of gravity. The quantity of groundwater released from a cubic foot of similar materials under artesian conditions is extremely small by comparison because, under artesian conditions, the aquifer is not drained but the released water is instead attributable solely to the expansion of the water and the compression of the solid material comprising the aquifer. This expansion of the water and contraction of the aquifer material is in response to the reduced water pressure caused by pumping the aquifer. The practical consequence of this difference in the origin of water taken from an unconfined aquifer, compared to a confined or artesian aquifer, is that pumping from an artesian aquifer affects an immense area compared to the area affected by pumping at an equivalent rate from a water table aquifer of similar vertical and horizontal extent and material.

Hydrologic Characteristics by Aquifer

There are three principal aquifers underlying the Kinnickinnic River watershed: the sandstone aquifer, the deepest of the three; the dolomite aquifer; and the sand and gravel aquifer, the shallowest of the three. The latter two are hydraulically interconnected and, therefore, are sometimes considered to comprise a single aquifer. The dolomite aquifer also is commonly, although incorrectly, called the "limestone" aquifer. The deep sandstone aquifer is separated from the shallower dolomite aquifer by a layer of relatively impermeable shale. The more important of the three aquifers are the sandstone and the dolomite aquifers, which underlie the entire watershed and are generally available for use in any locality. The sand and gravel aquifer is of lesser importance because, although it reaches a thickness of 250 feet in some watershed areas, it does not yield large quantities of water, and it is particularly susceptible to pollution from overlying land uses. The stratigraphic units comprising each of the three aquifers are summarized in Table 14 of Chapter III. Hydrologic characteristics of each of the three principal aquifers are discussed below.

The Sandstone Aquifer: In the Kinnickinnic River watershed, the sandstone aquifer includes all of the geologic units bounded above by the Maquoketa shale and bounded below by the Precambrian rocks. Although it is commonly referred to as the sandstone aquifer, some of the units contained within it—for example, the Galena dolomite—are not sandstones. The Maquoketa shale confines water in the sandstone aquifer under artesian pressure and the shale is normally cased off in wells to prevent distruction of the well by caving of the formation.

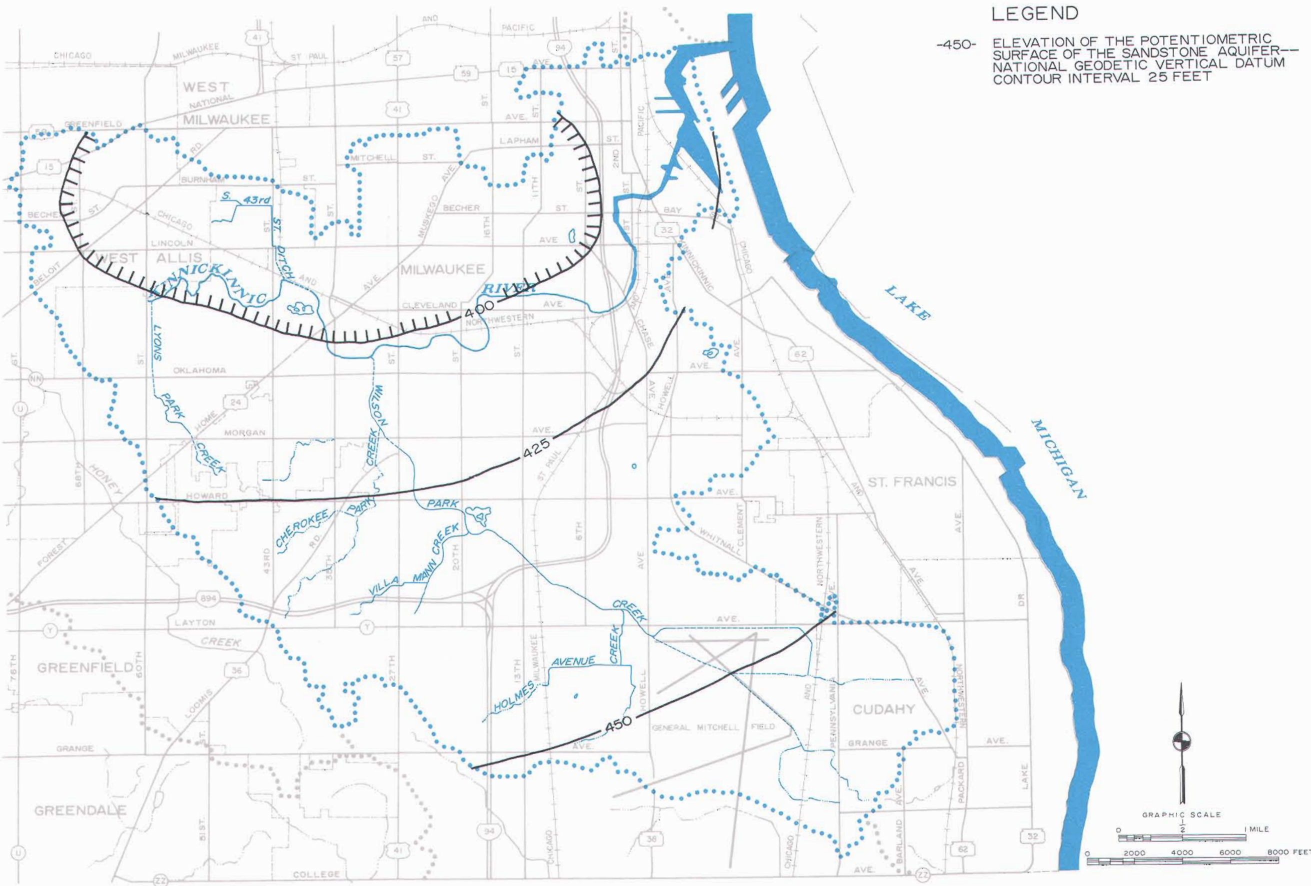
The surface of the sandstone aquifer is located approximately 600 to 750 feet beneath the ground surface of the Kinnickinnic River watershed. The sandstone aquifer dips gently downward in an easterly direction at a slope of about 40 feet per mile (about 0.75 feet per 100 feet). The thickness of the sandstone aquifer beneath the watershed is known to exceed 1,400 feet. Assuming an average porosity of 15 percent, it is estimated that at least 3.33 million acre-feet of water are contained within that portion of the aquifer lying immediately beneath the Kinnickinnic River watershed. This volume of water would be sufficient to cover the entire watershed to the depth of 210 feet.

Recharge to the sandstone aquifer enters the aquifer system in three ways. It occurs as infiltration of precipitation through glacial deposits in a recharge area located west of the watershed along the western edge of the seven-county Planning Region where the Maquoketa shale and younger formations are absent. Secondly, a small amount of recharge occurs as vertical leakage through the Maquoketa shale because of the hydraulic head difference existing between the top and the bottom of the shale. Thirdly, and also because of that hydraulic head difference, deep wells uncased in both the dolomite and sandstone aquifers allow movement of water from a dolomite aquifer immediately above the Maquoketa shale to the sandstone aquifer beneath. Map 20 utilizes isopleths of equal hydraulic head to depict the potentiometric surface of the sandstone aquifer. The elevation of the potentiometric surface ranges from a high of about 450 feet above National Geodetic Vertical Datum (Mean Sea Level Datum) in the extreme southeastern portion of the watershed to a low of about 400 feet in the northern portions of the basin.

The direction of groundwater movement in the sandstone aquifer is defined by the potentiometric surface of the aquifer. Flow occurs down the hydraulic gradient and, therefore, in a direction perpendicular to the isopleths on the potentiometric map. Map 20 indicates that groundwater in most of the sandstone aquifer beneath the Kinnickinnic River watershed flows in a generally northerly direction toward a concentration of wells located in the central Milwaukee industrial-commercial area.

Map 20

GENERALIZED POTENTIOMETRIC SURFACE OF THE SANDSTONE AQUIFER IN THE KINNICKINNIC RIVER WATERSHED: 1973



The elevation of the potentiometric surface of the deep sandstone aquifer—the elevation to which water would rise in an open well tapping the aquifer—ranges from a high of about 450 feet above National Geodetic Vertical Datum in the extreme southeastern portion of the watershed to a low of about 400 feet above that datum in the northern portions of the basin. The potentiometric surface of the aquifer has declined locally by over 350 feet since these water-bearing strata were first tapped about 1880.

Source: U. S. Geological Survey and SEWRPC.

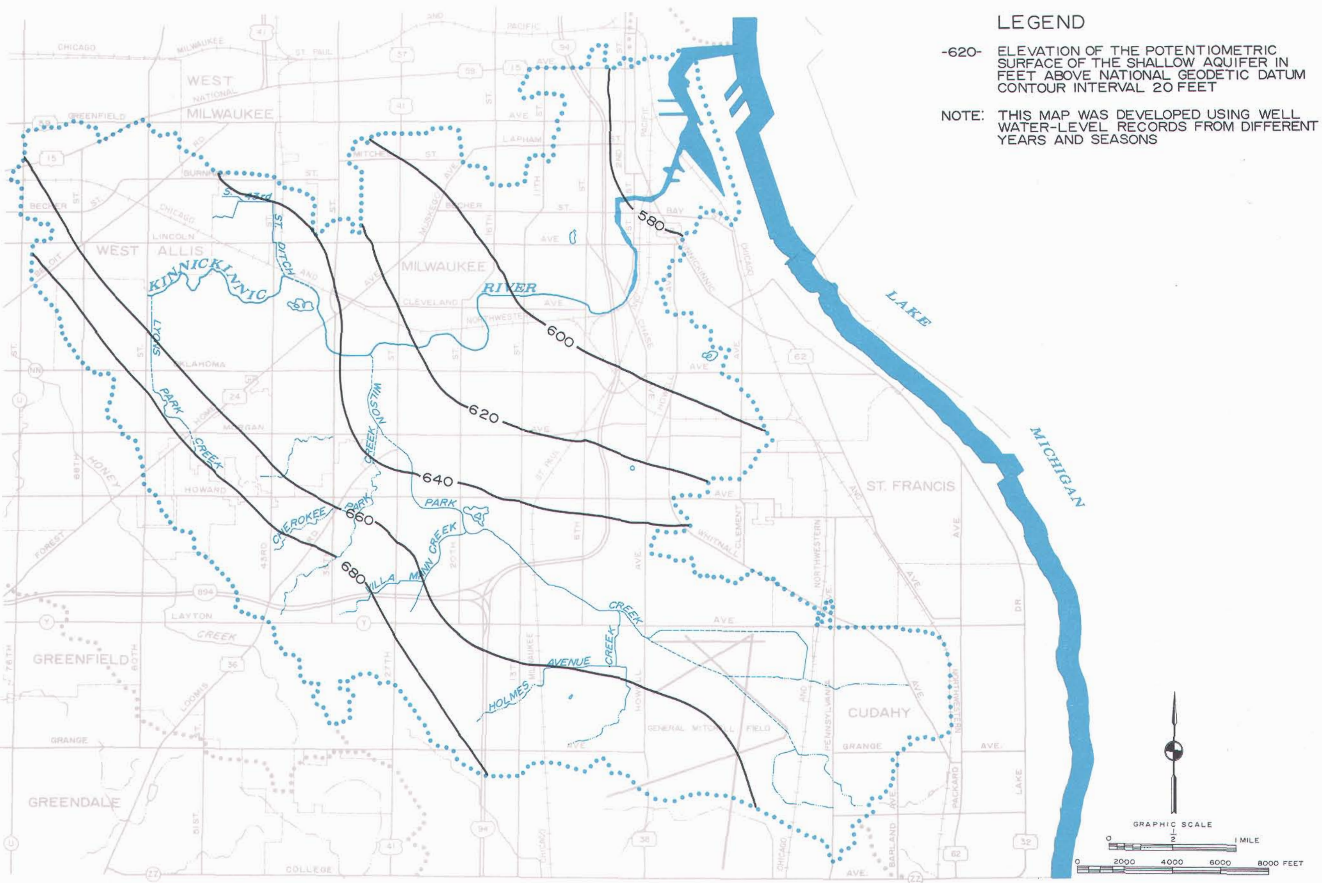
The potentiometric surface of the sandstone aquifer sloped gently eastward throughout the watershed in 1880, when the sandstone aquifer was first tapped by wells. Wells in the aquifer in the Milwaukee area generally flowed at the surface as a result of the artesian pressure. Subsequent development of the aquifer in the Milwaukee area has resulted in a decline of the potentiometric surface within the Kinnickinnic River watershed in excess of 350 feet and consequently wells no longer flow.

As noted earlier, a small amount of sandstone aquifer recharge occurs as downward flow through the Maquoketa shale from the overlying dolomite aquifer. This flow occurs because there is a hydraulic head difference between the dolomite and sandstone aquifers. The difference in elevation between the potentiometric surfaces of these two aquifers defines the approximate head difference acting across the Maquoketa shale at any locality. If the vertical permeability of the Maquoketa shale is assumed to be uniform, leakage will be greatest where the head differences are largest.

Map 20 indicates the potentiometric surface of the sandstone aquifer and Map 21 indicates the potentiometric surface for the combined dolomite aquifer and the glacial deposits. A comparison of the two maps indicates that the elevation of the potentiometric surface of the combined dolomite aquifer and glacial deposits is greater than the elevation of the potentiometric surface of the sandstone aquifer throughout the watershed. The difference in hydraulic head for the two aquifers ranges from 140 to 280 feet. Because of the head difference between these aquifers, deep wells encased in both the dolomite and sandstone aquifers allow easy movement of water from the dolomite aquifer into the sandstone aquifer.

Map 21

GENERALIZED POTENTIOMETRIC SURFACE OF THE DOLOMITE AQUIFER AND GLACIAL DEPOSITS IN THE KINNICKINNIC RIVER WATERSHED



The approximate direction of groundwater movement in the dolomite aquifer and glacial deposits in the watershed is shown by the above map of the potentiometric surface—the elevation to which water would rise in an open well tapping the aquifer. Movement is down the hydraulic gradient towards discharge points generally located at the mouth of the watershed near the Lake Michigan shoreline. Groundwater discharge sustains the dry-weather flow of the streams in the watershed.

Source: U. S. Geological Survey and SEWRPC.

The Dolomite Aquifer: The dolomite aquifer underlies the entire Kinnickinnic River watershed and consists of silurian dolomite. Maps 15 and 16 in Chapter III graphically represent, respectively, the surface topography of the dolomite aquifer and the thickness of the sand and gravel aquifer. The relatively impermeable Maquoketa shale is positioned immediately below the aquifer whereas unconsolidated glacial till, drift and alluvial deposits, varying in thickness from 100 to 250 feet, lie immediately above.

The topography of the surface of the dolomite aquifer, as shown on Map 15 in Chapter III, indicates that the aquifer surface exhibits an overall downward slope in a northeasterly direction as a result of erosion prior to deposition of the overlying glacial till. The aquifer has a thickness of approximately 300 feet and dips gently downward in an easterly direction at about 40 feet per mile (about 0.75 feet per 100 feet).

Recharge to the dolomite aquifer is primarily from infiltration of precipitation through overlying glacial deposits. The entire 300-foot thickness of the dolomite aquifer lies beneath the water table and is, therefore, saturated with groundwater. Assuming an average porosity of 5 percent, about 238,000 acre-feet of water exist beneath the Kinnickinnic River watershed in the dolomite aquifer. This quantity of water would be sufficient to cover the entire watershed to a depth of 15 feet.

The potentiometric surface for the combined dolomite aquifer and glacial deposits, as shown on Map 21, approximately defines the direction of the groundwater movement in these units in the watershed. The elevation of the potentiometric surface ranges from a high of about 680 feet above National Geodetic Vertical Datum along the southwesterly edge of the watershed to a low of about 580 feet near the watershed outlet at the confluence of the Kinnickinnic and Milwaukee Rivers. Movement is down the hydraulic gradient in a northeasterly direction to discharge areas along the lower Kinnickinnic River and Lake Michigan shoreline area.

The Sand and Gravel Aquifer: The sand and gravel aquifer consists of stratified, unconsolidated glacial and alluvial sand and gravel deposits. As shown on Map 16 in Chapter III, the thickness of the unconsolidated deposits forming the sand and gravel aquifer varies from 100 to 250 feet in the Kinnickinnic River watershed. While the thickness of the sand and gravel overlaying the watershed ranges from 100 to 250 feet, the thickness of the zone of saturation varies from 180 to 30 feet with an average value of about 80 feet. Assuming an average porosity of 0.30, about 397,000 acre-feet of water exist within the saturated strata of the sand and gravel. This quantity of water would be sufficient to cover the watershed to a depth of 25 feet.

Direct infiltration of precipitation is a major source of recharge through the sand and gravel aquifer. Recharge is greatest where the sand and gravel deposits and associated permeable soils occur at the surface, and it is smallest where fine-grain soils, clay, silt, or till form the surficial deposits. Water in the subsurface moves downward through the soils to the water table and then laterally towards streams and pumping areas. The potentiometric surface for the combined dolomite aquifer and glacial deposits, as shown on Map 21, defines approximately the direction of movement of the groundwater in these units and also the approximate elevation of static water levels in wells tapping these units.

Natural discharge of groundwater from the glacial deposits occurs as seepage into the surface water system by direct evaporation to the atmosphere where the water table is shallow, by plant transpiration during growing seasons, and by infiltration to the dolomite aquifer. Groundwater discharge, primarily from glacial deposits, is estimated to be 3.8 inches[6] under existing land use-floodland development conditions. This is approximately one-third of the total dry-weather flow of streams in the watershed: the remaining two-thirds come from industrial point source discharges.

Map 22 shows the estimated depth to seasonal high water in the sand and gravel aquifer for the Kinnickinnic River watershed. Seasonal high water is the average of annual highest groundwater levels most of which occur in the spring. Soils mapping and soils moisture information were used by the U. S. Geological Survey to determine the seasonal high water levels.[7] Seasonal high water in this aquifer may be expected to be less than 10 feet beneath the land surface for about 40 percent of the watershed area. The seasonal high water may be expected to be between 10 and 30 feet beneath the land surface for 55 percent of the watershed area and in excess of 30 feet beneath the land surface for the remaining 5 percent of the watershed.

[6] *Determined using the hydrologic-hydraulic model described in Chapter VIII.*

HYDRAULICS OF THE WATERSHED

As defined earlier in this chapter, hydraulics—in the context of comprehensive watershed planning—involves the inventory and analysis of those factors that affect the physical behavior of water as it flows within stream channels and on the attendant natural floodplains, under and over bridges, culverts and dams; through lakes and other impoundments; and within the watershed aquifer system. The preceding portion of this chapter has concentrated on the hydrology of the Kinnickinnic River watershed under the broad categories of surface water and groundwater hydrology. This section of the chapter describes the results of the inventory and initial analysis of surface water hydraulics in the Kinnickinnic River watershed. Inasmuch as there are no major lakes in the Kinnickinnic River watershed, the surface water system of the watershed consists essentially of the streams and associated floodplains. An overview of the watershed surface water resources is presented in Chapter III, "Description of the Watershed."

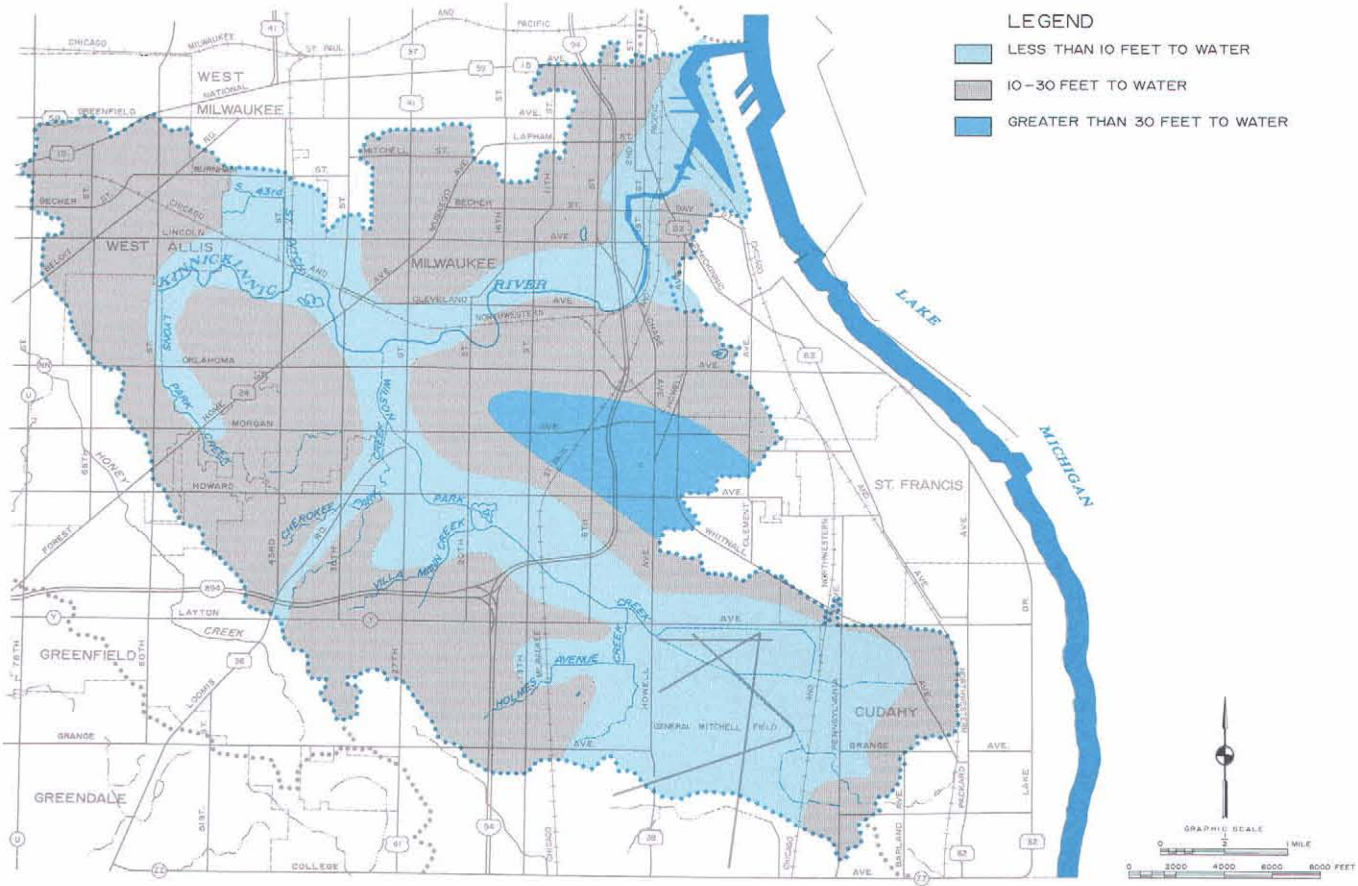
Portion of the Stream System Selected for Development of Detailed Flood Hazard Data

The lineal extent of the perennial and intermittent streams in the watershed is extensive if each tributary to the Kinnickinnic River is traced upstream to its origin. The cost of hydrologic-hydraulic simulation (which includes the cost of data collection, collation and coding; the cost of computer runs; and the cost of analyzing model results) increases in proportion to the lineal miles of streams that are modeled. Therefore, a decision was required on the portion of the watershed stream system for which detailed flood hazard information would be developed by hydrologic-hydraulic simulation studies prior to inventorying the hydraulic features of the stream system. Detailed flood hazard data are defined to include discharge-frequency relationships under existing and probable future land use conditions and corresponding flood stage profiles and areas subject to inundation by floods of selected recurrence interval.

[7] *Map 22 was developed from an unpublished map of the Planning Region entitled "Depth to Seasonal High Water" prepared by the U. S. Geological Survey in January 1977 for the SEWRPC areawide water quality management planning program.*

Map 22

SEASONAL HIGH WATER IN THE KINNICKINNIC RIVER WATERSHED



Seasonal high water in the watershed may be expected to be less than 10 feet beneath the land surface for about 40 percent of the watershed area. The seasonal high water may be expected to be between 10 and 30 feet beneath the land surface for 55 percent of the watershed area and in excess of 30 feet for the remaining 5 percent of the basin. As would be expected, seasonal high water is closest to the land surface in topographically low areas such as those along the Kinnickinnic River, Wilson Park Creek, and major tributaries.

Source: U. S. Geological Survey.

Selection Criteria: Five factors were considered in selecting streams and stream reaches of the Kinnickinnic River watershed for development, through hydrologic-hydraulic modeling techniques, of detailed flood hazard information:

1. The hydraulic importance of the stream in the context of the total watershed stream system. For example, most of the main stem of the Kinnickinnic River is included in the hydrologic-hydraulic modeling since flood stages on the Kinnickinnic River significantly affect flood stages on the lower portions of tributary streams.

2. Existing flood problems. For example, the Wilson Park Creek reach in the City of Cudahy—"Edgerton Ditch"—was considered for the development of detailed flood hazard data because, although there is no evidence of historic flood problems, there is potential for future development of such problems as evidenced by simulation studies. Detailed flood hazard information is needed for this and other similar reaches to permit proper consideration of alternative solutions to the existing and potential future flood problems.

3. Potential flood problems related to planned land use development. For example, the adopted regional land use plan envisions new urban development occurring in the southern portions of the watershed in the area tributary to Wilson Park Creek. Detailed flood hazard information is needed for this and other similar reaches to assure that future riverine area land use is placed and future channel modifications are sized so as to accommodate the likely higher flood stages and discharges.

4. Availability, without cost to the watershed planning program, of large-scale topographic maps of riverine areas or of other similar information such as detailed engineering plans or as-built drawings of major channelization projects. For example, the availability of orthophotogrammetric mapping for most of the Kinnickinnic River and Wilson Park Creek allowed the Commission to obtain field-surveyed channel-floodplain cross section data for the study of additional stream reaches such as "Edgerton Ditch." Acquisition of channel-floodplain cross sections for additional reaches would not have been possible, within budgetary limitations, had it been necessary to obtain such data for the Kinnickinnic River and Wilson Park Creek.

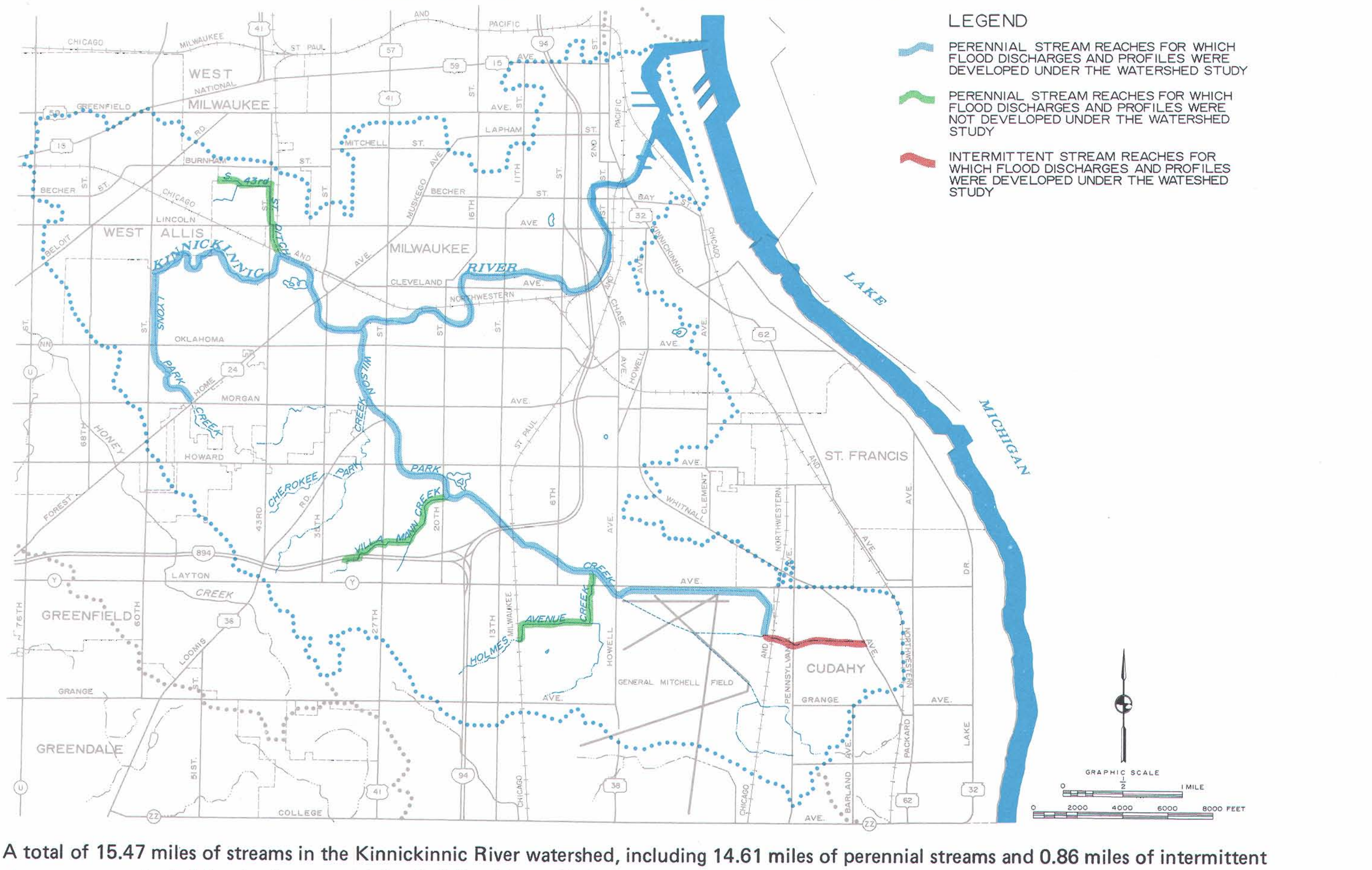
5. Wisconsin Department of Natural Resources (DNR) guideline: As a general rule, the DNR requires preparation and adoption of floodland use regulations along streams where serious flood damage may occur. This guideline was applied to the Kinnickinnic River watershed during selection of stream reaches for development of flood hazard information. For example, hydrologic-hydraulic simulation was extended far up Wilson Park Creek so as to include the "Edgerton Ditch" reach in the City of Cudahy which was determined by simulation studies to have the potential for flood damage under existing and future land use conditions.

It should be noted that the above selection criteria are independent of the perennial or intermittent nature of a stream as defined on U. S. Geological Survey quadrangle maps. The perennial or intermittent classification of a stream, particularly in an urban area, is of minor consequence relative to the above five factors. Classification of a stream as perennial or intermittent is not an index to the severity of either existing or potential flood problems in an urban area or an indication of the availability of data for analyzing those problems.

Selected Reaches: Based on the above criteria, parts of three streams within the Kinnickinnic River watershed were selected for hydrologic-hydraulic simulation leading to the development of detailed flood hazard information including discharge-frequency relationships under existing and future development of floodland and nonfloodland areas; and corresponding flood stage profiles and areas of inundation. These streams are shown on Map 23 and

Map 23

STREAM REACHES IN THE KINNICKINNIC RIVER WATERSHED SELECTED FOR PREPARATION OF FLOOD HAZARD INFORMATION



A total of 15.47 miles of streams in the Kinnickinnic River watershed, including 14.61 miles of perennial streams and 0.86 miles of intermittent streams, were selected for development of detailed flood hazard information. A detailed inventory was conducted of the 15.47 miles of selected stream reach to determine the storage and conveyance characteristics of the floodlands and the hydraulic capacity of all bridges, culverts, dams, and drop structures.

Source: SEWRPC.

consist of: 1) the main stem of the Kinnickinnic River which flows through the Cities of Milwaukee and West Allis; 2) that portion of Lyons Park Creek, a Kinnickinnic River tributary, lying within the City of Milwaukee; and 3) Wilson Park Creek, a Kinnickinnic River tributary, which passes through the Cities of Cudahy and Milwaukee. Tables 19 and 20 present more detailed information on the selected stream reaches and the tributary drainage areas; as indicated therein, detailed flood hazard information was developed for a total of 14.61 miles of perennial streams and 0.86 mile of intermittent streams or for a total of 15.47 miles of streams in the Kinnickinnic River watershed.

Subsequent to the identification of the above 15.47 miles of stream, the Commission conducted a detailed engineering inventory of the selected reaches. This inventory included collection, collation, and preliminary analysis of floodland characteristics as well as definitive data on bridges and culverts and physical information about dams and drop structures.

Floodland Characteristics: Included in the category of floodland characteristics are the magnitude and variation of channel slope, floodland shape and roughness, and the extent and nature of channel improvements. For a given discharge, each of these floodland characteristics can be a primary determinant of river stage.

Channel Profiles: Figure 19 shows channel profiles for the 15.47 miles of perennial and intermittent stream selected for the development of detailed flood hazard information. The sources of data for these channel bottom profiles were channel bottom elevations at bridges, culverts, dams, and drop structures which were determined from Milwaukee-Metropolitan Sewerage Commissions' contract drawings, City of Milwaukee Bureau of Engineers' contract drawings, and field surveyed channel cross sections. All of these data were collected or collated as part of the watershed hydraulic structure inventory.

Channel slopes are irregular with the steepest slopes being on Lyons Park Creek and generally flatter slopes on the Kinnickinnic River and Wilson Park Creek. All other hydraulic factors being equal or similar, steep channel slopes result in high stream flow velocities and shorter runoff times, whereas flat slopes produce lower velocities and longer runoff times. The steepest channel slopes in the Kinnickinnic River stream system approximate 41 feet per mile and are found along the 1.31-mile reach of Lyons Park Creek in the City of Milwaukee.

Although the channel profiles do illustrate the magnitude and variation of slopes throughout the watershed stream system, the primary purpose of developing the profiles was to provide a basis for estimating channel bottom elevations for channel-floodplain cross sections located

Table 19

SELECTED HYDRAULIC DATA FOR THE KINNICKINNIC RIVER WATERSHED BY SUBWATERSHED: 1977

Subwatershed		Stream Reach for Which Flood Stage Profiles Were Developed												
		Perennial[a]					Intermittent							
		Downstream End		Upstream End			Downstream End		Upstream End					
Number	Name	Location	River Mile	Location	River Mile	Length (miles)	Location	River Mile	Location	River Mile	Length (miles)	Total (miles)	Stream Slope (feet/mile)
1	Lyons Park Creek	Confluence with Kinnickinnic River at River Mile 8.01	0.00	Forest Home Avenue Outlet (S-395)	1.31	1.31	--	--	--	--	0.00	1.31	41.4
2	Upper Kinnickinnic River	Kinnickinnic River Parkway (S-235)	5.14	S. 60th Street Outfall (S-290)	8.05	2.91	--	--	--	--	0.00	2.91	19.3
3	Upper Wilson Park Creek	0.18 Mile Upstream of S. 20th Street	1.88	Upstream end of channelization in Mitchell Field	5.25	3.37	Upstream end of channelization in Mitchell Field	5.25	Whitnall Avenue (S-476)	6.11	0.86	4.23	7.1
4	Lower Wilson Park Creek	Confluence with Kinnickinnic River at River Mile 5.14	0.00	0.18 mile upstream of S. 20th Street	1.88	1.88	--	--	--	--	0.00	1.88	12.4
5	Lower Kinnickinnic River	Confluence with Milwaukee River	0.00	Kinnickinnic River Parkway (S-235)	5.14	5.14	--	--	--	--	0.00	5.14	14.4
	Total	--	--	--	--	14.61	Total	--	--	--	0.86	15.47	--

Subwatershed		Hydraulic Structures on That Portion of the Stream for Which Flood Stage Profiles Were Developed																			
		Bridges and Culverts[b]			Dams and Sills			Drop Structures			All Structures			Channel Modifications							
														Minor		Major		Conduit		Total	
Number	Name	Hydraulically Significant	Hydraulically Insignificant	Total	Hydraulically Significant	Hydraulically Insignificant	Total	Hydraulically Significant	Hydraulically Insignificant	Total	Hydraulically Significant	Hydraulically Insignificant	Total	Miles	Percent	Miles	Percent	Miles	Percent	Miles	Percent
1	Lyons Park Creek	7	5	12	0	0	0	9	0	9	16	5	21	0.29	22.1	0.80	61.1	0.22	16.8	1.31	100.0
2	Upper Kinnickinnic River	7	3	10	0	0	0	1	0	1	8	3	11	0.24	8.2	1.00	34.4	0.13	4.4	1.37	47.1
3	Upper Wilson Park Creek	15	1	16	0	0	0	1	0	1	16	1	17	0.86	20.4	2.34	55.3	1.03	24.3	4.23	100.0
4	Lower Wilson Park Creek	7	1	8	1	0	1	1	0	1	9	1	10	0	0	1.42	75.5	0.46	24.5	1.88	100.0
5	Lower Kinnickinnic River	32	1	33	0	0	0	3	0	3	35	1	36	0	0	4.84	94.2	0.00	0.00	4.84	94.2
	Total	68	11	79	1	0	1	15	0	15	84	11	95	1.39	9.0	10.40	67.2	1.84	11.9	13.63	88.1

[a] *As determined from U. S. Geological Survey Quadrangle maps and field surveys.*

[b] *Includes tunnel inlets and outlets and outfall structures.*

Source: SEWRPC.

Table 20

SELECTED HYDROLOGIC DATA FOR THE KINNICKINNIC RIVER WATERSHED BY SUBWATERSHED: 1975

Subwatershed[a]		Area			Total Area Tributary to Downstream-Most Point		Subbasins				1975 Land Use: Rural: Agriculture and Related		Other Open Lands[b]		Total Rural	
Number	Name	Acres (1975)	Square Miles (1975)	Percent of Watershed	Acres	Square Mile	Number	Largest (square miles)	Smallest (square miles)	Mean Area (square miles)	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed
1	Lyons Park Creek	644.67	1.01	3.9	647.77	1.01	3	0.48	0.38	0.43	--	--	3	0.5	3	0.5
2	Upper Kinnickinnic River	2,848.35	4.45	17.4	3,497.25	5.46	9	0.61	0.30	0.48	--	--	71	2.5	71	2.5
3	Upper Wilson Park Creek	4,499.37	7.03	27.4	4,503.32	7.04	14	1.70	0.05	0.50	144	3.2	659	14.6	803	17.8
4	Lower Wilson Park Creek	2,729.96	4.26	16.6	7,225.51	11.29	11	0.66	0.06	0.37	2	0.1	172	6.3	174	6.4
5	Lower Kinnickinnic River	5,694.45	8.90	34.7	16,400.59	25.62	14	1.00	0.19	0.57	--	--	317	5.6	317	5.6
	Total	16,416.80	25.65	100.0	--	--	51	1.70	0.05	0.49	146	0.9	1,222	7.4	1,368	8.3

Subwatershed[a]		1975 Urban Land Use: Residential		Retail and Service		Industrial		Governmental and Institutional		Park and Recreation		Transportation, Communications, and Utility Facilities		Total Urban	
Number	Name	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed	Acres	Percent of Subwatershed
1	Lyons Park Creek	382	59.2	15	2.3	--	--	31	4.8	20	3.1	194	30.1	642	99.5
2	Upper Kinnickinnic River	1,220	42.8	85	3.0	284	10.0	152	5.3	219	7.7	817	28.7	2,777	97.5
3	Upper Wilson Park Creek	933	20.7	97	2.2	255	5.7	135	3.0	129	2.9	2,147	47.7	3,696	82.2
4	Lower Wilson Park Creek	1,214	44.5	112	4.1	13	0.5	346	12.7	119	4.3	752	27.5	2,556	93.6
5	Lower Kinnickinnic River	1,963	34.5	223	3.9	407	7.1	541	9.5	317	5.6	1,927	33.8	5,378	94.4
	Total	5,712	34.8	532	3.2	959	5.9	1,205	7.3	804	4.9	5,837	35.6	15,049	91.7

[a] *With the exception of subbasin areas, data presented in this table were determined by means of approximating the subwatersheds by U. S. Public Land survey quarter sections. The actual measured total watershed area is 24.78 square miles, whereas the watershed area as approximated by 103 quarter sections is 25.65 square miles.*

[b] *Includes water, wetlands, woodlands, quarries, and other open lands.*

Source: SEWRPC.

at points in between the bridges, culverts, dams, and drop structures at which channel bottom elevations were not determined by field surveys and channel modification contract drawings. Channel bottom elevations for these intermediate locations—as obtained from the channel bottom profiles and field-surveyed channel cross sections—were required for the development of floodland cross sections as discussed below. This procedure was used for about 13 percent of the floodland cross sections developed under the Kinnickinnic River watershed planning program.

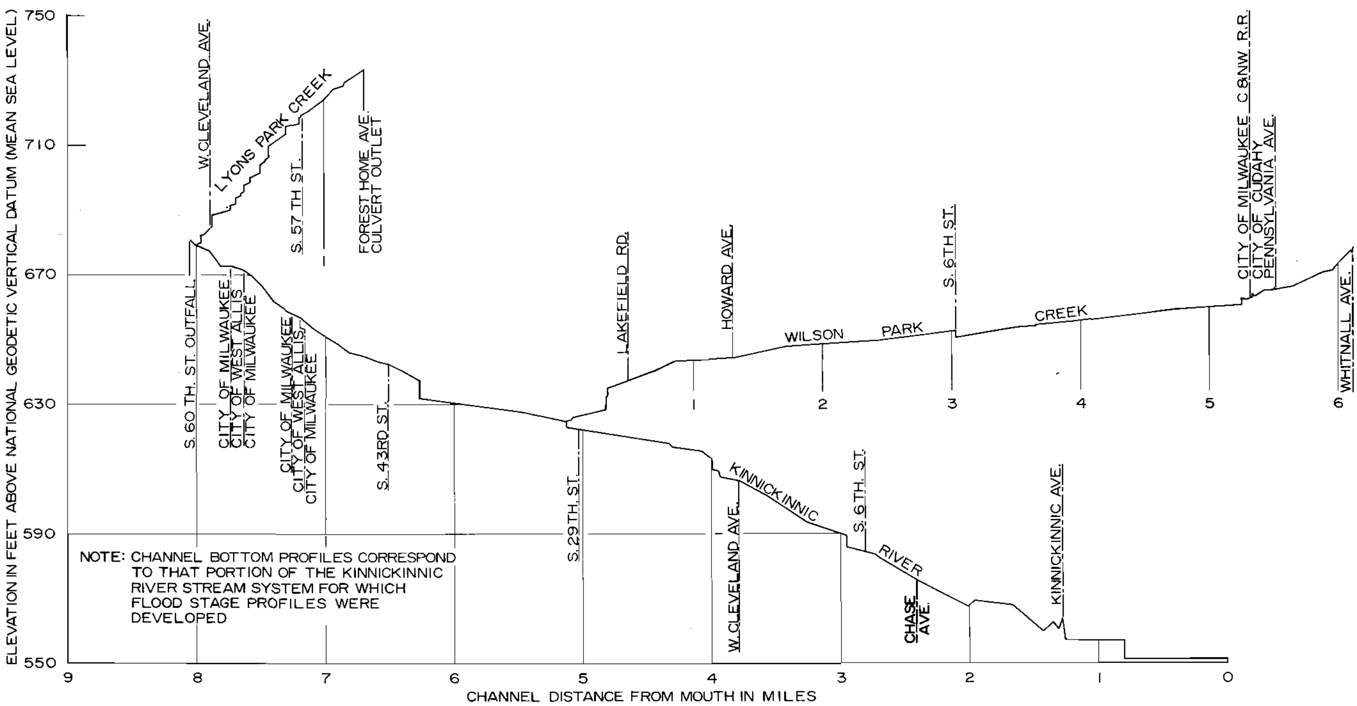
Floodland Cross Sections: The size and shape of the floodlands, that is, the channel and its natural floodplain, particularly the latter, are important floodland characteristics inasmuch as they influence flood stages and the lateral extent of inundation for a given flood discharge. Approximately 225 floodland cross sections at an average spacing of 500 feet were developed for the 15.47 miles of stream in the Kinnickinnic River watershed selected, as described above, for the development of detailed flood hazard information. The aforementioned cross sections exclude those immediately upstream and downstream of bridges, culverts, and other hydraulic structures inasmuch as the latter are intended to represent the configuration of the riverine area near and around the structure. In contrast, cross sections located 50 or more feet upstream and downstream of structures are intended to reflect the full conveyance of the unobstructed floodland area. After conversion to numerical form, these cross sections were input to the hydraulic submodel of the hydrologic-hydraulic simulation model as described in Chapter VIII, "Water Resources Simulation Model."

Floodland cross sections were developed from several sources including riverine area large-scale topographic maps, field-surveyed cross sections obtained under the watershed study, and channel improvement plans. Channel bottom elevations for some cross sections were obtained from the channel profiles prepared under the study. Map 24 indicates the primary source of floodland cross-section data by river reach throughout the 15.47 miles of stream for which detailed flood hazard information was developed. A floodland cross section, typical of those that were drawn prior to coding the data for input to the hydraulic submodel, is shown in Figure 20.

Numerous factors were considered in selection of the location, length, and orientation of floodland cross sections. These factors included strictly hydraulic considerations as well as nonhydraulic plan preparation and implementation considerations.

Figure 19

CHANNEL BOTTOM PROFILES FOR THE KINNICKINNIC RIVER AND SELECTED TRIBUTARIES



Source: SEWRPC.

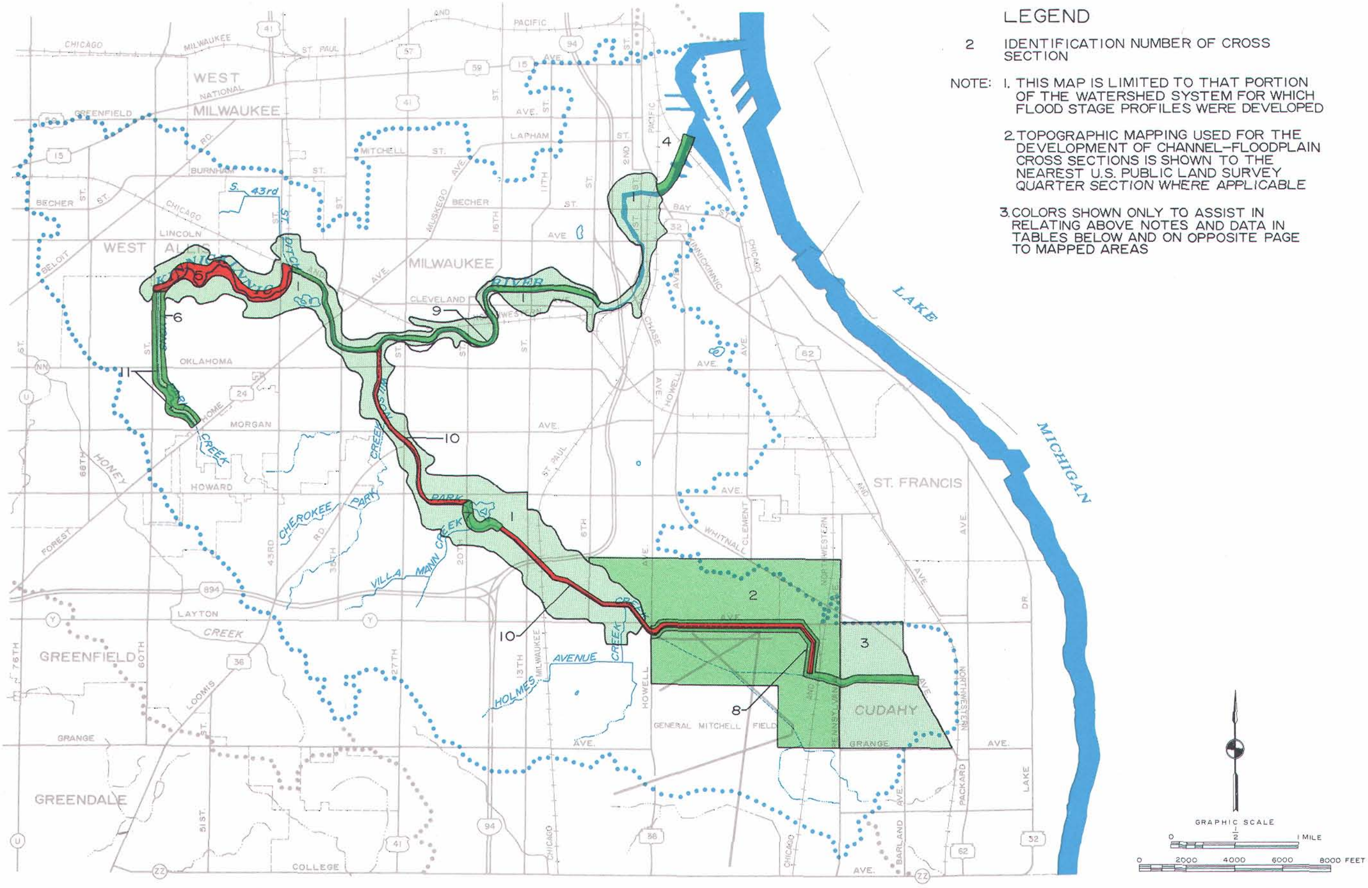
A principal hydraulic consideration was the selection of locations representative of the reach encompassed by the cross section. Other hydraulic factors influencing cross-section location included placement at abrupt changes in cross-sectional area or shape of the channel or natural floodplain roughness and at discontinuities in channel slope. Cross sections were generally located at close regular intervals so as to assure that computed flood stages would be of sufficient accuracy to be useful in all phases of floodland management including the delineation of floodland regulatory zones. Furthermore, closely spaced cross sections facilitate, subsequent to completion of the watershed plan, the hydraulic evaluation of proposed floodland developments or other riverine area changes. One nonhydraulic factor entering into the location of floodland cross sections was placement at points where civil division boundaries intersect the streams to permit the evaluation of the hydraulic effect of proposed riverine area developments in one community on upstream or downstream communities. Another nonhydraulic consideration was placement of cross sections at the points where U. S. Public Land Survey section and quarter section lines intersect the streams in order to facilitate the preparation of large-scale flood hazard maps showing the numerical value of the regulatory flood stages related to real property boundary lines.

With respect to orientation, the floodland cross sections were positioned to be approximately perpendicular to the main flow of the stream and its floodplain during flood flow conditions. The terminal points of the cross section were established at sufficient distance laterally from the stream so as to be well outside of the anticipated 100-year recurrence interval floodland limits.

Roughness Coefficients: The Manning roughness coefficient is a relative measure of the ability of a channel and its floodplain to convey flow. The discharge that can be conveyed in a given reach of channel at a specified channel slope and water stage is inversely proportional to the Manning roughness coefficient. Therefore, the carrying capacity of the channel and its floodplain diminishes as the value of the roughness coefficient increases.

Map 24

SOURCES OF CROSS SECTION DATA FOR CHANNEL AND FLOODPLAIN IN THE KINNICKINNIC RIVER WATERSHED



Approximately 225 floodland cross sections at an average spacing of 500 feet were developed for the 15.47 miles of stream modeled under the Kinnickinnic River watershed study. The floodland cross sections were developed from the several sources shown above which include large-scale topographic maps of the riverine areas, field-surveyed cross sections of the riverine areas, and channel modification plans. Floodland cross sections are used to determine the hydraulic characteristics of the stream channel and floodplains, characteristics that determine flood stage and the lateral extent of inundation for a given flood discharge.

Source: SEWRPC.

Large-Scale Topographic Mapping

Identification Number on Map 24	Civil Division City, Village, or Town	Scale	Contour Interval (feet)	Agency or Community for Which Mapping Was Originally Prepared	Date of Photography or Field Work	Date of Map Preparation
1	Cities of Milwaukee and West Allis	1″ = 200′	2	U. S. Geological Survey Orthophotographs	1975	1976
2	Cities of Cudahy, Milwaukee, and St. Francis	1″ = 100′		Milwaukee County Airport Department	1966	1966
3	City of Cudahy	1″ = 100′	2	City of Cudahy	1958	1958

Map 24 (continued)

SEWRPC Photogrammetric Cross Sections

Identification Number on Map 24	Stream Reach	Scale		River Mile		Date of Field Work
		Horizontal	Vertical	From	To	
4	Kinnickinnic River	1″ = 100′	1″ = 10′	0.82	1.26	1976
5	Kinnickinnic River	1″ = 10′	1″ = 1′	6.271	7.91	1976
6	Lyons Park Creek	1″ = 100′	1″ = 10′	0.00	1.31	1976
		1″ = 10′	1″ = 1′			
7	Wilson Park Creek	1″ = 10′	1″ = 1′	1.72	2.10	1976
8	Wilson Park Creek	1″ = 100′	1″ = 10′	3.66	6.12	1976

Milwaukee Metropolitan Sewerage Commission Channel Improvements Contract Drawings

Identification Number on Map 24	Stream Reach	Contract Number	River Mile		Date	
			From	To	Awarded	Completed
9	Kinnickinnic River	651	5.71	6.27	12-05-63	5-06-65
		705	2.74	3.59	9-29-60	6-30-61
		708	3.59	4.32	9-12-61	11-30-62
		710	4.32	5.12	3-15-63	11-07-63
		732	5.12	5.20	3-15-63	10-17-63
		735	5.20	5.71	9-26-63	5-07-64
		778	3.79	6.00	6-15-66	6-30-67
10	Wilson Park Creek	520	0.29	0.85	5-29-50	7-02-50
		534	1.30	1.70	1-02-52	6-08-52
		562	0.85	1.30	7-26-54	1-17-55
		598	2.12	2.42	7-20-56	11-13-56
		632	2.42	3.03	5-19-60	12-19-60
		685	0.70	0.85	12-18-57	7-15-58
		707	3.03	3.64	7-22-65	3-22-67
		749	0.00	0.33	1-29-71	12-29-71
		805	3.64	5.25	8-03-73	10-01-75

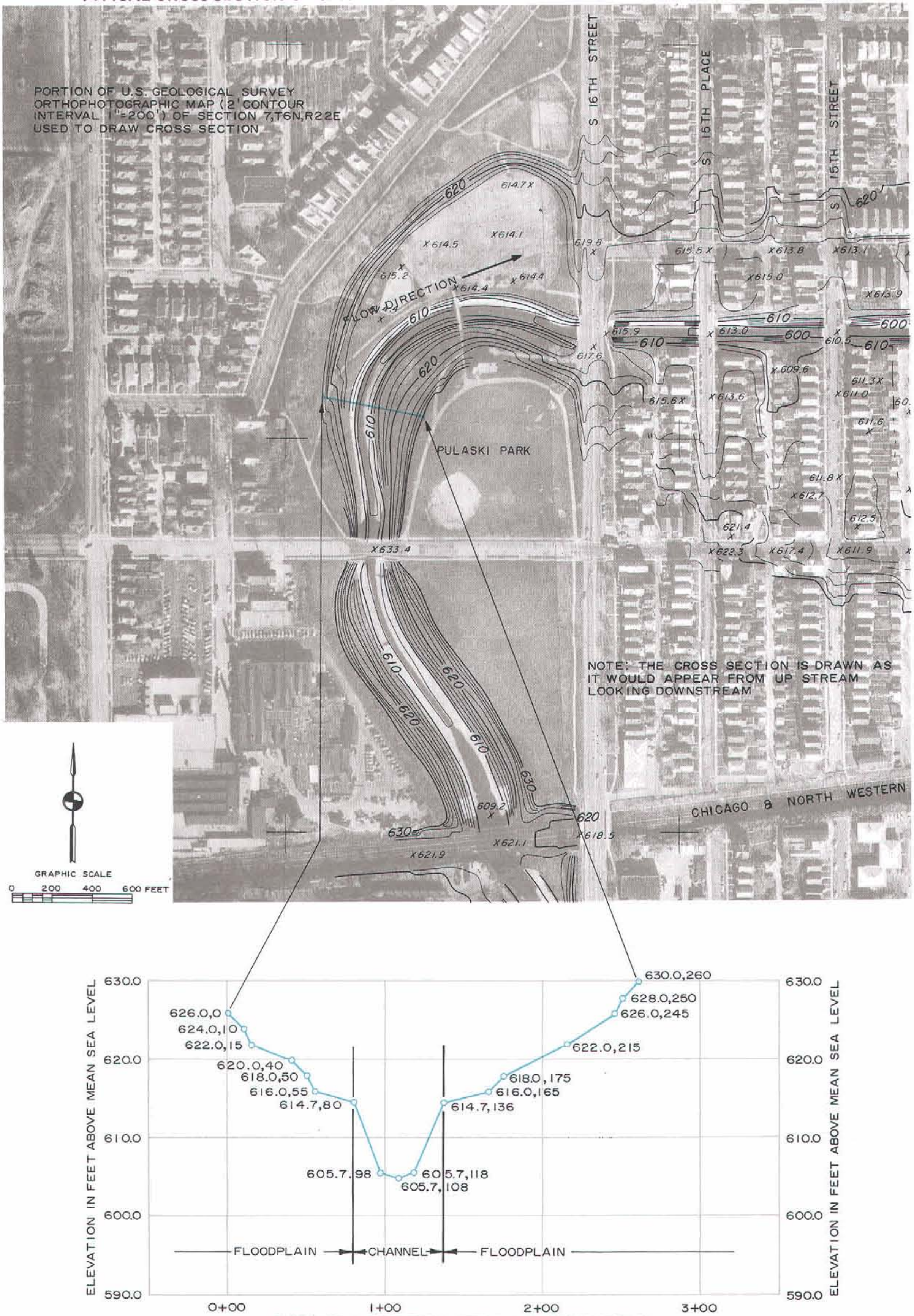
City of Milwaukee, Bureau of Engineers Channel Improvement Contract Drawings

Identification Number on Map 24	Stream Reach	Contract Number	River Mile		Date	
			From	To	Awarded	Completed
11	Lyons Park Creek	12-55	1.16	1.18	12-08-54	7-01-55
		16-55	1.06	1.31	12-15-54	7-22-55
		70-64	0.69	0.82	3-25-64	8-11-64
		541-65	0.54	0.57	9-22-65	5-25-66
		586-65	0.37	0.54	10-08-65	11-11-66
		376-67	0.27	0.30	8-27-67	9-29-67
		156-69	0.12	0.35	5-19-69	11-04-69
		C710287	0.02	0.06	10-06-71	7-06-72

Source: SEWRPC.

Figure 20

TYPICAL CROSS SECTION OF CHANNEL AND FLOODPLAIN IN THE KINNICKINNIC RIVER WATERSHED



Source: SEWRPC.

Table 21

MANNING ROUGHNESS COEFFICIENTS APPLIED TO THE CHANNEL AND FLOODPLAINS OF THE KINNICKINNIC RIVER WATERSHED

Channel

Condition		Roughness Coefficient Component[a]	
Material Involved	Concrete	n_1	0.013
	Earth		0.020
	Rock cut		0.025
	Fine gravel		0.024
	Coarse gravel		0.028
Degree of Irregularity	Smooth	n_2	0.000
	Minor		0.005
	Moderate		0.010
	Severe		0.020
Relative Effect of Obstructions	Negligible	n_3	0.000
	Minor		0.010-0.015
	Appreciable		0.020-0.030
	Severe		0.040-0.060
Vegetation	Low	n_4	0.005-0.010
	Medium		0.010-0.025
	High		0.025-0.050
	Very high		0.050-0.100
Degree of Meandering	Minor	k	1.000
	Appreciable		1.150
	Severe		1.300

Floodplain

Condition		Roughness Coefficient Minimum	Roughness Coefficient Normal	Roughness Coefficient Maximum
Pasture	Short grass	0.025	0.030	0.035
	High grass	0.030	0.035	0.050
Cultivated Areas	No Crop	0.020	0.030	0.040
	Mature row crops	0.025	0.035	0.045
	Mature field crops	0.030	0.040	0.050
Brush	Scattered brush, heavy weeds	0.035	0.050	0.070
	Light brush and trees, in winter	0.035	0.050	0.060
	Light brush and trees, in summer	0.040	0.060	0.080
	Medium to dense brush, in winter	0.045	0.070	0.110
	Medium to dense brush, in summer	0.070	0.100	0.160
Trees	Dense willows, summer, straight	0.110	0.150	0.200
	Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
	Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
	Heavy stand of timber a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
	Same as above, but with flood stage reaching branches	0.100	0.120	0.160

[a] *The composite Manning roughness coefficient for a channel reach* $= k(n_1 + n_2 + n_3 + n_4)$.

Source: Chow, V. T., Open Channel Hydraulics, Chapter 5, McGraw-Hill Book Co., 1959.

Roughness coefficients are a function of several factors including the kind of material—such as earth, gravel, and rock—forming the channel and attendant natural floodplain; the kind and density of vegetation—for example, rooted aquatic plants in the channel, and grass, agricultural crops, brush, and trees on the adjacent natural floodplain; and the sinuosity or degree of meandering of the channel. Floodland Manning roughness coefficients were assigned on the basis of field examination to the 15.47 miles of stream in the Kinnickinnic River watershed for which detailed flood hazard information was to be developed. Values were estimated on the basis of the various factors summarized in Table 21, assuming summer or growing season conditions. These data which, in a particular reach, were developed separately for the channel and each attendant natural floodplain were input to the hydrologic-hydraulic model used in the watershed planning program.

Channel Modification: Channel modifications—or channelization as it is commonly termed—usually include one or more of the following changes to the natural stream channel: straightening, channel deepening and thereby lowering of the channel profile, channel widening, placement of a concrete invert and sidewalls, and reconstruction of selected bridges and culverts. At times the natural channel may be relocated or completely enclosed in a conduit. These modifications to the natural channel generally yield a lower, hydraulically more efficient waterway, that results in significantly lower flood stages within the channelized reach. While channelization can be an effective means of reducing flood damages, it may entail high aesthetic and ecological costs. Furthermore, because of the increased streamflow velocities resulting from channelization, channel modifications tend to increase downstream peak flood discharges and stages, and, therefore, may cause new flood problems or aggravate existing ones.

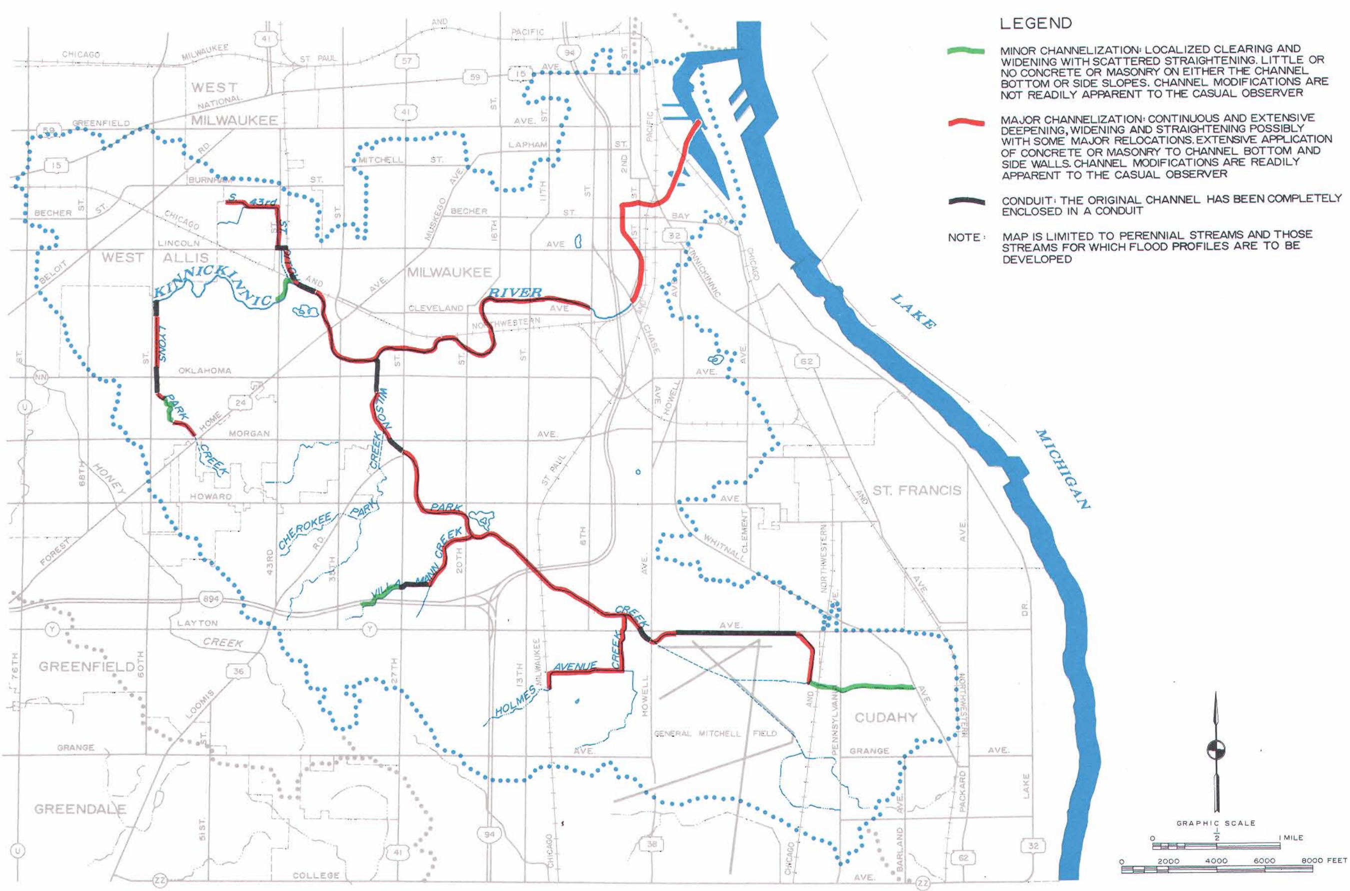
In contrast to most of the other watersheds in the Region, a large portion of the stream system of the Kinnickinnic River watershed has been intentionally modified for flood control purposes. Of the 15.47 miles of stream system in the watershed selected for development of detailed flood hazard data, approximately 13.63 miles, or 88 percent, are known to have undergone some type of man-made channel modification.

Map 25 shows the lineal extent and the nature of known man-made channel modifications within the Kinnickinnic River watershed on perennial streams plus the other portions of the stream system selected for development of detailed flood hazard data. The following three types of channelization were defined, and are shown on Map 25 to illustrate the extent to which the original stream channel system has been altered:

1. Minor channelization: Localized clearing and widening with scattered straightening. Little or no concrete or masonry on either the channel bottom or side slopes. Channel modifications not readily apparent to the casual observer. Examples of minor channelization include drainage improvements along Wilson Park Creek—Edgerton Ditch—in the City of Cudahy and urban area modifications along the Kinnickinnic River in Jackson Park in the City of Milwaukee.

Map 25

CHANNEL MODIFICATIONS IN THE KINNICKINNIC RIVER WATERSHED



In contrast to most of the other watersheds in the Region, a large portion of the stream system of the Kinnickinnic River watershed has been intentionally modified for flood control purposes. For example, of the 15.47 miles of stream system in the watershed selected for development of detailed flood hazard data approximately 13.63 miles, or 88 percent, are known to have undergone some type of man-made channel modification. These stream reaches selected for development of flood hazard data include portions of the Kinnickinnic River, Wilson Park Creek, and Lyons Park Creek.

Source: SEWRPC.

2. Major channelization: Continuous and extensive deepening, widening, and straightening, possibly with major relocations. Extensive application of concrete or masonry to channel bottom or side walls. Channel modifications are readily apparent to the casual observer. Major channelization is exemplified by the main stem of the Kinnickinnic River between S. 6th Street and Jackson Park in the City of Milwaukee and by that portion of Wilson Park Creek between W. Euclid Avenue and W. Layton Avenue in the City of Milwaukee.

3. Conduit: The original natural channel has been completely enclosed in a conduit. The principal example of this form of channel modification is the 0.89-mile-long reach of Wilson Park Creek passing through General Mitchell Field in the City of Milwaukee.

The above classification of channel modifications, particularly the minor and major channelization categories, is intended to describe the degree to which the channel proper has been altered and is not, therefore, necessarily an indicator of the aesthetic impact of the channelization. Compare, for example, the 0.77-mile portion of the Kinnickinnic River between S. 6th Street and S. 16th Street and the 1.45-mile segment of the River immediately upstream between S. 16th Street and S. 29th Street. While both of these urban area reaches underwent major channelization, the reach of the Kinnickinnic River between S. 16th Street and S. 29th Street exhibits a significantly higher aesthetic quality primarily because of the contiguous open space that is wide, relative to the channel, and that lies on both sides of the channel. This large "green area" has the effect of ameliorating the potentially negative aesthetic impact of the channelization of the river.

In accordance with the above definitions, the 15.47 miles of the watershed stream system selected for hydrologic-hydraulic simulation contain, as shown in Table 19, 1.39 miles of minor channelization, 10.40 miles of major channelization, and 1.84 miles of conduit, for a total of 13.63 miles of channel modifications. The value, which encompasses about 88 percent of the stream system selected for development of detailed flood hazard data, is necessarily a minimum or lower limit inasmuch as it is difficult to identify with certainty all of those stream reaches in the minor channelization category. As is evident on Map 25, channel modifications are located throughout the intensely developed Kinnickinnic River watershed which suggests that widespread mitigation of flood damage to riverine area urban development has been the primary motivation for channel modifications in the Kinnickinnic River watershed.

As for downstream riverine areas, the hydraulic effect of channelization is very similar to that of floodplain fill and development. Channelization, like floodplain fill and development, reduces the floodwater storage capability of the modified reach, thereby generally giving rise to downstream flood hydrographs that have, relative to prechannelization conditions, shorter bases and higher peaks. It is possible, however, depending on the relative position of the channelized reach or reaches in the watershed stream system, for channelization to result in reduced downstream discharges. For example, channelization in the lower reaches of a watershed may provide for the rapid removal of runoff from the lower portion of the watershed prior to the arrival of middle and upper watershed drainage, thereby reducing lower watershed discharges and stages.

The effects of channel improvement projects are the reverse of the effect of other structural flood control measures, such as reservoirs, which are designed to impede flow, decrease velocity, and cause backwater effects. Channel improvements accelerate flow, increase velocity, and reduce upstream backwater effects. Floodwater storage structures tend to prolong the base time of surface runoff and decrease peak discharges in the downstream direction, while channel improvements have the effect of decreasing base time and increasing stage and peak flow rate downstream from the improvement.

It is apparent, therefore, that haphazard and uncoordinated channel modification may cause adverse effects elsewhere in a watershed, resulting in little or no net overall benefits on the surface water problems of a watershed. This possibility points to the need for proper water management practices based upon a comprehensive watershed plan. In recognition of the need to evaluate the potential downstream effect of channelization proposals within the Kinnickinnic River watershed, one of the standards supporting the adopted water control facility development objectives, as set forth in Chapter X, "Watershed Development Objectives, Principles and Standards," requires the explicit determination of the downstream impact of proposed channel modifications.

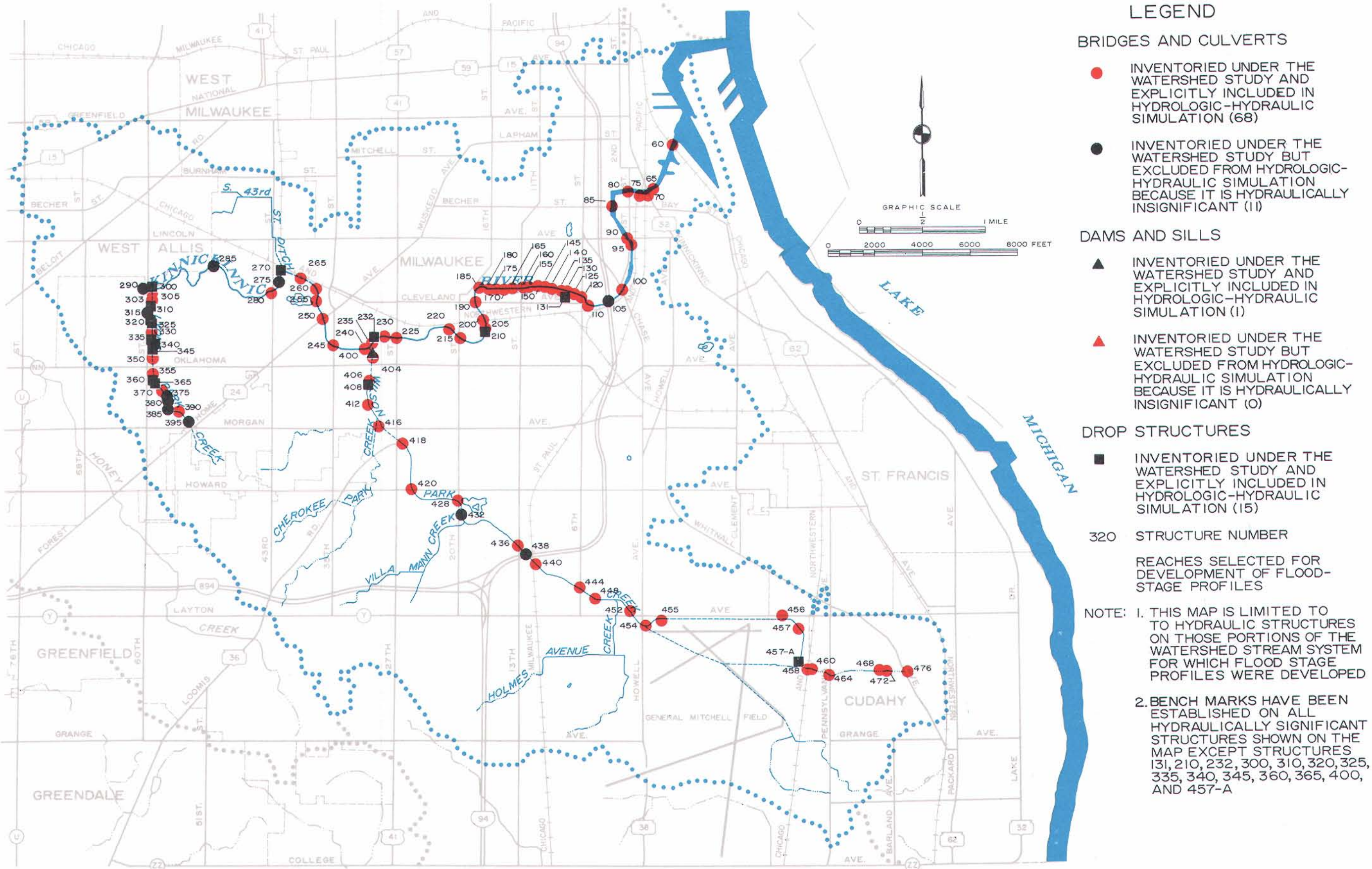
Because adequate historic data are lacking, it is extremely difficult to make a meaningful quantitative evaluation based solely on such data of the overall effect which existing channel improvement projects have had on the flow regimen of the stream system of the whole watershed. It is reasonable to assume, however, that extensive additional channelization in the upper reaches of the watershed could increase flood flows in the lower portion of the basin.

Bridges and Culverts: Depending on the size of the waterway opening and the characteristics of the approaches, bridges and culverts can be important elements in the hydraulics of a watershed, particularly with respect to localized effects. The constriction caused by an inadequately designed bridge or culvert can result under flood discharge conditions in a large backwater effect and thereby create upstream flood stages that are significantly higher and an upstream floodland that is significantly larger than would exist in the absence of the bridge or culvert.

As of the end of 1976, the 15.47 lineal miles of Kinnickinnic River watershed stream system selected for hydrologic-hydraulic modeling were crossed, as shown on Map 26, by 79 bridges and culverts having an average spacing of 0.2 mile. The heavy concentration of bridges and culverts in the stream system reflects the urban nature of the watershed. While the hydraulic submodel of the hydrologic-hydraulic simulation model, as described

Map 26

HYDRAULIC STRUCTURE INDEX FOR THE KINNICKINNIC RIVER WATERSHED: 1975



One sill, 15 channel drop structures, and 79 bridges and culverts were inventoried during the course of the Kinnickinnic River watershed study. Data obtained from this inventory were used to identify those sills, channel drop structures, bridges, and culverts that can be expected, by virtue of hydraulic capacity and location in the watershed, to significantly influence flood discharges and stages along the principal stream channels in the basin. As a result of this screening process, a total of 68 bridges and culverts, one sill, and 15 channel drop structures were identified for later incorporation into the water resources simulation model, as described in Chapter VIII.

Source: SEWRPC.

in Chapter VIII, has the capability of accommodating any number or type of bridge or culvert, the cost of the field surveys necessary to acquire the input data for the submodel required that a determination be made, based on a field reconnaissance, of the hydraulic significance of each bridge or culvert in order to significantly reduce the number of structures for which complete physical descriptions would have to be obtained.

A bridge or culvert was defined as being hydraulically significant if field inspection suggested that the structure might influence flood stages by 0.5 foot or more for the 10- through 100-year recurrence interval flood discharges. In examining each bridge or culvert to evaluate its potential hydraulic significance, the structure was considered to consist of the roadway or railroad approaches as well as structural components such as abutments, piers, and deck in the immediate vicinity of the waterway opening.

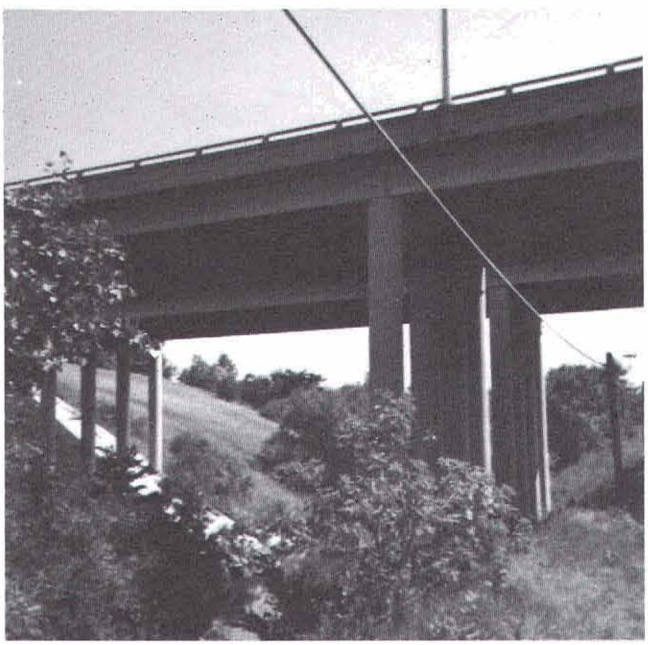
One category of hydraulically insignificant bridges and culverts consists of those having a relatively small superstructure relative to the combined width of the channel and its natural floodplain. Such structures typically have approaches that do not rise significantly above the floodplain while the portion of the structure in the immediate vicinity of the channel simply spans the channel. Pedestrian crossings and private roadway bridges and culverts comprise most of the bridges and culverts in this category of hydraulically insignificant structures. An example of this type of hydraulically insignificant structure is, as shown in Figure 21, a park pedestrian bridge over the Kinnickinnic River in Jackson Park in the City of Milwaukee.

The second category of hydraulically insignificant bridges and culverts consists of those that are elevated on piers well above the channel and the floodplain. While being

Figure 21

EXAMPLES OF HYDRAULICALLY INSIGNIFICANT RIVER CROSSINGS IN KINNICKINNIC RIVER WATERSHED

Pedestrian bridge over the Kinnickinnic River in Jackson Park in the City of Milwaukee.

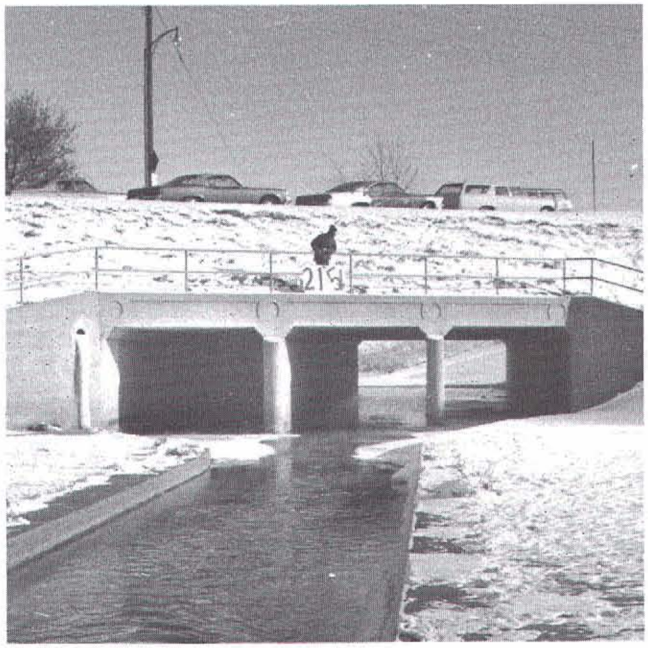


North-South Freeway (IH 94) bridge over the Kinnickinnic River in the City of Milwaukee.

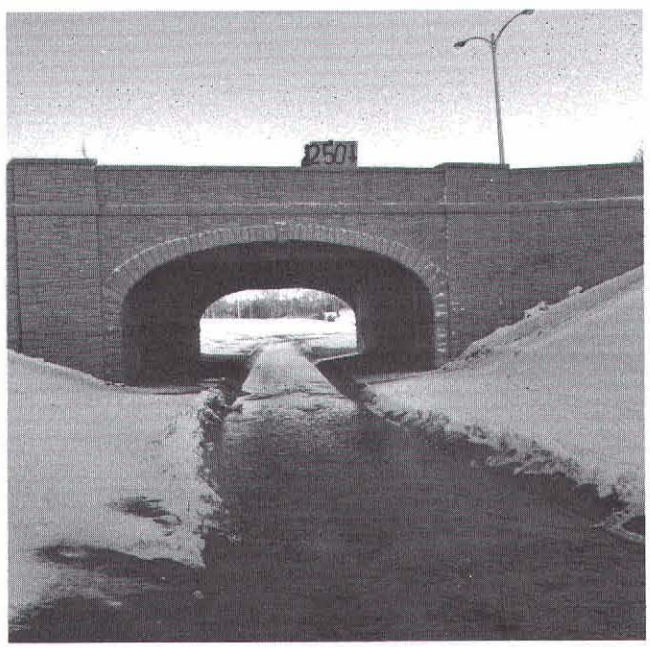
Source: SEWRPC.

Figure 22

EXAMPLES OF HYDRAULICALLY SIGNIFICANT RIVER CROSSINGS IN THE KINNICKINNIC RIVER WATERSHED



S. 20th Street Bridge over the Kinnickinnic River in the City of Milwaukee.



W. Forest Home Avenue bridge over the Kinnickinnic River in the City of Milwaukee.

Source: Alster and Associates.

major or significant structures in the transportation sense in that they carry railroads and public streets and highways and particularly arterial streets and highways across the floodland, they are hydraulically insignificant in that they utilize little or no fill for the approaches and, therefore, offer little impedance to flow during even major flood events. An example of this type of hydraulically insignificant structure, as shown in Figure 21, is the North-South Freeway (IH 94) bridge over the Kinnickinnic River in the City of Milwaukee.

Hydraulically significant bridges and culverts generally are characterized by relatively small waterway openings in combination with approaches that are constructed well above the elevation of the floodplain. Such structures function as dams and have the potential for obstructing streamflow during major flood events. As shown in Figure 22, examples of hydraulically significant structures include the S. 20th Street crossing of the Kinnickinnic River and the W. Forest Home Avenue crossing of the Kinnickinnic River in the City of Milwaukee.

Based on field reconnaissance, 68, or 86 percent, of the 79 bridges or culverts on that portion of the Kinnickinnic River watershed stream system selected for development of detailed flood hazard data were determined to be hydraulically significant. The location of these hydraulically significant bridges and culverts is shown on Map 26 whereas the number of structures on each of the selected stream reaches is set forth in Table 19. The average spacing of these hydraulically significant structures is 0.23 miles.

To meet the input data needs of the hydraulic submodel, it was necessary to obtain detailed data on these 68 structures. Data needs included measurement of the waterway opening, determination of channel bottom elevations, and construction of a profile—from one side of the floodplain to the other—along the crown of the roadway or the top of rail of the railroad. The necessary information for each of the 68 hydraulically significant bridges and culverts was obtained by field survey. A network of vertical survey control stations—bench marks—referenced to National Geodetic Vertical Datum as determined by the U. S. Coast and Geodetic Survey was established on all hydraulically significant bridges and culverts prior to the acquisition of detailed data on the structures. Closed spirit level circuits were run to establish permanent bench marks on each structure to third order accuracy. At least one reference bench mark was established for each permanent bench mark and a record of vertical survey control, like that shown in Figure 23, was prepared for each hydraulically significant bridge or culvert. As part of the field survey work needed to establish the vertical survey control network, the channel bottom elevation was determined at the upstream face of each of the 68 hydraulically significant bridges and culverts, which, in addition to providing information about the waterway opening, facilitated the drawing of channel bottom profiles.

Figure 23

TYPICAL RECORD OF A VERTICAL CONTROL STATION ALONG THE KINNICKINNIC RIVER WATERSHED STREAM SYSTEM: 1976

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
RECORD OF VERTICAL CONTROL STATION

SECTION 7, TOWNSHIP 6 N, RANGE 22 E

Milwaukee COUNTY

BENCH MARK NO. KN-64 ELEVATION 633.855'

REFERENCE BENCH MARK NO. RN-64 ELEVATION 636.004'

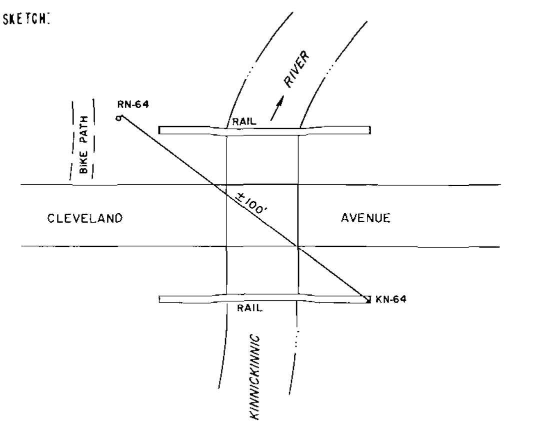
SET BY: ALSTER & ASSOCIATES, INC., ENGINEERS, MADISON, WISCONSIN

VERTICAL DATUM: MEAN SEA LEVEL, 1929 ADJUSTMENT

VERTICAL CONTROL ACCURACY:

DATE OF SURVEY: December 1976

LOCATION SKETCH:



DETAILED DESCRIPTION: About 0.2 mile east of the center of section 7, T 6 N, R 22 E; about 0.2 mile east of Twentieth Street; on the east end of the southeast wingwall; a chiseled square.
RN-64: On the NE flange bolt of a fire hydrant; a chiseled plus.

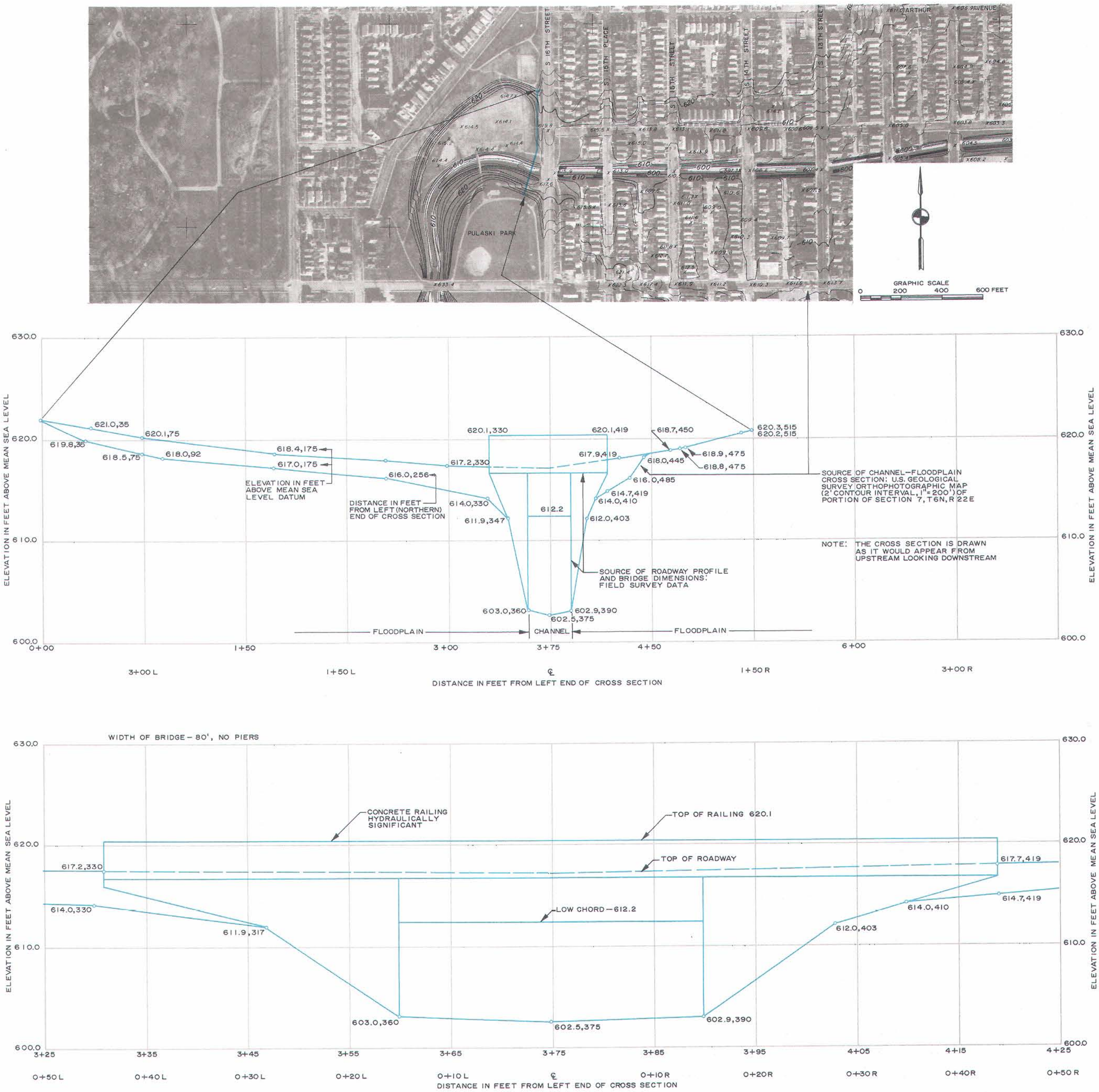
Source: SEWRPC.

Prior to coding the bridge and culvert data for input to the hydraulic model, the structure information was used to draw a cross section showing the physical configuration of the waterway opening and the approach roads. Figure 24 shows a structure drawing typical of those prepared for each of the hydraulically significant bridges and culverts in the Kinnickinnic River watershed.

Dams and Drop Structures: In addition to the 79 bridges and culverts located on that portion of the Kinnickinnic River watershed stream system selected for development of detailed flood hazard information, there are 15 drop structures and a low dam-like structure, here called a sill, for a total of 95 hydraulic control structures. Nine of the 15 drop structures are located along the channelized segments of Lyons Park Creek. The remaining six drop structures are located along the channelized portions of the Kinnickinnic River and Wilson Park Creek. These drop structures are an integral part of the channel modifications and provide for abrupt breaks in the channel bottom profile of the channelized reaches, thereby facilitating milder slopes between the structures which in turn provide for lower, less erosive velocities during flood events.

Figure 24

TYPICAL DRAWING OF A HYDRAULIC STRUCTURE IN THE KINNICKINNIC RIVER WATERSHED



Source: SEWRPC.

The sill, located on Wilson Park Creek immediately upstream of its confluence with the Kinnickinnic River, and all 15 of the channel drops were determined by field examination to be hydraulically significant using criteria similar to those applied to bridges and culverts. The location of the hydraulically significant dams and drop structures is shown on Map 26, whereas the number of such structures on each of the selected stream reaches is set forth in Table 19. Of the 95 hydraulic structures—bridges, culverts, sills, and drop structures—located on the stream system, a total of 84, or about 88 percent, were determined to be hydraulically significant.

The vertical survey control network discussed above was extended to the hydraulically significant dams and drop structures, and channel bottom elevations were determined at each such structure. Detailed information on the physical characteristics of some of the dams and drop structures was obtained from the Milwaukee-Metropolitan Sewerage Commissions and from the City of Milwaukee. Additional necessary information was obtained by field survey. Cross section drawings were prepared for each of the 16 hydraulically significant sills and drop structures prior to coding the data for use in the hydrologic-hydraulic modeling.

SUBWATERSHEDS AND SUBBASINS IN THE KINNICKINNIC RIVER WATERSHED

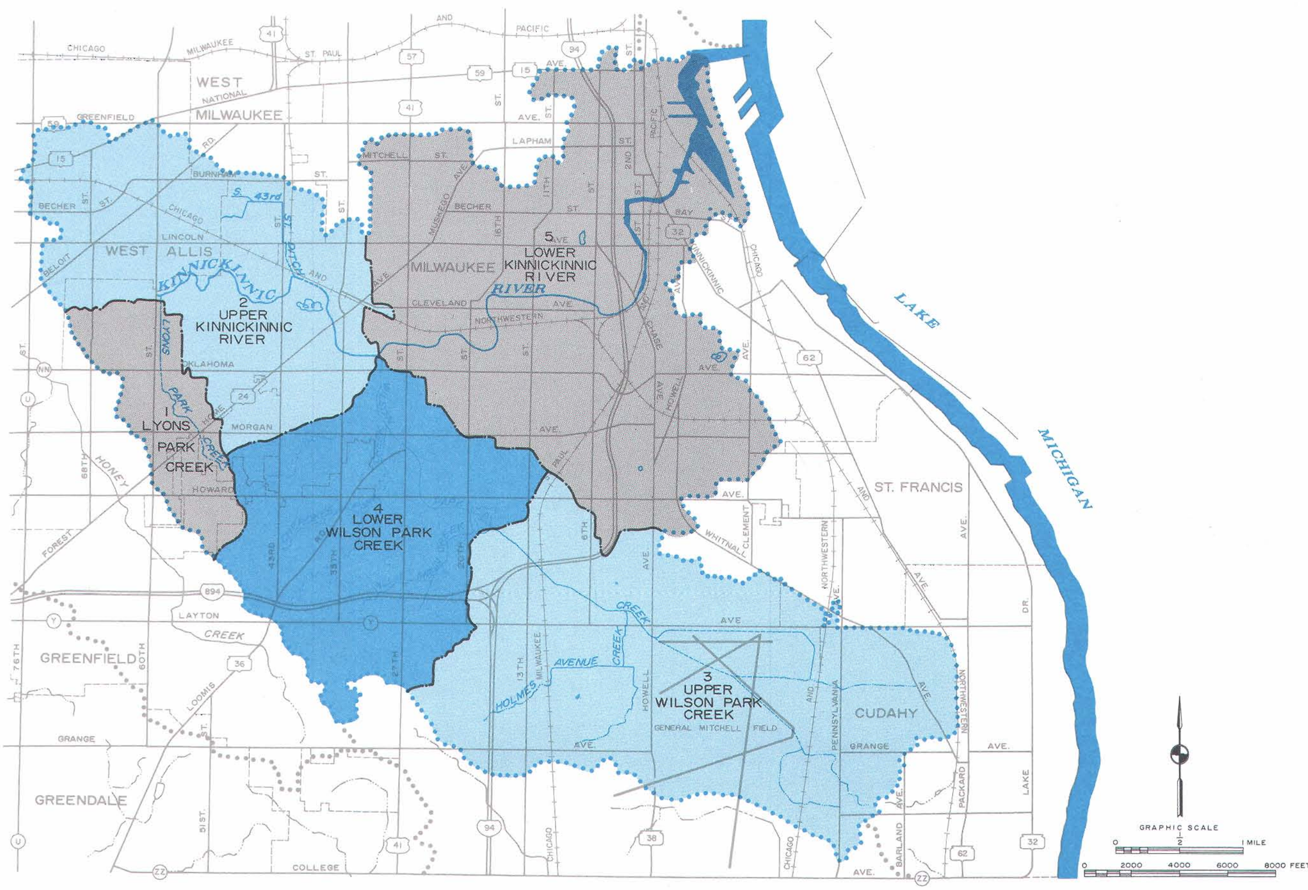
Whereas previous sections of this chapter have described watershed hydrologic-hydraulic characteristics on the basis of the entire watershed, this last section of the chapter presents hydrologic and hydraulic data for each subwatershed. More specifically, data and information on subbasins, land use, channel slopes, hydraulic structures, and channel modifications are presented and discussed below. Summaries of hydraulic and hydrologic data by subwatershed are set forth in Tables 19 and 20, respectively, and subwatershed and subbasin areas are set forth in Table 22.

Subwatersheds

The Kinnickinnic River watershed may be considered to be a composite of five subwatersheds, as shown on Map 27, each of which is defined as the area directly

Map 27

SUBWATERSHEDS OF THE KINNICKINNIC RIVER WATERSHED



Five subwatersheds were delineated within the Kinnickinnic River watershed ranging in area from the Lower Kinnickinnic River subwatershed, having a size of 8.9 square miles in area, to the Lyons Park Creek subwatershed with an area of about 1.0 square mile. In addition to providing rational units for hydrologic analysis, the subwatersheds serve as geographic units that enable the watershed resident to readily identify the relationship of his or her local drainage area to the large Kinnickinnic River watershed.

Source: SEWRPC.

Table 22

AREAS OF SUBWATERSHEDS AND SUBBASINS IN THE KINNICKINNIC RIVER WATERSHED

Subwatersheds				Subbasins		
Number	Name	Area[a] (square miles)	Total Area Tributary to Subwatershed Discharge Point (square miles)	Identification	Area[a] (square miles)	Total Area Tributary to Subbasin Discharge Point (square miles)
1	Lyons Park Creek	1.321	1.321	LC-1	0.462	0.462
				LC-2	0.483	0.945
				LC-3	0.376	1.321
2	Upper Kinnickinnic River. . .	4.287	5.608	WMD-1	0.600	0.600
				WMD-2	0.498	1.098
				WMD-3	0.595	1.693
				KKR-1	0.434	0.434
				KKR-2	0.466	3.914
				KKR-3	0.478	4.392
				KKR-4	0.299	4.691
				KKR-5	0.311	5.002
				KKR-6	0.606	5.608
3	Upper Wilson Park Creek	7.102	7.102	WPC-1	0.529	0.529
				WPC-2A	0.406	0.935
				WPC-2	0.560	1.495
				WPC-3	1.697	3.192
				WPC-4A	0.389	3.581
				WPC-4	0.333	3.914
				WPC-5	0.139	4.053
				HAC-1	0.764	0.764
				HAC-2	0.400	1.164
				HAC-3	0.394	1.558
				HAC-4	0.053	1.611
				WPC-6	0.616	6.280
				WPC-7	0.510	6.790
				WPC-8	0.312	7.102
4	Lower Wilson Park Creek	4.087	11.189	VMC-1	0.656	0.656
				VMC-2	0.395	1.051
				VMC-3	0.253	1.304
				WPC-9	0.061	8.467
				WPC-10	0.647	9.114
				WPC-11	0.282	9.396
				CPC-1	0.334	0.334
				CPC-2	0.494	0.828
				CPC-3	0.216	1.044
				WPC-12	0.477	10.917
				WPC-13	0.272	11.189
5	Lower Kinnickinnic River. . .	7.983	24.780	KKR-7[b]	0.786	17.583
				KKR-8	0.497	18.080
				KKR-9	0.563	18.643
				KKR-10	0.194	18.837
				KKR-11[b]	1.004	19.841
				KKR-12	0.777	20.618
				KKR-13	0.504	21.122
				KKR-14	0.343	21.465
				KKR-15[b]	0.792	22.257
				KKR-16[b]	0.404	22.661
				KKR-17[b]	0.330	22.991
				KKR-18[b]	0.449	23.440
				KKR-19[b]	0.399	23.839
				KKR-20[b]	0.941	24.780

[a] *Data presented in this table were determined by planimetering subbasin areas from a 1" = 2000' watershed map.*

[b] *Subbasins wholly within combined sewer service area, with the exception of subbasin 15 which is only partly within the combined sewer service area.*

Source: SEWRPC.

tributary to all or portions of the three stream reaches selected for application of hydrologic-hydraulic simulation culminating in the development of detailed flood hazard data. These subwatersheds are: 1) the Lower Kinnickinnic River subwatershed which encompasses 8.87 square miles, or 34.6 percent of the total watershed area, 2) the Upper Kinnickinnic River subwatershed which encompasses 4.45 square miles, or 17.4 percent of the total watershed area, 3) the Lower Wilson Park Creek subwatershed which encompasses 4.25 square miles, or 16.6 percent of the total watershed area, 4) the Upper Wilson Park Creek subwatershed which encompasses 7.04 square miles, or 27.5 percent of the total watershed area, and 5) Lyons Park Creek subwatershed which encompasses 1.01 square miles, or 3.9 percent of the total watershed area.

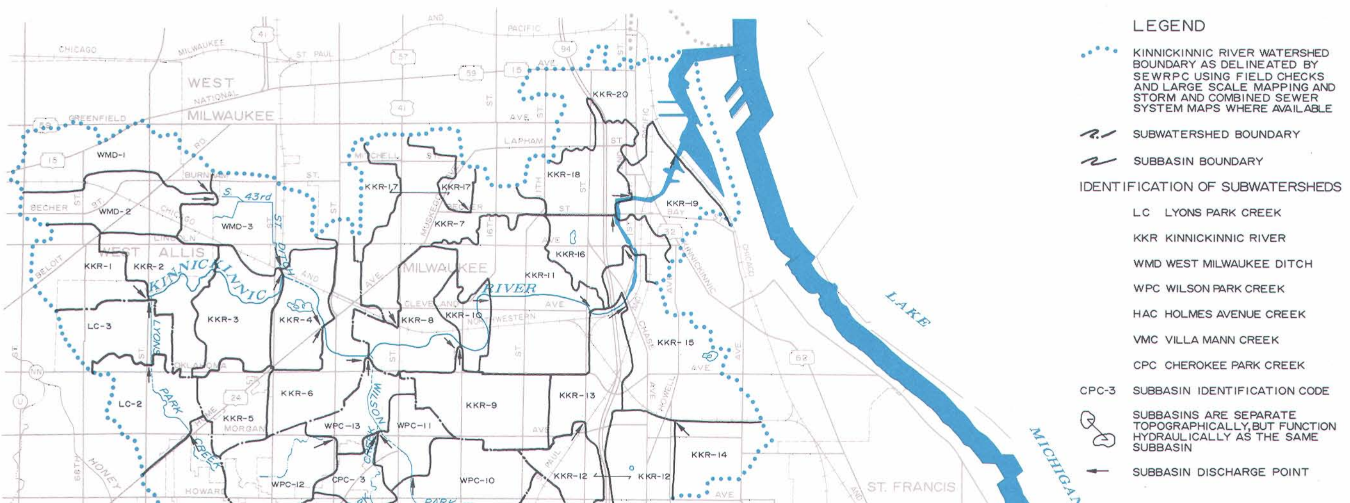
A subwatershed by subwatershed examination of the hydrologic-hydraulic characteristics of the Kinnickinnic River watershed, as set forth in Tables 19 and 20, indicates that those features are relatively homogeneous within the watershed. With the exception of the Upper Kinnickinnic River subwatershed, over 85 percent of the stream reaches selected for development of flood hazard information within each subwatershed has undergone channel modifications.

Subbasins

Hydrologic-hydraulic simulation modeling, the function of which is described in Chapter VIII, "Water Resource Simulation Model," requires that the subwatersheds be further subdivided into subbasins. Subbasins are the basic "building blocks" for simulating the hydrologic-hydraulic response of the watershed land surface. A total of 51 subbasins was delineated in the watershed, as shown on Map 28, ranging in size from 1.70 to 0.05 square miles and having an average area of 0.49 square mile. These subbasins were delineated using the best available topographic maps ranging from large scale 1" = 100', 2-foot contour interval maps to small scale 1" = 2000', 10-foot

Map 28

SUBBASINS OF THE KINNICKINNIC RIVER WATERSHED



A total of 51 subbasins was delineated within the Kinnickinnic River watershed for purposes of hydrologic-hydraulic simulation, ranging in size from 1.70 to 0.05 square mile and having an average area of 0.49 square miles. The boundaries of subbasins were selected to reflect homogeneous hydrologic soil groups, land use, vegetal cover, and land slope, and thus permit more ready characterization of hydrologic-hydraulic behavior of the land surface.

Source: SEWRPC.

contour interval U. S. Geological Survey quadrangle maps. The maps were supplemented with street grade data and information on the location, configuration, and elevation of storm and combined sewer systems.

Many factors entered into delineation of the subbasins. Some of these were strictly hydrologic-hydraulic factors while others were more directly related to plan preparation and implementation. Subbasins were delineated to encompass areas tributary to intermittent streams, drainageways, and storm sewers even though those streams and drainageways may not have been selected for development of detailed flood hazard data under the watershed planning program since such delineations may be useful in subsequent extensions and refinements of the Kinnickinnic River watershed plan. The boundaries of subbasins were selected to reflect land use, vegetal cover, and land slope. The existence of prominent natural features, such as potential sites for surface water impoundments, and prominent man-made features, such as dams and long and high railroad and roadway embankments, entered into selection of the discharge point for some subbasins. Subbasins were delineated to terminate at streamflow and water quality monitoring stations, at village and city boundaries, and at the upstream end of stream reaches for which flood hazard data were to be developed. Some subbasins were established to correspond with special interest areas such as those likely to be subject to urbanization pressures or other significant land use changes.

SUMMARY

This chapter describes those elements of the hydrologic-hydraulic system of the Kinnickinnic River watershed which constitute the framework within which all the water resource and water resource-related problems of the watershed must be analyzed and resolved. Included in the discussion of the hydrology of the watershed are data on precipitation, evapotranspiration, and other aspects of the hydrologic budget; data on the volume and timing of runoff as revealed by stream gaging records; and data on the location and quantity of water contained within the aquifers lying beneath the watershed. Included in the discussion of the hydraulics of the watershed are data on the length, slope, and flow resistance of the stream system; and an evaluation of the hydraulic significance of hydraulic structures.

Knowledge of the complex hydrologic cycle as it affects the watershed is necessary to assess the availability of surface and groundwater for various uses and to improve the management potential of water during times of flooding or drought. The quantitative relationships between inflow and outflow, termed the hydrologic budget, were determined for the watershed. Precipitation is the primary source of water to the watershed and averages 30.1 inches annually. Surface water runoff and evapotranspiration losses constitute the primary outflow from the basin. The average annual runoff approximates 15 inches and the annual evapotranspiration loss also totals about 15 inches.

Although only minimal streamflow and flood stage records are available for the Kinnickinnic River stream system, these records do reveal two key characteristics of the watershed's hydrologic-hydraulic system. First, major flood discharges in the watershed tend to result from rainfall events as opposed to either snowmelt or combined rainfall-snowmelt events, which have historically produced the major floods in the larger watersheds of southeastern Wisconsin. As a consequence, peak floods are distributed throughout the winter, spring, summer, and fall seasons rather than concentrated in the late winter and early spring as is the case in the larger watersheds. Second, as a result of extensive urbanization and the attendant large extent of impervious surface and extensive storm water drainage systems and channelization works, the response of the watershed to large rainfall events is rapid in that peak discharges generally occur near the lower end of the watershed within hours after the initiation of such an event.

Approximately 15 lineal miles of the watershed stream system were selected for development of detailed flood hazard information including discharge-frequency relationships, flood stage profiles, and mapped areas of inundation for selected flood recurrence intervals. Detailed data were obtained for 84 hydraulically significant bridges, culverts, dams, and drop structures on that portion of the stream system and 225 floodland cross sections were prepared, all of this required as input to the hydrologic-hydraulic model developed for the watershed.

There are three main groundwater aquifers beneath the watershed: the deep sandstone, the shallow dolomite, and the unconsolidated sand and gravel aquifers. The confined or artesian sandstone aquifer is the deepest of the three systems and, except for minor leakage and a connection to the recharge area, is hydraulically separated from the remainder of the hydrologic-hydraulic system by the overlying semipermeable Maquoketa shale formation. The dolomite aquifer and the unconsolidated sand and gravel aquifers are, in contrast to the sandstone aquifer, recharged locally. It is estimated that the volume of water contained within the three aquifers directly beneath the watershed would be sufficient to cover the entire watershed to a depth of at least 250 feet. Groundwater in the deep sandstone aquifer beneath the aquifer moves in a generally northerly direction. Flow in the dolomite and sand and gravel aquifers tends to be more varied but exhibits an overall movement in a northeasterly direction.

The Kinnickinnic River watershed may be considered as a composite of five subwatersheds ranging in size from the 1.0-square-mile Lyons Park Creek subwatershed to the 8.9-square-mile Lower Kinnickinnic River subwatershed. Hydrologic-hydraulic information, including land use, channel slopes, hydraulic structure, and channel modification data were inventoried and analyzed for each of the subwatersheds, revealing the relatively homogeneous character of this intensely urbanized basin.

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Chapter VI

HISTORIC FLOOD CHARACTERISTICS AND PROBLEMS

INTRODUCTION

Flooding of the stream system of the Kinnickinnic River watershed has been, and, in the absence of corrective action, may be expected to continue to be a common and natural occurrence. In portions of the watershed, the streams leave their channels and occupy portions of the adjacent natural floodplains almost annually as a result of late winter-early spring snowmelt or snowmelt-rainfall events or in response to spring, summer, and fall thunderstorms. Damage from this flooding has been largely a consequence of the failure to recognize and understand the relationships which should exist between the use of land—in both floodland and nonfloodland areas of the basin—and the hydrologic-hydraulic behavior of the stream system. Unnecessary occupancy of the natural floodlands by flood-vulnerable land uses, together with development-induced changes in the flow characteristics of the streams, has produced serious flood problems in the watershed. Some of these problems, but not all, have been at least partially resolved through the construction of channel improvements.

Comprehensive watershed planning is the first step in achieving or restoring a balance between the use of land and the hydrologic-hydraulic regimen of the watershed. To ensure that future flood damage will be held to a minimum, plans for the proper utilization of the riverine areas of the watershed must be developed so that control of land uses in flood hazard areas, public acquisition of floodlands, and river engineering can be used to properly direct new development into a pattern compatible with the demands of the river system on its natural floodlands and to achieve an adjustment or balance between land use development and floodwater flow and storage needs.

Flood damage potential and flood risk have grown from a nuisance level during initial development of the watershed to substantial proportions as urban land use has increased. Practically all of the present flood risk can be ascribed to unnecessary location of flood damage-prone urban development in the natural floodlands—unnecessary since adequate alternative locations are available within the watershed and Region for such development—aggravated by increased flood flows attributable to upstream urbanization. Although the Kinnickinnic River watershed is highly urbanized, some opportunity still exists for limiting flood damage risk through sound land use development in relation to the riverine areas of the watershed.

This chapter presents a summary of historic information on the character and nature of flooding within this heavily developed basin. Included in this chapter are discussions of direct, indirect, and intangible flood losses and risks; the categorization of flood losses and risks by private and public ownership; and the methodology used to quantify flood risks in monetary terms.

This chapter, which discusses historic flood characteristics and damage, and most of Chapter XII, "Alternative Floodland Management Measures," are directed primarily to the inventory, analysis, and resolution of flood problems along the 15.47 miles of stream channels in the Kinnickinnic River watershed selected for development of detailed flood hazard data and attendant flood control plans as shown on Map 23. The Kinnickinnic River watershed plan is intended to provide recommendations for the resolution of existing flood problems along the selected stream channel reaches and the prevention of future flood problems in the associated riverine areas. The watershed planning process is not intended to address the resolution of storm water problems not directly attributable to flooding of the watershed stream system.

Basic Concepts and Related Definitions

Flooding is herein defined as inundation of the floodplains of the watershed, that is, of the relatively wide, low-lying, flat to gently sloping areas contiguous to and usually lying on both sides of the stream channels, as a direct result of stream water moving out of and away from the major stream channels. Flooding is a natural and certain process in hydrologic-hydraulic systems—one that is unpredictable only in the sense that the exact time of occurrence of a flood of a given magnitude cannot be predetermined although the average recurrence interval of such a flood is amenable to engineering analyses. How much of a natural floodland will be occupied depends on the severity of the flood and, more particularly, on the peak elevation of the floodwaters. Thus, an infinite number of outer limits of natural floodlands may be delineated, each related to a specified recurrence interval as determined by engineering analyses. Based upon such analyses, floodlands may be accurately and precisely delineated on large-scale topographic maps as continuous linear areas lying along the streams and water courses. Flooding is not necessarily synonymous with the presence of flood problems. Flood problems—and the demand for flood control works and measures—are created only when flood-damage-prone land uses are allowed to intrude upon the natural floodlands of the watershed in such a fashion and to such an extent that the certain, although random, inundation of the floodlands results in disruption, monetary damages, and risks to human health and life.

Storm water inundation is defined herein as the localized ponding of storm water runoff which occurs when such runoff moving towards streams and other low-lying areas via small intermittent channels, storm sewers, and other drainageways, or as overland or sheet flow, either exceeds the conveyance capacity of those channels, sewers, or drainageways and flows onto adjacent low-lying areas, or, in the case of overland flow, encounters flow resistance or obstruction and temporarily accumulates on the land surface.

Storm water inundation and riverine area flooding, as defined herein, differ in several significant ways. While storm water inundation involves water moving downslope towards major rivers, flooding is caused by water moving in the opposite way, that is, out and away from major stream channels. Flooding is generally associated with river reaches having tributary drainage areas of tens or hundreds of square miles, whereas tributary drainage areas pertinent to storm water inundation are small—generally less than one square mile. Flooding generally occurs along the major perennial streams, whereas storm water inundation is associated with intermittent channels or man-made drainageways or drainage swales. In contrast to areas experiencing flooding, areas experiencing storm water inundation tend to be discontinuous, consisting of a series of relatively small and scattered pockets not necessarily located in the lowest areas or near major streams or even near small intermittent channels or other well-defined drainageways. The definition of urban areas subject to storm water inundation requires detailed analysis of local topography and local street and associated building grades and of local storm water drainage and sanitary sewerage systems whereas the definition of flood-prone areas requires a broader, watershedwide analysis of the riverine areas of the major streams.

Storm water problems are not necessarily synonymous with storm water inundation. Storm water problems, and the demand for works and measures to control storm water runoff, are created only when urban development occurs without proper regard for storm water runoff conveyance and storage needs. For this latter reason, and with the exception of storm water control problems directly related to flood stages on major stream channels, the analysis of storm water drainage problems is considered to be beyond the scope of the comprehensive watershed planning studies conducted by the Commission generally, and of the Kinnickinnic River watershed study specifically, as set forth in the Kinnickinnic River Watershed Planning Program Prospectus.

USES OF HISTORIC FLOOD INFORMATION

Definitive historic flood data and information are available for the Kinnickinnic River watershed for the 62-year period from 1912 through 1973. These data include measurements or observations of flood flows, peak river stages, and areas of inundation; personal accounts—sometimes supported with photographs—of flood flow characteristics and the resulting flood damage; and reported monetary flood losses. The collection, collation, and analysis of such historic flood information are important elements of any comprehensive watershed study. Historic flood data have six primary applications in watershed planning and plan implementation, each of which is discussed below. Five of these applications occur during the planning process and one is directly related to plan implementation.

Identification and Delineation of Flood-Prone Areas

While the location and extent of some flood-prone areas within the Kinnickinnic River watershed were known at the outset of the watershed study, the location and extent of all such areas within the watershed were not known, nor was the existing information adequate to facilitate the development of alternative solutions to the flood problems. One important use of historic flood information in the watershed study, therefore, was the precise identification and delineation of all riverine areas in the watershed that not only are subject to flooding, but in which the flooding either causes or has the potential for causing significant monetary flood damages.

Determination of the Cause of Flooding

Residential, commercial, and industrial structures are particularly vulnerable to flood damage partly because of the many ways in which floodwaters can enter such structures. As illustrated in Figure 25, an unprotected floodland structure is a virtual "sieve" for the entry of floodwaters. Rising floodwaters may surcharge the sanitary, storm, or combined sewers in an urban area thereby reversing the flow in these sewers and forcing water into the structures through basement floor drains, plumbing fixtures, and other openings connected to the sewer system. As a result of saturated soil conditions around the structure foundation, water may enter through cracks or structural openings in basement walls or floors. If overland flooding occurs—that is, flood stages rise above the elevation of the ground near a particular residential, commercial, or industrial structure—additional floodwater may enter the basement of the structure through basement doors, windows, and other structural openings. If flood stages rise high enough, floodwaters similarly may gain access to the first or main floor of a structure. In addition to the inundation damage to the structure and its contents, external hydrostatic pressures may cause the uplift and buckling of basement floors and the collapse of basement walls. Finally, floodwaters may exert hydrostatic or dynamic forces of sufficient magnitude to lift or otherwise move a structure from its foundation.

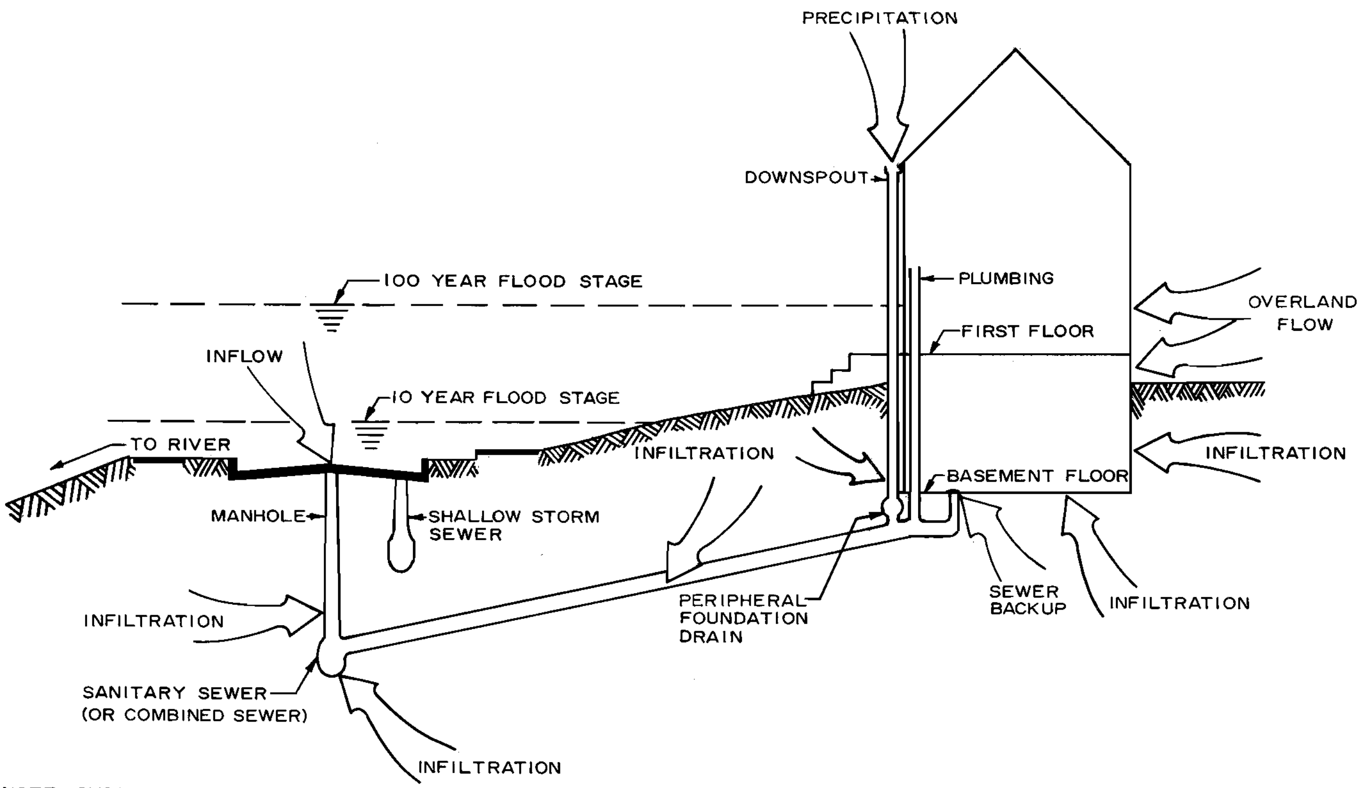
It should be noted that flood damage can occur to the basements of structures located outside of the geographic limits of the overland flooding when floodwaters gain access to basements via the hydraulic connections between the inundated area—the area of primary flooding—and basements that are provided by the sanitary, storm, or combined sewer systems. Such flooding of basements outside of, but adjacent to, the area of primary flooding is herein defined as secondary flooding. Primary and secondary flooding zones are illustrated in Figure 26.

Calibration of the Hydrologic-Hydraulic Model

Flood flows, stages, and areas of inundation throughout the watershed were developed by application of a mathematical simulation model. Sound engineering practice

Figure 25

MEANS BY WHICH FLOODWATERS MAY ENTER A STRUCTURE



NOTE: TYPICAL AND GENERALLY PREFERABLE VARIATIONS INCLUDE DOWNSPOUTS DISCHARGING TO THE GROUND SURFACE AND FOUNDATION DRAINS CONNECTED TO STORM SEWERS OR CONNECTED TO A SUMP FROM WHICH WATER IS PUMPED TO THE GROUND SURFACE AT SOME POINT AWAY FROM THE STRUCTURE

Source: SEWRPC.

requires "calibration" of such a model through careful comparisons between the model results and reliable observations of the actual hydrologic-hydraulic behavior of the stream system. Such comparisons permit adjustments to and refinements in the model and thereby result in a more accurate model and representation of watershed hydrology and hydraulics. As described in Chapter VIII, "Water Resource Simulation Model," extensive use was made of historic flood information during the model calibration process.

Computation of Monetary Flood Risk

Monetary flood risks for flood events of specified recurrence intervals, as well as average annual risks under existing and probable future land uses, must be determined for selected stream reaches in order to permit economic evaluation to be made of alternative flood control measures. The information required to compute monetary flood risks includes: data on the type of structures affected; the elevation of the ground at the structure and the elevation of the first floor; the existence of a basement; and the market value of the structure and land excluding structure contents. Some of the necessary data for representative structures were obtained as part of the survey of historic flooding.

Formulation of Alternative Flood Control Measures

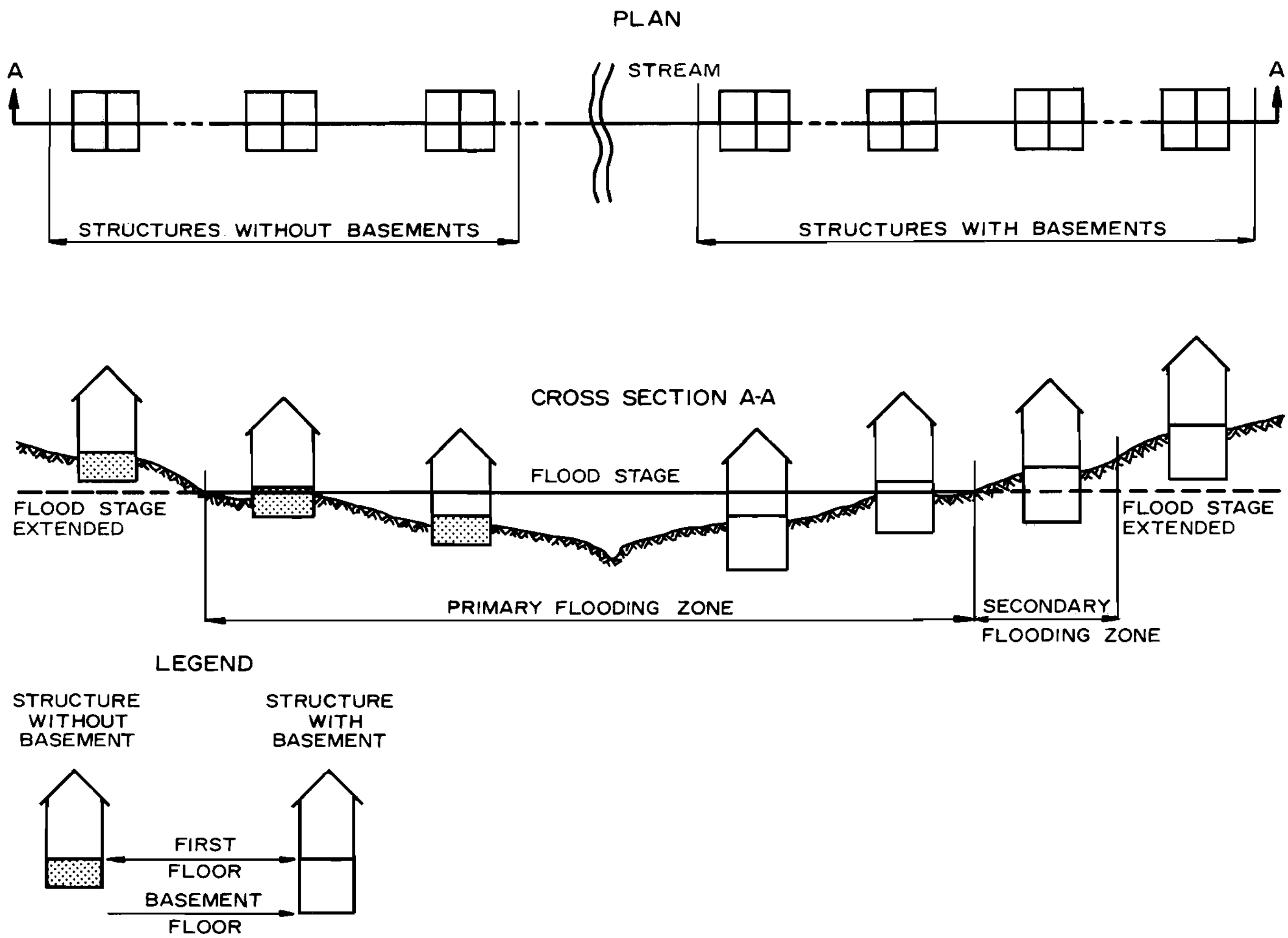
Alternative flood control measures include acquisition and removal of flood-prone structures, structure floodproofing, channel modification, and construction of dikes, floodwalls, and flood control reservoirs. To be technically feasible, the measures and combinations of measures formulated for each flood-prone stream reach must be directed at the primary cause of the flooding. For example, earth dikes and concrete floodwalls are technically feasible solutions in river reaches that historically have been subjected to overland flooding but are not effective, if used alone, in those riverine areas that incur extensive secondary flooding. Formulation of alternative flood control measures for a particular reach, therefore, is influenced by the nature and causes of the flood problems in that reach as determined from historic flood information.

Postplan Adoption, Information, and Education

The above-listed uses of historic flood information relate to the preparation of comprehensive watershed plans. The sixth and last use of such information occurs during the plan implementation process after the plan is completed. Experience indicates that some segments of the public are very concerned about flood problems imme-

Figure 26

PRIMARY AND SECONDARY FLOOD ZONES



Source: SEWRPC.

diately after a severe flood event whereas, with the passage of time—months and years—concern diminishes until the next severe event. Other segments of the public tend to the opposite extreme, that is, exaggeration of the seriousness of the flood problem in general and specific flood events in particular.

Documented historic flood information is an effective way to bring the seriousness of flood problems into proper focus and perspective for rational consideration. This information provides a common basis for understanding the nature of the problem in a particular locality and, thus, promotes implementation of the flood control recommendations contained in the adopted watershed plan. Historic flood information—in contrast with flood hazard information produced by mathematical modeling—is particularly effective in improving public understanding of the need for plan implementation, since laymen can more readily understand and relate to such graphic data as a photograph of flood damage, a peak flood stage measured from and related to a bridge, or the delineation of the lateral extent of flooding based on the deposit of debris as observed in the field. A considerable amount of historic flood information, accordingly, has been included in this chapter so that it will be readily and widely available to both public officials and interested citizens and thereby contribute to plan implementation.

INVENTORY PROCEDURE AND INFORMATION SOURCES

A comprehensive research effort employing a variety of procedures and information sources was required to develop the account of historic flooding in the Kinnickinnic River watershed as presented in this chapter. The inventory of historic flooding was initiated by reviewing engineering and planning reports prepared by governmental agencies and private consulting firms and addressed to flood problems in all or parts of the watershed.[1] Records for crest stage gages operated by the Milwaukee-Metropolitan Sewerage Commissions were obtained and analyzed to identify probable flood dates. These dates were supplemented with dates of major historic flood events in the adjacent Menomonee River watershed as documented in the recently completed Commission comprehensive planning study for that watershed.

This initial reconnaissance of published reports and data was followed by a review of newspapers and newspaper files. In this review effort, many potential sources were examined, a long period of history was considered, and information was assembled on each of numerous historic floods. The principal sources of information for this phase of the historic flooding inventory were past issues of The Milwaukee Journal, with supplemental information obtained from the issues of the Milwaukee Sentinel, the West Allis Press, the Milwaukee Southside Times, the Cudahy-St. Francis Reminder, and the Cudahy Free Press. Paralleling the review of historic issues of these newspapers, the Commission staff contacted various organizations. Useful historical flood information was obtained from the files of the City of Milwaukee Public Library, the Milwaukee Journal-Sentinel newspaper library, the Legislative Reference Bureau (Milwaukee City Hall) and the Milwaukee County Historical Society.

[1] *Engineering and planning reports that were reviewed in the preparation of the chapter and found to contain some historic flood information or to propose solutions to flooding problems are:*

a. *"Reconnaissance Report on Flood Problems on the Kinnickinnic River at Milwaukee, Wisconsin Under Section 205 of the 1948 Flood Control Act, as Amended," Department of Army, Chicago District, Corps of Engineers, June 1975.*

b. *"Report on Improving the South Branch of the Kinnickinnic River from W. Manitoba Street to W. Euclid Avenue," by J. C. Zimmerman Corp., 1970.*

c. *"Report on Proposed Kinnickinnic River Improvements through the Kinnickinnic River Parkway—South 43rd Street to South 60th Street," Hartman, Strass, Inc., October 1967.*

d. *"Preliminary Report on Airport Storm Drainage at General Mitchell Field—Milwaukee County," Milwaukee County Airport Department, February 1966.*

e. *"Survey Report for Flood Control on Milwaukee River and Tributaries." U. S. Army District-Chicago, Corps of Engineers, November 1964.*

Copies of these reports are on file and available for public examination at Commission offices.

The Commission staff also contacted local public officials either during preparation of this report or during preparation of the previously published Kinnickinnic River Watershed Planning Program Prospectus to obtain historic flood data from their files and, equally important, to benefit from these local public officials' firsthand knowledge of historic and recent flood problems. Such contacts were made with officials of the Cities of Milwaukee, West Allis, and Cudahy. Officials in these communities were able to identify areas that had incurred overland and secondary flooding and, in some cases, were able to provide detailed information on such matters as flood stages and area of inundation for some flood events.

The Commission staff also conducted a personal interview survey of the owners or tenants of riverine area structures. Selected information pertaining to the interviews is set forth in Table 23, while the riverine areas in which the personal interview survey was conducted are shown on Map 24. A total of 172 personal interviews were completed in portions of the Cities of Milwaukee, West Allis, and Cudahy.

The first step in conducting a survey is identification of the universe, or total population, about which information is desired. In the case of the personal interview survey, the population consisted of riverine area structures located along those reaches of the watershed stream system (see Map 29) where the above research indicated that flooding or flood-related problems have occurred. Within each reach, the lateral extent of the riverine area included in the survey was selected so as to approximate that area subject to primary or secondary flood damage under a major flood event.

The second step in conducting a survey is to identify the sample—that is, a portion of the total population that has characteristics representative of that population. In the case of the personal interview survey, the interviews were conducted so as to be spatially representative of the target area and of the types of structures present in that area. Thus, interviews were carried out along the length of each reach and were not limited to structures located closest to the stream. Furthermore, personal interviews were completed with the owners or tenants of a variety of structure types including single- and multiple-family residences and business and commercial buildings.

The form used in the personal interview survey is reproduced as Figure 27. As indicated by the sample form, the interviews were intended to provide information about the structure occupied by the owner or tenant as well as information about historic flood events that either affected the structure or had effects on the land used in conjunction with the structure.

Committed Solution to the Flood Problem Along the S. 6th Street to S. 16th Street Reach of the Kinnickinnic River

Although the research into historic flood events confirmed that the residential area along the S. 6th Street to S. 16th Street reach of the Kinnickinnic River in

Table 23

SELECTED INFORMATION ON INTERVIEWS CONDUCTED TO OBTAIN HISTORIC FLOOD INFORMATION AND STRUCTURE DATA IN THE KINNICKINNIC RIVER WATERSHED

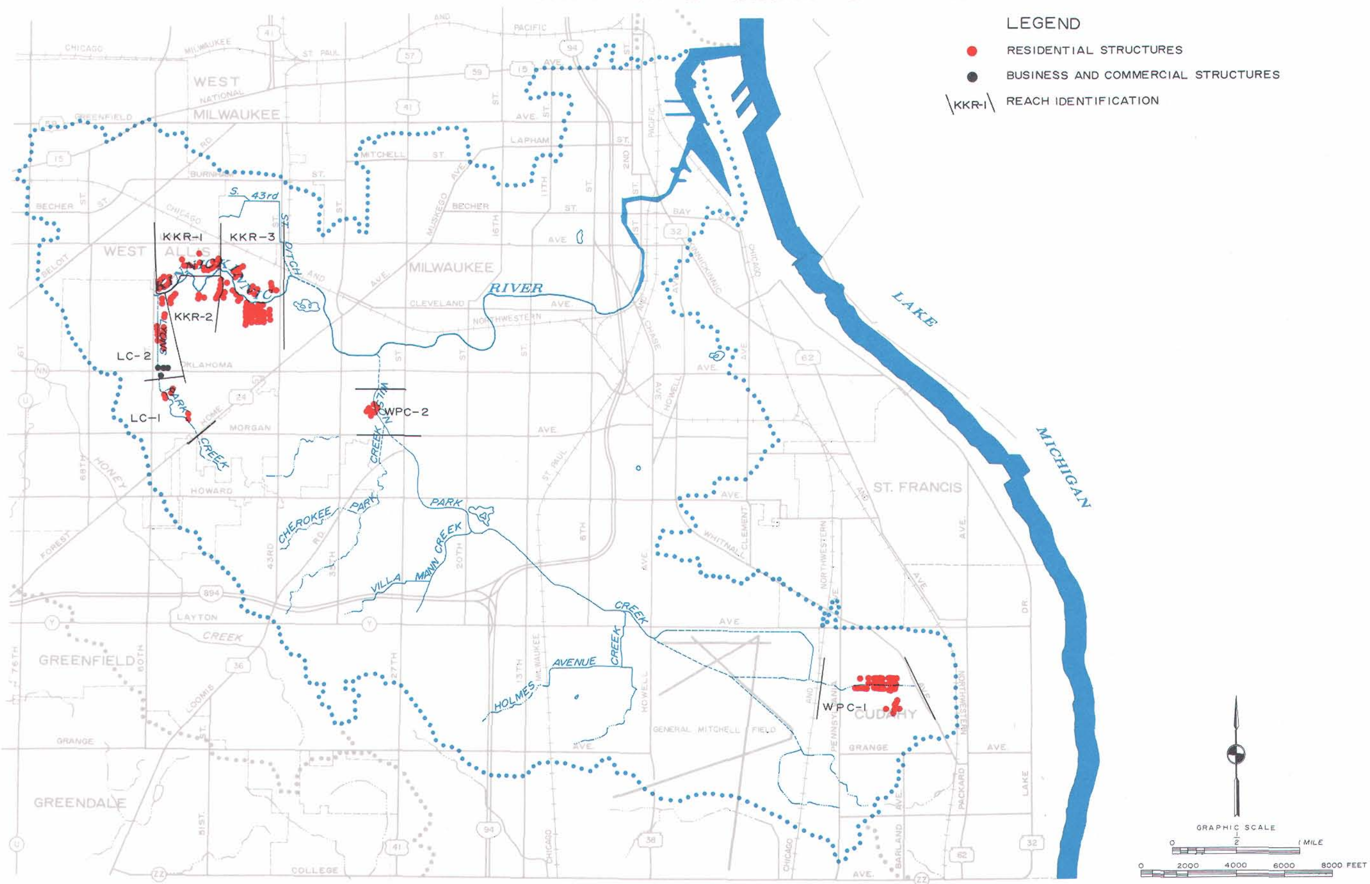
County	Civil Division[a]	Streams Along Which Interviews Were Conducted	Period During Which Interviews Were Conducted: Month Year	Single-Family Residence	Number of Interviews Completed with Owners or Tenants by Type of Structure or Property							
					Two-Family Residence	Multi-Family Residence	Mobile Home	Business-Commercial	Manufacturing-Industrial	School	Other	Total
Milwaukee	City of Cudahy	Edgerton Channel	March 1977	26	2	17	--	--	--	--	--	45
Milwaukee	City of West Allis	Kinnickinnic River	May 1977	23	2	--	--	--	--	--	--	25
Milwaukee	City of Milwaukee	Kinnickinnic River, Lyons Park Creek, Wilson Park Creek	May 1977	80	15	3	--	4	--	--	--	102
Total	--	--	--	129	19	20	--	4	--	--	--	172

[a] *Interviews were conducted with property owners or tenants in three of the six civil divisions located within the Kinnickinnic River watershed. Interviews were not conducted in the Cities of Greenfield and St. Francis and the Village of West Milwaukee because a preliminary survey of historic flood information indicated that these communities either had no flood problems or only minor flood problems.*

Source: SEWRPC.

Map 29

LOCATIONS OF FIELD INTERVIEWS CONDUCTED TO OBTAIN HISTORIC FLOOD INFORMATION AND STRUCTURE DATA IN THE KINNICKINNIC RIVER WATERSHED



Following analysis of precipitation and flood stage records, review of newspaper accounts, examination of historic information maintained by libraries and historical societies, and discussions with community officials, personal interviews were conducted with the owners or tenants of 172 structures located in potential flood-prone areas of the Kinnickinnic River watershed. The historic flood information assembled by this procedure was used to help identify flood-damage-prone areas and to help determine the causes of flooding in those areas.

Source: SEWRPC.

Figure 27

FORM USED TO INTERVIEW OWNER OR TENANT OF A STRUCTURE LOCATED NEAR A RIVER

FIELD SURVEY
of
STRUCTURE DATA AND FLOOD INFORMATION
for the
KINNICKINNIC RIVER WATERSHED PLANNING PROGRAM

INTERVIEWER: ____________________ DATE: __________

(Take the following items into the field: topographic maps, low flight aerial photographs, folding rule, camera, hand level.)

STRUCTURE IDENTIFICATION:

1. Civil Division Name: __________ 2. Civil Division No. ______ 3. Structure Ident. No.: ______

4. Address: ____________________

5. Type: Indicate one of the following:
   - 1 single family residence
   - 10 two family residence
   - 20 multi-family residence
   - 30 mobile home
   - 40 residence under construction
   - 100 business-commercial
   - 200 manufacturing-industrial
   - 300 school
   - 400 church
   - 500 other public __________
   - 600 other private __________
   - 700 other __________

6. Comments, Condition, etc: ____________________

INTERVIEWEE:

1. Name(s): ____________________

2. No answer: __________ 3. Refused to Cooperate: __________

4. How long have you lived here? ____________________

5. Comments: ____________________

STRUCTURE DATA:

1. Basement: Yes ____ No ____ If yes, is it used as living quarters? __________

2. Vertical distance from yard grade to main entrance of structure to first liveable floor: __________

3. Estimated market value of structure and land excluding structure contents: $ __________

4. Floodproofing measures available or in effect:
   - ________ sump pump
   - ________ drain tile
   - ________ glass block windows
   - ________ other (describe below)

5. Comments: ____________________

STRUCTURE IDENTIFICATION:

1. Civil Division Name: __________ 2. Civil Division No. ______ 3. Structure Ident. No. ______

FLOOD INFORMATION:

1. Event
   - a. Date: ____________________
   - b. Water in basement?: Yes ____ No ____ Depth ____ c. Water on first floor? Yes ____ No ____ Depth ____
   - d. Means by which water entered structure: Indicate one or more of the following:
     - 1 sanitary sewer back-up through floor drain, sink, etc.
     - 2 cracks or other openings (other than floor drain or sump reservoir) in basement floor.
     - 3 cracks or other openings (other than windows) in basement wall.
     - 4 back-up through sump reservoir.
     - 5 overland flow through basement windows.
     - 6 overland flow through doorways.
     - 7 overland flow through first floor windows.
     - 8 other __________
   - e. Floodproofing or protection measures used: __________
   - f. Peak stage relative to structure or other nearby reference point: __________
   - g. Type(s) of damage sustained including cost(s) if known: __________
   - h. Planimetric extent of surface inundation near structure: Shown on aerial photograph __________
   - i. Personal records or photos of flooding available? __________
   - j. Comments: __________

2. Event
   - a. Date: ____________________
   - b. Water in basement?: Yes ____ No ____ Depth ____ c. Water on first floor?: Yes ____ No ____ Depth ____
   - d. Means by which water entered structure: Indicate one or more of the following:
     - 1 sanitary sewer back-up through floor drain, sink, etc.
     - 2 cracks or other openings (other than floor drain or sump reservoir) in basement floor.
     - 3 cracks or other openings (other than windows) in basement wall.
     - 4 back-up through sump reservoir.
     - 5 overland flow through basement windows.
     - 6 overland flow through doorways.
     - 7 overland flow through first floor windows.
     - 8 other __________
   - e. Floodproofing or protection measures used: __________
   - f. Peak-stage relative to structure or other nearby reference point: __________
   - g. Type(s) of damage sustained including cost(s) if known: __________
   - h. Planimetric extent of surface inundation near structure: Shown on aerial photograph __________
   - i. Personal records or photos of flooding available? __________
   - j. Comments __________

Source: SEWRPC.

the City of Milwaukee had experienced serious flooding, that area was excluded from the costly and time-consuming personal interview survey. The seriousness of the flood problem in this reach had been previously established,[2] and the Milwaukee-Metropolitan Sewerage Commissions and the City of Milwaukee took steps, prior to the July 1976 initiation of SEWRPC staff work on preparation of the watershed plan, to solve that problem by means of implementation of certain alternatives set forth in the Corps report, namely, bridge removal or alteration and channel modification. This committed solution to the S. 6th Street to S. 16th Street flood problem eliminated the need for intensive inventory, analysis, and alternative plan preparation efforts under the study for this reach. The following summarizes the actions of the Corps of Engineers, Milwaukee-Metropolitan Sewerage Commissions, City of Milwaukee, the Kinnickinnic River Watershed Committee, and the SEWRPC in seeking an early resolution of the severe flood problems existing along the Kinnickinnic River between S. 6th Street and S. 16th Street in the City of Milwaukee.

- November 1974—Kinnickinnic River Watershed Committee completes work on Kinnickinnic River Watershed Planning Program Prospectus and the prospectus is published by SEWRPC.

- August 26, 1975—Corps transmits report, "Reconnaissance Report on Flood Problems on the Kinnickinnic River at Milwaukee, Wisconsin," to City of Milwaukee. The following four flood control alternatives were examined and are described in the report:

  1. Remove 13 bridges (S. 6th Street through S. 16th Street) and one box culvert (at abandoned North Shore Railroad) and construct four new bridges (S. 6th, S. 9th, S. 13th, and S. 16th Streets).

  2. Alternative 1 plus channel alteration and widening between abandoned North Shore Railroad bridge and S. 6th Street and between S. 8th Street and S. 12th Street.

  3. Remove structures from 10- or 100-year floodplain.

  4. Floodproof structures in 10- or 100-year floodplain.

  The report concludes that further study of all plans is justified.

- September 30, 1975—City of Milwaukee Common Council adopts a resolution "authorizing and directing the City Engineer and the Commissioner of Public Works to transmit a Reconnaissance Report on Flood Problems on the Kinnickinnic River" to the Sewerage Commission for study and further implementation.

- November 25, 1975—Metropolitan Sewerage District adopts resolution 1) recommending and authorizing that the City of Milwaukee "program bridge removal and reconstruction as indicated in Plans 1 and 2 of the Reconnaissance Report without authorizing or requesting further studies by the Corps of Engineers"; and 2) recommending and authorizing that the District be directed to program channel improvements, as indicated in Plan 2 of the Reconnaissance Report, said improvements to be planned and programmed consistent with the planning and programming of the bridge improvements by the City of Milwaukee."

- December 15, 1975—Watershed Committee meets, reviews Corps report, and raises three questions. These questions were posed in a December 29, 1975, letter from SEWRPC to Corps and subsequently answered by the Corps representatives:

  1. Was the study conducted with sufficient depth to assure that the recommended flood abatement alternative will not be changed if more detailed study is carried out? Answer: No.

  2. Was the study carried out to sufficient depth to assure that the peak rate of discharges reported in the study can be used in the design of bridges? Answer: No.

  3. When could additional studies be carried out by the Corps? Answer: After October 1977.

- April 20, 1976—Watershed Committee receives above answers from Corps representatives, discusses the matter, and adopts a resolution recommending that "the Metropolitan Sewerage Commission determine and provide to the Milwaukee City Engineer specific design discharges and attendant channel cross sections which should be used in the consideration by the City of the bridge removal and design of replacement bridges, in order that the City may proceed with the demolition and reconstruction of the bridges between S. 6th Street to S. 16th Streets; and further, that the Committee urge the Metroplitan Sewerage Commission and the City of Milwaukee to proceed with the reconstruction of the channel and bridges, respectively, in the reach of the river between S. 6th and S. 16th Streets, while continuing to pursue funding for a compre-

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[2]*Refer to the historic accounts later in this chapter plus:*

a. "Reconnaissance Report on Flood Problems on the Kinnickinnic River at Milwaukee, Wisconsin Under Section 205 of the 1948 Flood Control Act, as Amended," Department of Army, Chicago District, Corps of Engineers, June 1975.

b. Kinnickinnic River Watershed Planning Program Prospectus, SEWRPC, November 1974.

hensive watershed study, which, if funded, would include these particular channel modifications as committed facilities."

- July 1, 1976—Necessary funding commitments are obtained and SEWRPC staff begins work on the Kinnickinnic River Watershed Planning Program.

- March 9, 1977—Watershed Committee conducts initial public hearing on the Kinnickinnic River Watershed Study. City of Milwaukee residents living along the S. 6th Street to S. 16th Street reach of the Kinnickinnic River described recent flood damage and supported a public works project to provide flood damage relief.[3]

- May 26, 1977—Milwaukee-Metropolitan Sewerage Commissions provide the City of Milwaukee with a design discharge, channel bottom elevations and typical cross sections for each bridge over the Kinnickinnic River from S. 6th Street to S. 16th Street. The Commissions stated that funds for the improvement project were included in the 1977 Commission budget and in the proposed 1978 budget and indicated that a firm channel improvement construction schedule would be established upon receipt of a bridge removal schedule from the City of Milwaukee.

- June 30, 1977—City of Milwaukee Common Council adopts a resolution authorizing and directing City of Milwaukee officials to cooperate with the Sewerage Commission of the City of Milwaukee in implementing its proposed channel improvements to alleviate flooding conditions along the Kinnickinnic River between a point east of S. 6th Street and extending upstream to S. 16th Street, and to proceed with public hearings, street vacations, preparation of plans and estimates of costs, as required, to undertake the removal and replacement of bridges and approaches.

- July 6, 1977—Watershed Committee reviews proposed schedule for removal and replacement of bridges over the Kinnickinnic River between S. 6th Street and S. 16th Street, as prepared by the City Engineer of Milwaukee, and acts unanimously to recommend that the City of Milwaukee Common Council approve proposed schedule for removal and replacement of bridges.

- July 26, 1977—City of Milwaukee Common Council adopts a resolution approving, in principle, the schedule for the removal and replacement of bridges over the Kinnickinnic River between S. 6th Street and S. 16th Street, inclusive, as prepared by the City Engineer of Milwaukee. The City of Milwaukee Common Council also adopts a resolution authorizing and directing carrying out the procedures and hearing necessary for vacation of a portion of S. 8th Street and S. 9th Street in the vicinity of the Kinnickinnic River.

- November 1, 1977—Public hearing is held at the City Hall on Wednesday, November 2, 1977; source Milwaukee Journal, November 1, 1977.

- November 1, 1977—Milwaukee Common Council approves funds to begin redesigning four bridges—$90,000 to be spent in 1978 to design new bridges and remove two of the old ones. Sewerage Commission budgeted $405,000 for 1978 to "move out uneven parts of the concrete river walls"; source Milwaukee Journal, November 1, 1977.

ACCOUNTS OF HISTORIC FLOODS

Method of Presentation

The historic flood information for the Kinnickinnic River watershed, as obtained by means of the inventory efforts described above, is presented in this study by major flood events. Major flood events are defined here as those known to have caused relatively heavy widespread flooding, significant damage to property, and disruption of normal community activities. Seven such events were identified beginning with the March 18, 1912, flood and extending through the April 21, 1973, flood. Although the damage and disruption associated with each major flood were of several days' duration, a flood event is identified by the date on which the highest, or peak, flood stage was known, or believed to have occurred. Selected information about each of the seven major flood events is presented in Table 24.

Within each account of a major flood, damage and disruption experienced along the main stem of the Kinnickinnic River are discussed first, proceeding in the upstream direction, followed by descriptions of problems encountered along various tributaries. The flood problems discussed herein were selected to be representative of the kind of damage or disruption that occurred and of the locations in which it occurred. Monetary flood losses included in the descriptions of historic flooding are those reported or otherwise recorded during or shortly after each flood event and have not been adjusted to current economic levels. In addition to describing the damage and disruption attributed to each flood, the meteorologic and hydrologic conditions prior to and during the flood are discussed for those events where such data are available. These descriptions include a review of antecedent moisture conditions as well as precipitation amounts and flood stages recorded during the events.

Historic high water marks for major floods are shown in Appendix C of this report. These marks are among the best means of documenting in a detailed and definitive manner the severity of historic flooding by graphically presenting peak stages relative to the channel bottom and relative to various hydraulic structures located along

[3] *See "Minutes of Initial Public Hearing—Kinnickinnic River Watershed Study," Southeastern Wisconsin Regional Planning Commission, March 1977.*

Table 24

SELECTED INFORMATION ON MAJOR HISTORIC FLOODS IN THE KINNICKINNIC RIVER WATERSHED

Date[a]	Causative Event	Reaches Affected
March 18, 1912	Snowmelt	Kinnickinnic River from S. 6th Street to S. 16th Street
June 22, 23, 1917	Rainfall	Not Available
January 24, 1938	Rainfall	Kinnickinnic River-scattered sites
March 29, 30, 1960	Snowmelt-Rainfall	Kinnickinnic River-from S. 6th Street to S. 43rd Street and scattered locations along or near Wilson Park Creek
August 2, 3, 1960	Rainfall	
September 18, 1972	Rainfall	Kinnickinnic River from S. 6th Street to S. 16th Street
April 21, 1973	Rainfall	Kinnickinnic River from S. 6th Street to S. 16th Street and Mitchell Field

[a]*Flood events are identified by the day on which peak discharges and stages occurred.*

Source: SEWRPC.

many of the 15.47 miles of stream selected for development of detailed flood hazard information under the watershed study. All historic water marks were referred to National Geodetic Vertical Datum (Mean Sea Level).

Some of the data used to reconstruct historic high water marks was obtained from staff and crest stage gages operated by the U. S. Geological Survey, the Milwaukee-Metropolitan Sewerage Commissions, and the City of Milwaukee. Other data sources include high water marks observed by private citizens as well as April 21, 1973, flood stage data recorded by the staff of the Regional Planning Commission.

Flood of March 18, 1912

The Monday, March 18, 1912, flood was the earliest major flood of record within the watershed for which any significant amount of information is available. This first serious flood of record was caused by snowmelt. As shown on Map 30, damage caused by this flood was concentrated in the 0.77 mile reach of the Kinnickinnic River bounded at the downstream end by S. 6th Street (formerly First Avenue) and at the upstream end by S. 16th Street (formerly 10th Avenue).

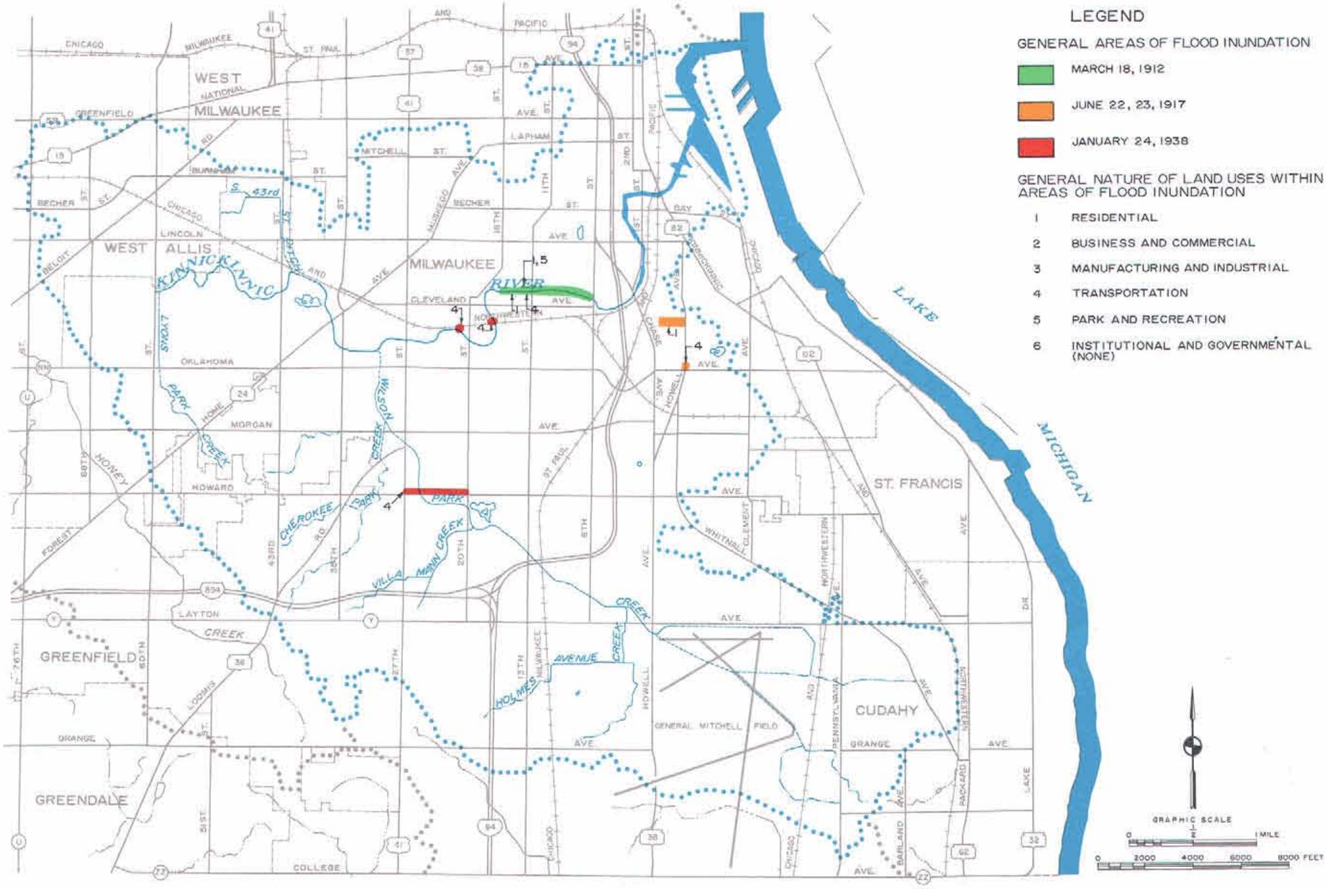
Thousands of dollars of damage were done to homes along this reach of the Kinnickinnic River with flood waters reported above the window sills of some of the structures. In order to provide some relief, the City of Milwaukee Department of Public Works sent crews to the flooded area to pump water from flooded basements. A newly constructed concrete bridge at S. 12th Street (formerly 7th Avenue) was reportedly cracked in the center as a result of the force of the floodwaters. Chicken coops, sheds, and other out-buildings were demolished and carried away by the flood waters.

The depth of flooding was reportedly increased as the result of wooden materials being used in the construction of a bridge. These materials were buoyed up by the flood waters and accumulated on the upstream side of downstream bridge waterway openings. The blockage caused by the timbers was aggravated by accumulation of large blocks of ice on the upstream sides of bridge waterway openings. In addition to causing property damage, the deep and rapidly moving floodwaters threatened the health and well-being of residents of the area. Two patrolmen rescued a mother and her two daughters from their home along the Kinnickinnic River which was inundated by several feet of water.

No flooding was reported upstream along the Kinnickinnic River, Wilson Park Creek, or other tributaries. The absence of reported flood damage elsewhere in the water-

Map 30

FLOOD PROBLEM AREAS IN THE KINNICKINNIC RIVER WATERSHED FOR THE MARCH 1912, JUNE 1917, AND JANUARY 1938 FLOODS



The March 1912 flood is the first major flood event in the watershed for which descriptive information is available and for which serious flood damage was known to have occurred. An examination of riverine areas affected by this and subsequent floods indicates a definite correlation between the spatial extent of urban growth in the Kinnickinnic River watershed and the extent of the watershed stream system incurring flood damage and disruption. The primary cause of flooding as a serious problem within the watershed has been failure to adjust and adapt land use in floodland areas to the natural floodwater conveyance and storage function of those areas.

Source: SEWRPC.

shed probably reflects the fact that urban growth in the watershed, by the early part of this century and as shown on Map 6, had encompassed only about the northeastern one-third of the Kinnickinnic River watershed.

Flood of June 22, 1917

The flood of Friday, June 22, 1917, caused extensive damage in the lower Menomonee River watershed[4] and apparently also in the Kinnickinnic River watershed. Historic accounts include detailed descriptions of the extensive damage that occurred in the lower Menomonee River watershed, particularly in the industrial valley. While general reference is made to serious flooding in the Kinnickinnic River watershed, few specific examples of flood damage are cited. It is reasonable to assume, however, that considerable damage occurred in the Kinnickinnic River watershed because of the general references to flooding in this basin and because of the intensity and volume of the rainfall associated with this flood as recorded in Milwaukee. The total of 5.5 inches of rainfall occurred on Friday, June 22, 1917, and another 0.3 inches was recorded on the morning of June 23, 1917, giving a 24-hour total of 5.8 inches. This is the largest 24-hour rainfall amount recorded at the Milwaukee National Weather Service office since 1870 when measurements first began. This volume of rainfall concentrated in a short period would be expected to cause serious flooding and storm water inundation in urban areas.

The only specific problem within the Kinnickinnic River watershed that is cited in the historic accounts is the storm water drainage problem that occurred in a several square block area on the eastern edge of the watershed immediately northwest of Humboldt Park (Map 30). Up

[4] *SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume 1, "Inventory Findings and Forecasts," Chapter VI, "Historic Flood Characteristics and Damages," October 1976.*

to 10 feet of water were reported standing in this area, and the second stories of some homes and places of business were inundated with storm water. Part of the road at the intersection of S. Howell Avenue and E. Oklahoma Avenue was washed out and this area experienced a variety of damage and disruption including basement flooding, interruption of telephone service, impassable streets, sewer surcharge, and deposition of sand and other debris on streets, lawns, and in buildings. Fire and police personnel obtained boats from Humboldt Park and used them to remove people from the roofs and upper stories of inundated structures.

It is interesting to note that, subsequent to the 1912 and 1917 floods, a box tunnel was proposed to enclose the 0.77-mile-long Kinnickinnic River reach from S. 6th Street to S. 16th Street at a cost of $217,000. A March 9, 1931, newspaper account of this proposal indicates that it generated considerable controversy. The Milwaukee City Council passed a resolution calling for construction of the tunnel and subsequently overrode the Mayor's veto of the resolution. Proponents of the tunnel apparently believed it to be an effective way to cover or enclose a small, formerly natural creek that had become a nuisance in an urban area. Based on the March 1912 and June 1917 flood experiences, tunnel opponents argued that construction of the tunnel would aggravate flood problems because of inadequate capacity and the added potential for ice jams. Furthermore, they argued that the tunnel would interfere with plans for beautification of the riverine area on the southside of Milwaukee as advocated by Charles B. Whitnall. The tunnel opponents prevailed in that the proposal to enclose this reach of the Kinnickinnic River was defeated in 1933.

Flood of January 24, 1938

As shown on Map 30, the flood of Monday, January 24, 1938, is known to have affected only scattered areas along the lower Kinnickinnic River and along Wilson Park Creek. The Kinnickinnic River overflowed its banks near the railroad bridge crossing at S. 18th Street extended, depositing large blocks of ice on the tracks. A short distance upstream, the Kinnickinnic River flooded the railroad bridge located immediately west of S. 20th Street and the structure was threatened by large blocks of ice pushed against the pilings by the flood waters. Wilson Park Creek inundated a seven-block segment of W. Howard Avenue between S. 20th Street and S. 27th Street and five automobiles were abandoned by motorists in this area.

Although this flood occurred in January, it was attributed to the occurrence of heavy rainfall. Rainfall records for the National Weather Service office at Mitchell Field indicate that 2.4 inches of rainfall were recorded on January 24, 1938, and 0.2 inch on the preceding day for a two-day total of 2.6 inches. The volume and rate of runoff probably were increased by frozen or saturated ground conditions thus further increasing peak flows and stages on the Kinnickinnic River and tributaries.

Flood of March 30, 1960

In terms of damage and disruption, the Wednesday, March 30, 1960, snowmelt-rainfall event caused widespread damage in the City of Milwaukee along the Kinnickinnic River and scattered problems in the City along Wilson Park Creek. Riverine areas affected by the flood are shown on Map 31 which, when compared to the urban growth map included as Map 6, indicates a close correlation between the flood damage areas and the extent of urban development as of 1960. While the damage resulting from previous major floods had been concentrated in the downstream one-third of the basin, the March 1960 flood caused problems along the Kinnickinnic River as far west as S. 43rd Street and along Wilson Park Creek as far south as Mitchell Field.

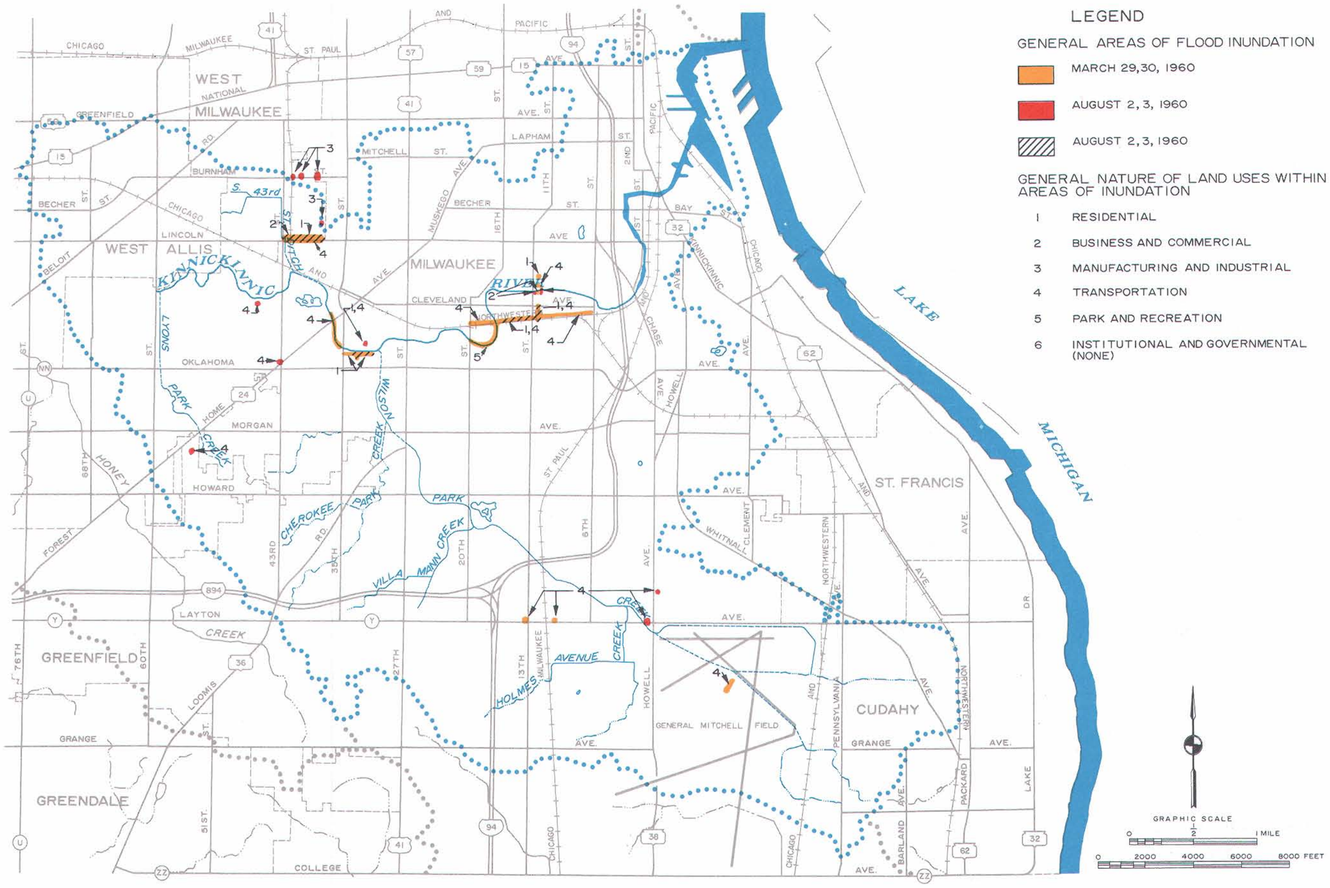
Flood inundation and damage occurred along and immediately south of the Kinnickinnic River reach bounded by S. 6th Street and S. 16th Street. Kinnickinnic River floodwaters overtopped the S. 12th Street bridge and flooded the intersection of S. 12th Street and W. Harrison Avenue located immediately north of the River. The section of S. 12th Street immediately south of the Kinnickinnic River was inundated by up to one and one-half feet of water, and basements of residential and commercial structures were flooded. Rising floodwaters forced some residents in this area to leave their basement apartments. A ballroom located in the basement of a building on S. 12th Street approximately one block south of the Kinnickinnic River was inundated to a depth of six feet, new wooden flooring was severely buckled and wooden paneling was damaged (see Figure 28), resulting in approximately $30,000 in damage. An approximately 0.75-mile-long section of the Chicago & North Western Railway paralleling and lying approximately one and one-half blocks south of the Kinnickinnic River between S. 6th and S. 16th Streets was inundated by up to four feet of water and, as a result, railroad traffic had to be diverted to other lines.

Farther upstream along the Kinnickinnic River between S. 16th Street and S. 20th Street, floodwaters overtopped the Chicago & North Western Railway, sidewalks were washed out, and railroad ties and other buoyant debris were left on lawns and streets. Still farther upstream, basement flooding to a depth of up to six feet was reported in homes located along W. Manitoba Street—which parallels and lies immediately south of the Kinnickinnic River—between S. 31st Street and S. 35th Street. Collapsed basement walls were reported at two homes in this area.

Upstream of S. 35th Street, the Kinnickinnic River overflowed its banks and inundated portions of Jackson Park. However, because of the compatible open space use of these floodplains, no significant damage or disruption was reported. Stormwater inundation occurred on the West Milwaukee-City of Milwaukee boundary along W. Lincoln Avenue about one-eighth mile north of the Kinnickinnic River between S. 37th Street and S. 43rd Street. Street flooding was reported and several buildings incurred damage as the result of basement flooding.

Map 31

FLOOD PROBLEM AREAS IN THE KINNICKINNIC RIVER WATERSHED FOR THE MARCH 1960 AND AUGUST 1960 FLOODS



Major floods are random events and, therefore, it is possible to have two major—relatively long recurrence interval—floods occur within a watershed in a single year, as occurred in 1960 in the Kinnickinnic River watershed. The areas along the Kinnickinnic River affected by these two floods were almost identical. Partly as a result of the occurrence of these two serious flood events, the Milwaukee-Metropolitan Sewerage Commissions initiated a project to deepen, widen, and line with concrete that portion of the Kinnickinnic River between S. 6th Street and S. 16th Street.

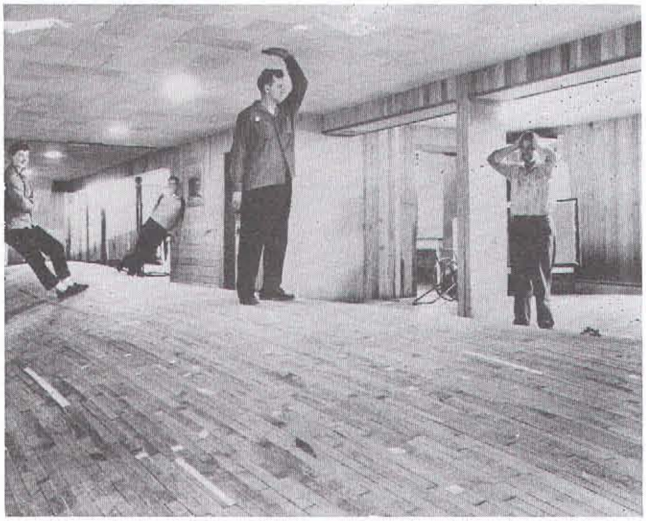
Source: SEWRPC.

Scattered instances of localized flooding and stormwater inundation were reported along Wilson Park Creek or tributaries to it. A semitrailer truck was stalled in four and one-half feet of water at the intersection of S. 13th Street and W. Layton Avenue and two men stranded on top of their cars in that area were rescued by police. Seven feet of water were reported in the intersection of W. Layton Avenue and S. 10th Street, and Mitchell Field was dotted with numerous ponds of stormwater.

A critical combination of rainfall and snowmelt was responsible for the March 1960 flood on the Kinnickinnic River watershed. There were 24 inches of snow on the ground at Milwaukee on March 4, the third largest snowpack that had been recorded to that date at Milwaukee. By March 27, about six inches of snow cover remained on the watershed based on measurements made at the Milwaukee National Weather Service office. Unusually low, subfreezing temperatures persisted during the first 26 days of March, with the average daily temperature 26.6°F. Temperatures rose sharply on Sunday, March 27, with a maximum of 46°F recorded at Milwaukee on that day, and maximum temperatures of 41°F, 62°F, and 52°F were reached on March 28, March 29, and March 30, respectively. This unusual and prolonged warm period accelerated the melting of the snow cover. Furthermore, precipitation began over the watershed at approximately 9:00 P.M. on Tuesday, March 29, the third day of the thaw, and continued through Wednesday, March 30. During this two-day period, 2.57 inches of rainfall were recorded in the watershed at Mitchell Field and 2.63 were measured immediately northwest of the watershed in the City of West Allis. A large proportion of this rainfall probably appeared as direct runoff in the streams since it fell either on impervious surface, on snowcover, or frozen ground or on soils still saturated with water as the result of the melting snowcover. Direct runoff from the rainfall, occurring in combination with direct runoff generated by melting of the watershed snowcover, produced flows well in excess of channel capacity.

Figure 28

INTERIOR DAMAGE TO A COMMERCIAL BUILDING



When floodwaters gain access to the interior of a residential or commercial structure, numerous types of severe flood damage result. As the result of the March 1960 flood, a ballroom located in the basement of the structure on S. 12th Street, approximately one block south of the Kinnickinnic River, was inundated by up to six feet of water. As the result of the saturation by floodwaters, the wooden dance floor expanded and buckled up to two feet above its original height and approximately $30,000 in damage was incurred. This building incurred similar flood damage five months later in August 1960 when another major flood struck the watershed.

Source: Milwaukee Journal.

Flood of August 3, 1960

Serious flooding occurred a second time in the Kinnickinnic River watershed in 1960 when heavy rains on August 2 and 3 resulted in extensive flooding along the Kinnickinnic River downstream of S. 43rd Street on Wednesday, August 3, 1960. As shown on Map 31, the resulting damage in terms of areas affected was very similar to that experienced in March 1960. The basement ballroom located on S. 12th Street about one block south of the Kinnickinnic River again experienced flood damage. Up to five feet of floodwater were reported on the ballroom floor, damaging amusement devices and once again buckling the newly reconstructed floor. The Kinnickinnic River overtopped the S. 12th Street bridge and damaged sidewalks which had been replaced as the result of the March 1960 flood.

A portion of the flood flow from the Kinnickinnic River was diverted from the stream at W. Montana Street extended and flowed five blocks in an easterly direction along the Chicago & North Western Railway right-of-way to S. 12th Street. At that location, flow turned northward moving about two blocks along S. 12th Street to rejoin the Kinnickinnic River. Considerable flood damage was incurred in basements along this route including damage to furnaces, food freezers, clothes washers and dryers, and other appliances and contents.

Farther upstream, residential structures along W. Manitoba Avenue again experienced flood damage similar to what had occurred in March 1960. Numerous basements were flooded and at least one incident of basement wall collapse was reported. During the night Milwaukee fire department personnel used boats to evacuate about 15 persons from their homes along W. Manitoba Avenue.

Still farther upstream, W. Lincoln Avenue between S. 37th and S. 43rd Streets was inundated and, in this same area, electrical equipment was damaged at the Froedtert Malt Corp. in the Village of West Milwaukee.

Scattered instances of flooding or storm water inundation were reported along Wilson Park Creek. For example, E. Layton Avenue between S. Howell Avenue and S. First Street was closed due to standing water and mud accumulation.

Mitchell Field precipitation records indicate that the August 3, 1960, flood in the Kinnickinnic River watershed resulted from a sequence of two closely spaced thunderstorms accompanied by wind and hail. The first storm began about 9 P.M. on Tuesday, August 2, 1960, and ended by about 1 A.M. on August 3, 1960. About 2.8 inches of rainfall occurred during this four-hour period, corresponding to a recurrence interval of about 12 years. A second less severe thunderstorm began at 9 A.M., August 3, 1960, and ended on about 12 A.M. that day, and about 0.9 inch of rainfall was recorded during this three-hour period. Therefore, a total of about 3.7 inches of rainfall occurred over the Kinnickinnic River watershed during a 15-hour period.

Partly as a result of the two serious flood events occurring in the Kinnickinnic River watershed in 1960, an approximately $300,000 channel improvement was undertaken by the Milwaukee-Metropolitan Sewerage Commission in late 1960 and completed in 1961. Under this program, the channel of the Kinnickinnic River was substantially deepened, widened, and lined with concrete throughout the reach bounded by S. 6th Street at the downstream end and by S. 16th Street at the upstream end. The Commission also announced, in late 1960, a plan to widen and deepen the Kinnickinnic River from S. 16th Street upstream into Jackson Park which, in combination with the S. 6th to S. 16th Streets reach improvements, would entail a total cost of about 1.5 million dollars. These channel improvements were completed in May 1965 and consist of 2.69 miles of concrete-lined channel extending from S. 16th Street at the downstream end to S. 42nd Street extended in Jackson Park at the upstream end (see Map 25 in Chapter V). Major channel modifications also were carried out by the Milwaukee-Metropolitan Sewerage Commission on the 5.25-mile reach of Wilson Park Creek extending from its confluence with the Kinnickinnic River to approximately the City of Milwaukee-City of Cudahy boundary on the eastern edge of Mitchell Field. This work, which resulted in 2.51 miles of enlarged, turf-lined channel; 1.25 miles of enlarged, concrete-lined channel; and 1.49 miles of conduit, was initiated in 1952 and completed in 1975. A major channelization project was carried out by the City of Milwaukee from 1954 to 1972 along most of the 1.31-mile-long reach of Lyons Park Creek lying within the City.

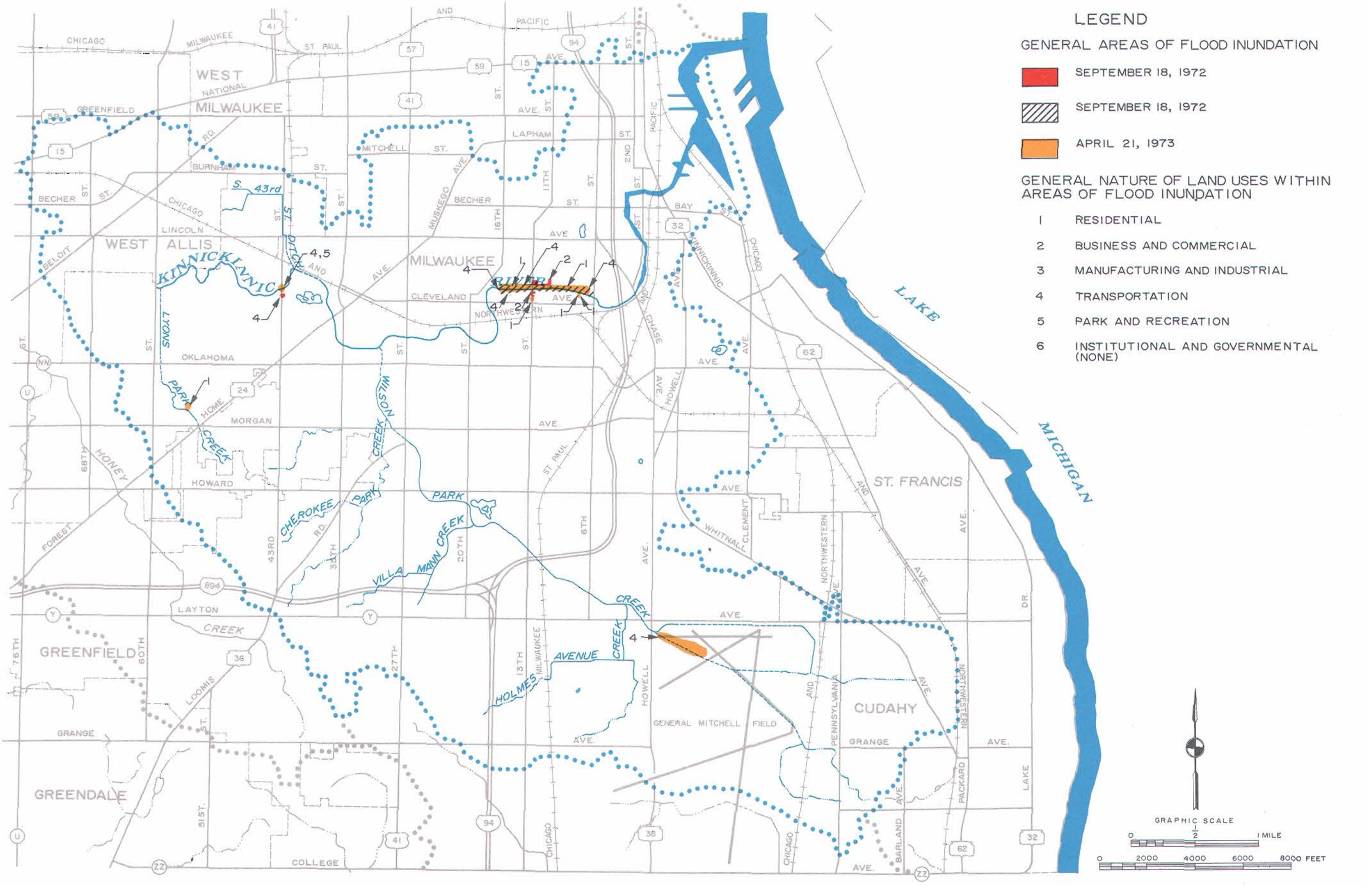
Flood of September 18, 1972

The late summer flood of September 18, 1972, occurred as the result of widespread rainfall observed over the Region during the period from Saturday, September 16, through Monday, September 18. The causative rainfall event was concentrated in an east-west zone approximately encompassing the northern halves of Milwaukee and Waukesha Counties. Therefore, the heaviest rainfalls occurred north of the Kinnickinnic River watershed. During the late afternoon and evening of September 17 and during the early morning hours of September 18, a total of 2.31 inches of rainfall were recorded at General Mitchell Field, located within and on the eastern edge of the watershed, while a total of 2.54 inches of rainfall were recorded at the West Allis Station located immediately northwest of the watershed. Based on a Thiessen polygon analysis, the average rainfall received over the Kinnickinnic River watershed in this period of less than two days was 2.40 inches. The resulting flooding was somewhat more serious than would be expected by the relatively moderate nature of the rainfall because of the wet antecedent moisture conditions during the two and one-half month period prior to the rainfall event.

The spatial extent of the resulting flood damage and disruption in the Kinnickinnic River watershed as well as the types of flood problems experienced are shown on Map 32. Most of the damage and disruption from this flood event were confined to the S. 6th Street to S. 16th Street reach of the Kinnickinnic River in the City of Milwaukee. The flood problems were restricted largely to this reach because of the considerable channel modifications, as shown on Map 25, that had been completed by this time within the Kinnickinnic River watershed on the Kinnickinnic River, Wilson Park Creek, Lyons Park Creek and other tributaries, thereby providing for the control of the relatively high flows that were experienced. Flood waters overtopped the low point of the roadways of the 10 bridges crossing the

Map 32

FLOOD PROBLEM AREAS IN THE KINNICKINNIC RIVER WATERSHED FOR THE SEPTEMBER 1972 AND THE APRIL 1973 FLOODS



Major flood damage and disruption attributed to the September 1972 and April 1973 floods were confined to the S. 6th Street to S. 16th Street reach of the Kinnickinnic River in the City of Milwaukee, although damages were known to have been incurred at the airport during the 1973 event. Although the area along the Kinnickinnic River between S. 16th Street and S. 43rd Street had experienced serious flood damage and disruption during previous major flood events which occurred in March 1912, June 1917, January 1938, and March and August 1960, these areas did not incur any flood problems as a result of the September 18, 1972 and April 21, 1973, flood events, even though flood flows generated by the earlier floods were probably of the same order of magnitude as the September 1972 and April 1973 floods. The absence of flood problems along the S. 16th Street to S. 43rd Street reach of the Kinnickinnic River probably reflects the effectiveness of the massive channel improvements made to the Kinnickinnic River and tributaries in this reach during the period from 1960 to 1965.

Source: SEWRPC.

Kinnickinnic River beginning with and including S. 7th Street and extending through S. 15th Street. Accordingly, overland flooding occurred on both sides of the Kinnickinnic River between S. 6th Street and S. 15th Street extending as much as about one city block away from the River. Because of secondary flooding, the areal extent of the effect of flooding undoubtedly extended outside of the area affected by the overland flooding. In addition to damage to residential buildings, commercial buildings in the area incurred damage to both structures and contents. For example, health officials condemned inventories stored in the flooded basements of a pharmacy and a tavern.

Farther upstream, the City of Milwaukee Bureau of Engineers reported that flood waters overtopped the bridge over the Kinnickinnic River at S. 43rd Street in the City of Milwaukee. However, except for the flood damage and disruption in the S. 6th Street to S. 16th Street reach of the Kinnickinnic River, no other serious flood problems were reported in the Kinnickinnic River watershed as the result of the September 18, 1972, flood event. Significantly, the area along and near the Kinnickinnic River between S. 16th Street and S. 43rd Street, which had experienced serious flood damage and disruption during previous major flood events in March 1912, June 1917, January 1938, and March and August 1960, did not encur any serious flood problems as the result of the September 18, 1972, flood even though the flood flows generated by these earlier floods were probably the same order of magnitude as the September 1972 flood. The absence of flood problems along the S. 16th Street to S. 43rd Street reach of the Kinnickinnic River probably reflects the effectiveness of the massive channel improvements made to the Kinnickinnic River in this reach during the period from 1960 to 1965.

Flood of April 21, 1973

The Saturday, April 21, 1973, flood event caused flood problems throughout most of southeastern Wisconsin with certain areas such as the Menomonee River and Kinnickinnic River watersheds experiencing severe flood damages. The spatial extent of the resulting flood damage and disruption in the Kinnickinnic River watershed as well as the types of flood problems experienced are shown on Map 32. Measured by the spatial extent of the damage and disruption, the April 1973 flood was not the most serious flood experienced in the Kinnickinnic River watershed. The causative rainfall was less severe over the Kinnickinnic River basin than it was over other parts of southeastern Wisconsin, such as over the Menomonee River watershed. Moreover, as shown on Map 25, in Chapter V, considerable channel modifications had been completed by this time within the Kinnickinnic River watershed on the Kinnickinnic River, Wilson Park Creek, Lyons Park Creek, and other tributaries thereby providing for the control of the relatively high flood flows that were experienced.

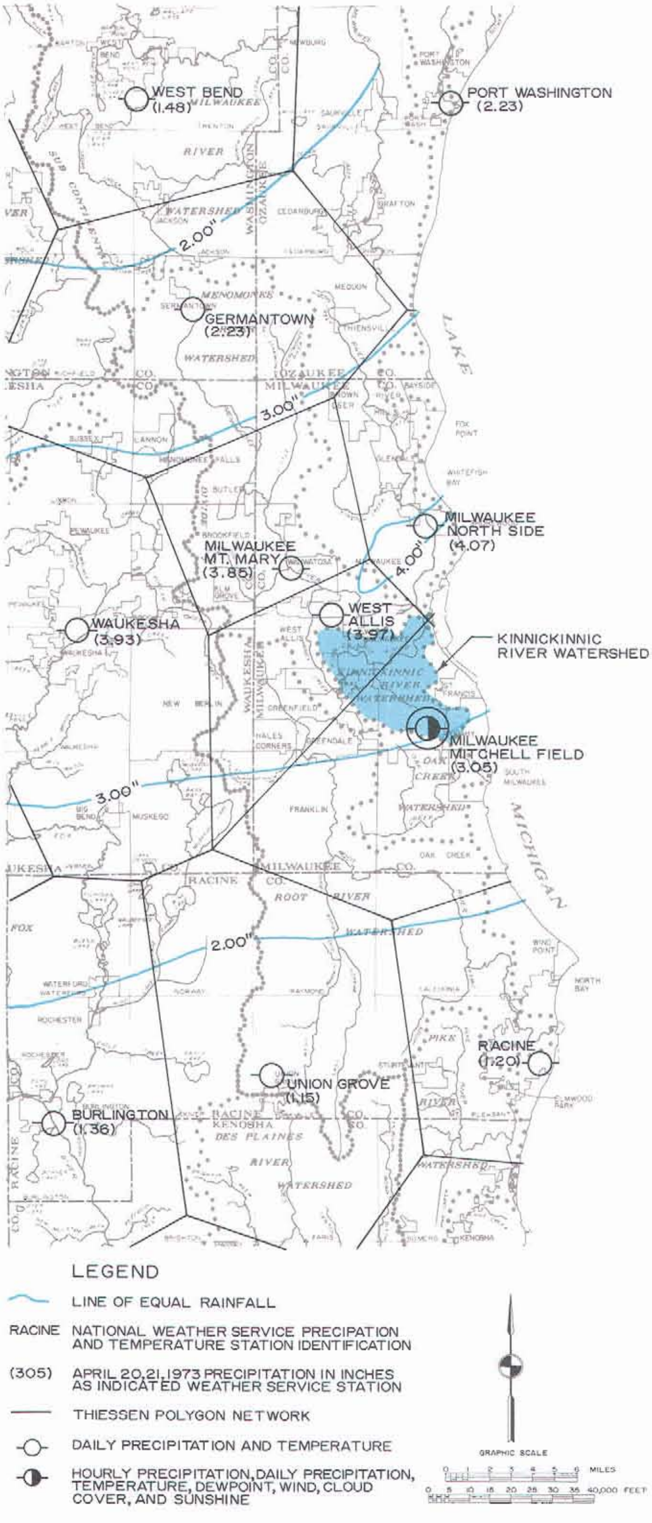
The immediate cause of the April 21, 1973, flooding in the Kinnickinnic River watershed and elsewhere in southeastern Wisconsin was widespread rainfall that occurred throughout the Region during the period of April 18 through April 21. Most of the rainfall was concentrated on Friday and Saturday, April 20 and 21, 1973. All 16 National Weather Service stations in operation within southeastern Wisconsin at that time recorded rainfall, with the April 20 and 21 totals ranging from a low of 1.15 inches at Union Grove in Racine County to a high of 4.07 inches at Milwaukee North Station in Milwaukee County. Regional rainfall amounts for the two days were largest along an east-west zone positioned immediately north of the Kinnickinnic River watershed through the middle of Milwaukee and Waukesha Counties.

Isohyetal lines constructed from rainfall amounts reported by National Weather Service stations in and near the watershed are shown on Map 33 and illustrate the spatial distribution of the April 20 and 21, 1973, rainfall. As noted on the map, 3.97 inches of rainfall were recorded in the City of West Allis immediately northwest of the watershed and 3.05 inches were recorded at General Mitchell Field within and on the eastern edge of the watershed. Based on a Thiessen polygon analysis, the average rainfall received over the Kinnickinnic River watershed in the two-day period was 3.41 inches. Assuming that approximately 82 percent, or 2.80 inches, of this occurred during a continuous eight-hour period late Friday night and early Saturday morning, as was the case at the Milwaukee National Weather Service station where hourly rainfall amounts are recorded, the recurrence interval of this storm was only about eight years.

The resulting flooding was somewhat more serious than would be expected by the relatively moderate nature of the rainfall because of the wet antecedent moisture conditions. Precipitation totals within the watershed during January, February, and March 1973 were close to average. However, during the first 19 days of April, the precipitation recorded at West Allis was 27 percent above average and that recorded at the Milwaukee National Weather station was 92 percent above average. The large precipitation amounts that occurred in the watershed during the first 19 days of April 1973 were influenced by heavy snowfall on April 8 through 12, during which 15.7 inches of snow fell at the Milwaukee National Weather Service station with 11.6 inches occurring on April 9. This snowfall was followed by several days of warm weather so that the snowcover had melted away by about April 15. This was followed by several days of light rain prior to heavy rainfalls of April 20 and 21, 1973, and the subsequent severe flood. In summary, then, the April 21, 1973, flood is attributable to a moderate, two-day rainfall of 3.41 inches over the watershed which occurred on the very wet antecedent moisture conditions thereby producing a relatively large quantity of direct runoff.

In the absence of a long series of stream discharge measurements on the Kinnickinnic River watershed on which statistical analyses could be performed, a calibrated hydrologic-hydraulic model was used, as described in Chapter VIII of this report, to determine that the approximate peak discharge of April 21, 1973, on the Kinnickinnic River at S. 7th Street was 4,600 cfs. This

Map 33
RAINFALL OF APRIL 20-21, 1973, OVER THE KINNICKINNIC RIVER WATERSHED AND ENVIRONS



The average rainfall over the watershed which caused the April 19, 1973, flood event was slightly in excess of 3.4 inches in a two-day period. Because of high antecedent moisture conditions, this rather moderate rainfall produced very large flood discharges in the watershed. The peak flood discharge for the Kinnickinnic River near the watershed outlet is estimated at 5,600 cubic feet per second with a recurrence interval of approximately 50 years. This large flood flow was accompanied by serious flood damage along the S. 6th Street to S. 16th Street reach of the Kinnickinnic River in the City of Milwaukee.

Source: SEWRPC.

discharge has a recurrence interval of about 60 years. A review of historic high water marks indicates that the April 1973 flood produced the highest flood stages ever recorded at 13 of the 33 locations maintained by the Milwaukee-Metropolitan Sewerage Commission and the City of Milwaukee as shown on Map 19.

Major damage and disruption attributed to the April 1973 flood were confined to the S. 6th Street to S. 16th Street reach of the Kinnickinnic River in the City of Milwaukee, although damages were known to have been incurred at the airport. Although major channel modifications had been completed throughout this reach in 1961, the modified channel in combination with the 13 stream crossings in this reach did not have sufficient capacity to convey the flood flows within the channel banks. As a result, and as shown in Figures 29 and 30, floodwaters overtopped the low point of the roadways of all 11 bridges crossing the Kinnickinnic River beginning with and including S. 7th Street and extending through and including S. 15th Place. Accordingly, and as shown on Map 34, overland flooding occurred on both sides of the Kinnickinnic River between S. 6th and S. 16th Streets extending as much as about 700 feet, or over one city block, away from the River. The areal extent of the effect of flooding undoubtedly extended outside of the area affected by the overland flooding in the form of secondary flooding.

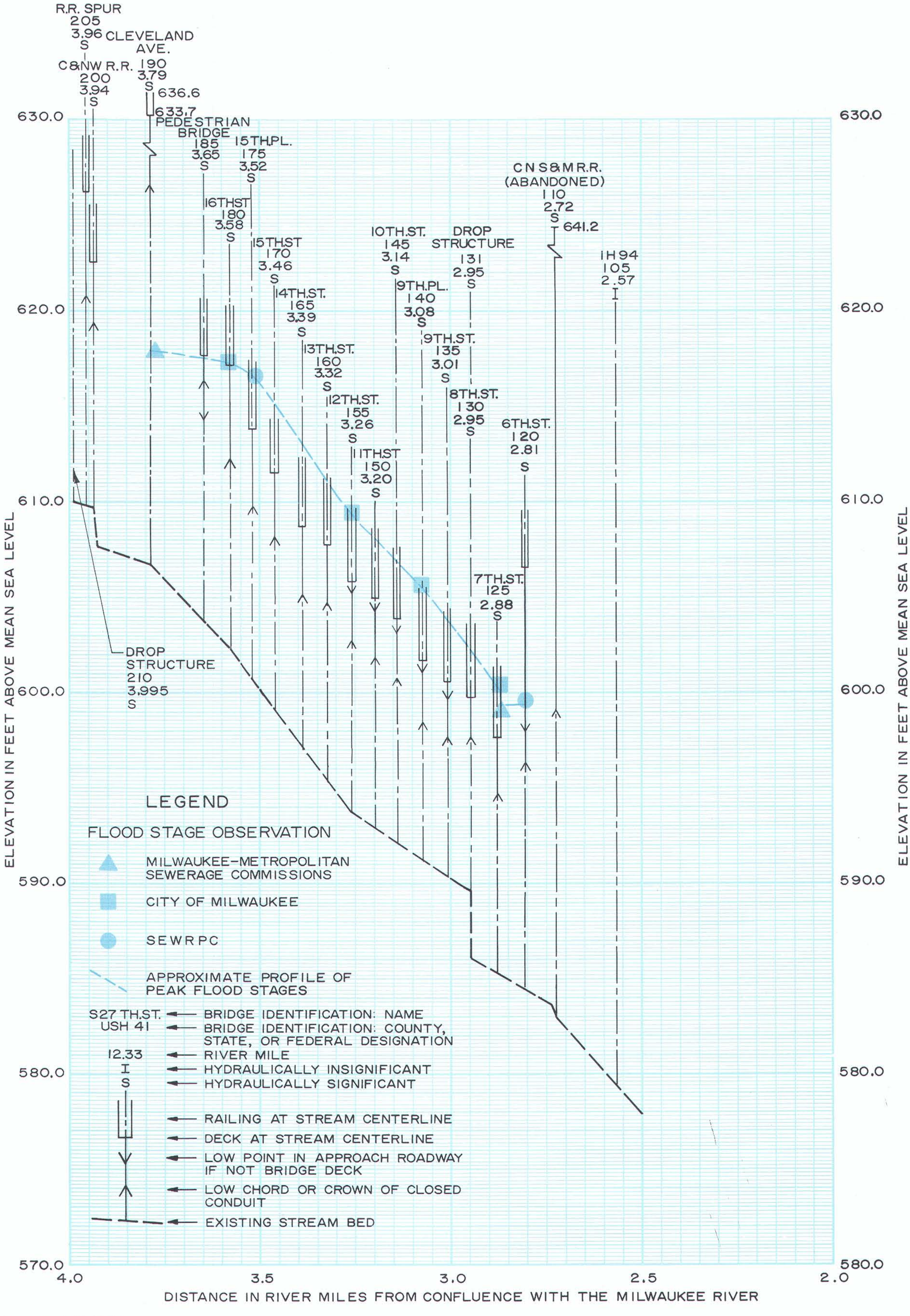
Many residential and commercial buildings in the area shown on Map 34 incurred damage to both structures and contents as a result of basement and first floor flooding. Examples of the severity of the flood damage and of the magnitude of the resultant clean-up and repair work are shown in Figures 31 through 33. Extensive monetary losses were inflicted on some individual structures. For example, the Polewski Pharmacy located about one-half block north of the Kinnickinnic River at the corner of S. 13th Street and W. Harrison Avenue incurred a $16,000 loss as a result of damage to inventory.

An isolated incident of flood damage was reported at General Mitchell Field. As the result of high storm water flows, a concrete box drainage structure beneath a taxiway in the northwest corner of Mitchell Field sustained damage consisting of erosion of the earth and gravel invert of the structure, undermining of footings, and collapse of portions of the crown of the structure. Milwaukee County received $166,000 in disaster assistance from the Wisconsin Division of Emergency Government to reconstruct the damaged drainage structure.

As to the extent and severity of flood damage and disruption along the S. 6th Street to S. 16th Street reach of the Kinnickinnic River, no other serious flood problems were reported in the Kinnickinnic River watershed as the result of the April 21, 1973, flood event. Significantly, the area along and near the Kinnickinnic River between S. 16th Street and S. 43rd Street, which had experienced serious flood damage and disruption during previous major flood events which occurred in March 1912, June 1917, January 1938, and March and August 1960, did not exhibit any flood problems as the result of the April 21, 1973, flood event even though the flood flows generated by those earlier floods were probably of the same order of magnitude as the April 1973 flood. The absence of flood problems along the S. 16th Street to the S. 43rd

Figure 29

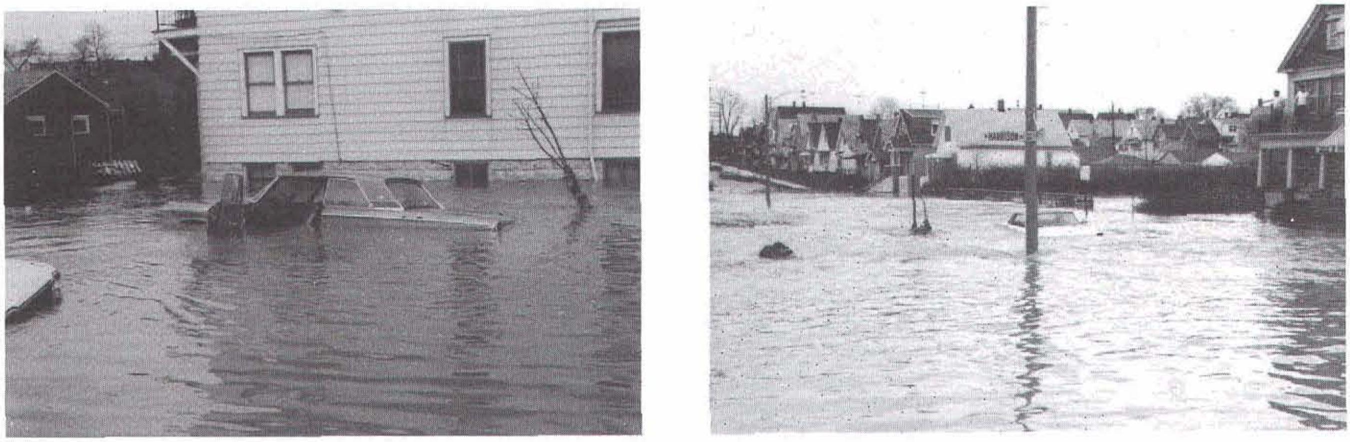
HIGH WATER LEVELS ON THE KINNICKINNIC RIVER FROM S. 6TH STREET TO CLEVELAND AVENUE: APRIL 1973 FLOOD EVENT



Source: SEWRPC.

Figure 30

OVERLAND FLOODING ALONG THE KINNICKINNIC RIVER DURING THE APRIL 1973 FLOOD EVENT

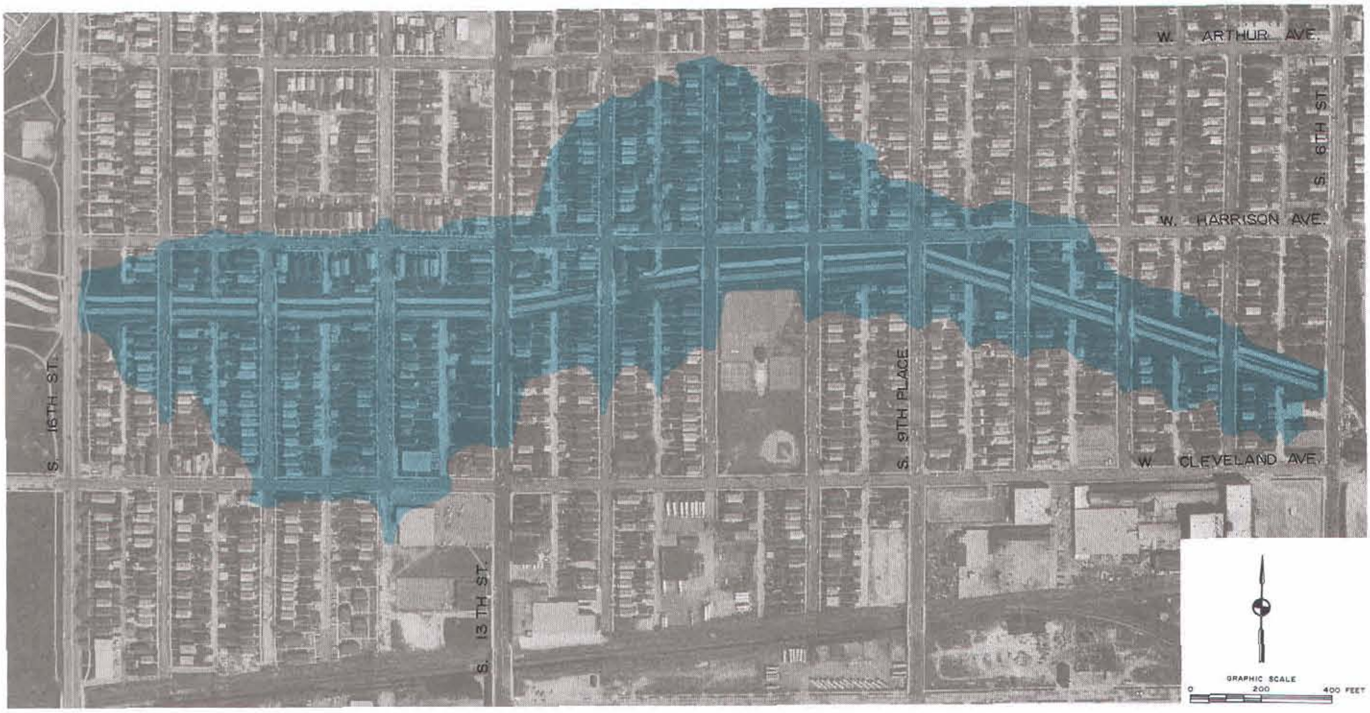


These photographs, taken on April 22, 1973, show the flooding of that date as it occurred along the Kinnickinnic River near the intersection of S. 9th Street and W. Harrison Avenue. The photographs clearly show both the depth and lateral extent of the serious flooding that occurred in this area.

Source: Anthony Jarozewski.

Map 34

AREAL EXTENT OF OVERLAND FLOODING ALONG THE KINNICKINNIC RIVER BETWEEN S. 6TH STREET AND S. 16TH STREET AS THE RESULT OF THE APRIL 1973 FLOOD EVENT

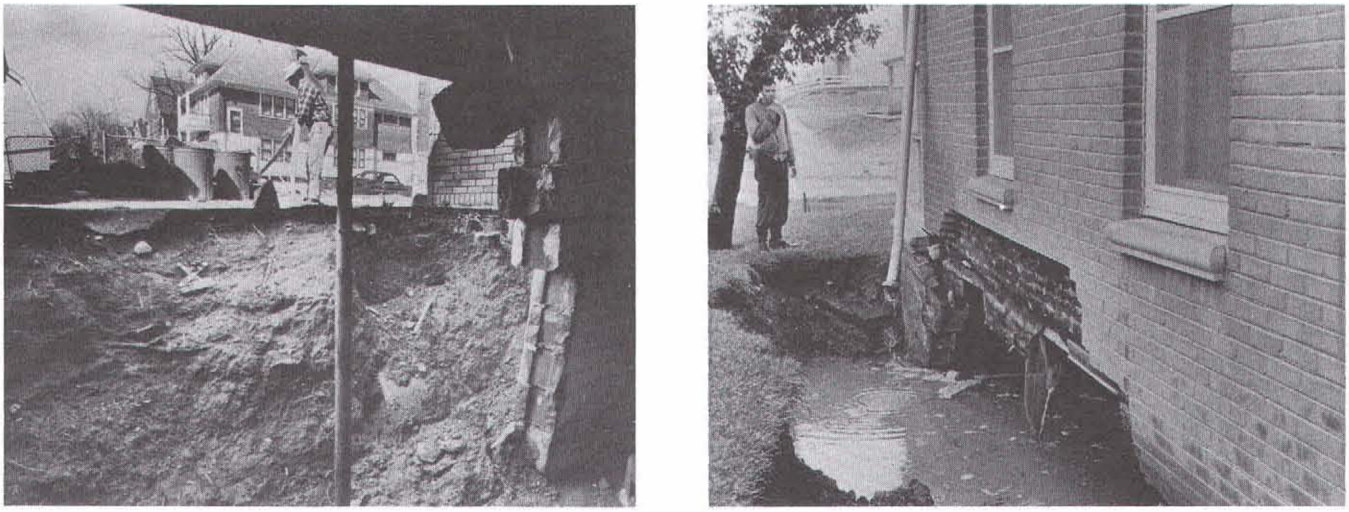


The April 1973 flood caused severe damage and disruption to low-lying lands along the Kinnickinnic River in the City of Milwaukee between S. 6th and S. 16th Streets. Approximately 0.10 square mile of land containing about 300 major residential and commercial structures was affected by overland flooding. As a result of secondary flooding, the total area within this reach affected by flooding undoubtedly extended outside of the area subjected to overland flooding. The Milwaukee-Metropolitan Sewerage Commissions and the City of Milwaukee have embarked on a joint project to resolve the flood problem in this reach of the Kinnickinnic River through a combination of bridge removal and further channel modification.

Source: U. S. Geological Survey and SEWRPC.

Figure 31

FLOOD DAMAGE TO BASEMENT WALLS



Flood waters exert large and potentially destructive inward forces on the basement walls of residential and commercial structures. This obviously occurs when flood levels are above ground grade at the structure but can also occur when floods are of sufficient duration to saturate the soil in immediate contact with the foundation of the structure. The collapse of basement walls results in inundation of the basement and subsequent major repair costs and can also threaten the structural soundness of the upper portion of the structure. The first photo shows damage that occurred to the basement of a commercial structure as a result of the April 1973 flood in the Kinnickinnic River watershed, and the second photo shows damage to the basement of a residential structure occurring as the result of flooding in the watershed in 1957.

Source: Milwaukee Journal.

Figure 32

AFTERMATH OF A FLOOD: PUBLIC COSTS

This photograph shows damage to a sidewalk in the vicinity of S. 13th Street and the Kinnickinnic River as the result of the April 21, 1973 flood. Costs for repair of these facilities are borne by the public at large—not just the residents of the flood-prone areas.

Source: City of Milwaukee, Department of Public Works, Bureau of Bridges and Public Buildings.

Figure 33

AFTERMATH OF A FLOOD: PRIVATE COSTS

This photograph shows damage to a residential property along the Kinnickinnic River as a result of the April 1973 flood. Subsequent to a flood event and upon recession of flood waters, the owner or tenant of residential property is faced with a costly, time consuming, and discouraging clean-up and, in some cases, rebuilding effort. Many functional items are seriously damaged or rendered useless and must be replaced. In addition, highly valued and irreplaceable objects and belongings are destroyed by exposure to floodwaters and sediment and must be discarded.

Source: Milwaukee Journal.

Street reach of the Kinnickinnic River probably reflects the effectiveness of the massive channel improvements made to the Kinnickinnic River in this reach during the period from 1960 to 1965.

To help alleviate the damages wrought by the April 1973 flood, federal loans and grants of up to a maximum of $55,000 per property were provided under the Federal Disaster Relief Act with the provision that the first $5,000 of the loan did not have to be repaid. The program was intended to provide for the repair or replacement of damaged essential items, that is, items important to the maintenance of health, safety or welfare and was intended only to provide relief where other forms of insurance or damage recovery were not available. Examples of such essential items include washing machines, clothes dryers, furnaces, and the walls and floors of the structure. Examples of nonessential items include recreation room improvements, pool tables, golf equipment, stamp or coin collections, and antique furniture.

Loans and grants were provided to 2,596 home owners in all six communities—the Cities of Cudahy, Greenfield, Milwaukee, St. Francis, and West Allis and the Village of West Milwaukee—located in part within the Kinnickinnic River watershed. The loans and grants made within the six communities, but not necessarily within the watershed, totaled $1,662,567 for an average of $640 per home. The average loan or grant ranged from a low of $410 per structure, based on five structures in the Village of West Milwaukee, to a high of $956 per structure, based on 76 structures in the City of Greenfield. In addition, loans and grants were made to a total of 91 businesses in four communities—the Cities of Cudahy, Greenfield, Milwaukee, and West Allis—located in part within the Kinnickinnic River watershed. Business loans and grants totaled $603,402 for an average business loan or grant of $6,630.

Actual losses incurred by property owners are probably significantly higher than the average or total loan and grant figures noted above for both homes and businesses because: 1) nonnecessities were excluded from the loan program, 2) some people were not aware of the loan program, 3) concern with the potential of having a home or business marked as flood-prone in government records, and 4) reluctance of some homeowners and businessmen to expend the effort required to procure the loans and grants.

Results of the Personal Interview Survey

As noted earlier in this chapter, a personal interview survey oriented to flood problems identification was carried out with the owners or tenants of structures located along selected reaches of the Kinnickinnic River,

Table 25

SELECTED RESULTS OF PERSONAL INTERVIEW SURVEY

Reach Description			Total Number of Structures in Reach[a]	Sample Size: Number of Structures for Which Personal Interviews were Completed				Structures Having Sump Pumps		Structures for Which Flood Problems were Reported		Types of Flood Problems and Number of Structures Affected One or More Times							
												Overland Flooding							
Civil Division	Stream or Lake	Identification Number		With Basements	With Crawl Space	Without Either	Total	Number	Percent of Sample	Number	Percent of Sample	Property	On Property and into Structure	First Floor Flooding	Sanitary Sewer Backup into Basement or Crawl Space	Seepage Through Walls or Floor into Basement or Crawl Space	Other	Total[b]	Comments
City of West Allis	Kinnickinnic River	KKR-1	--	25	0	0	25	2	8	2	8	0	0	0	2	0	0	2	One was about 1973; other unknown date
City of Milwaukee	Kinnickinnic River	KKR-2	--	13	1	0	14	9	64	2	14	0	0	0	1	1	0	2	Seepage in 1973, and sewer back-up in 1960
	Kinnickinnic River	KKR-3	--	53	0	0	53	13	25	20	38	1	0	0	19	2	0	22	Overland flooding on corner of property when intersection of W. Jackson Parkway and S. 51st Street flooded
	Lyons Park Creek	LC-1	--	6	0	0	6	5	83	3	50	0	0	0	3	0	0	3	--
	Lyons Park Creek	LC-2	--	19	0	1	20	11	55	5	25	0	0	0	3	2	0	5	Sewer back-up in early 1970's
	Wilson Park Creek	WPC-2	--	9	0	0	9	7	78	6	67	0	0	0	6	2	0	8	--
Subtotal			--	100	1	1	102	45	44	36	35	1	0	0	32	7	0	40	--
City of Cudahy	Wilson Park Creek	WPC-1	--	45	0	0	45	35	78	24	53	0	1	0	2	21	0	24	17 of 21 seepage problems are in Edgerton Garden Apts.; overland flooding along ditch
Total			--	170	1	1	172	82	48	62	36	1	1	0	36	28	0	66	--

[a] *Major structures within the area defined by the 100-year recurrence interval event plus 10 feet—approximate area in which basements are at or below the 100-year flood stage and therefore may be subject to flooding. (To be provided upon completion of hydrologic-hydraulic modeling.)*

[b] *May exceed sample size since some structures have experienced more than one type of flood problem.*

Source: SEWRPC.

Wilson Park Creek, and Lyons Park Creek within the Cities of West Allis, Milwaukee, and Cudahy (see Table 23). A total of 172 interviews were completed with the owners or tenants of a variety of structure types including single and multiple-family residences, and business and commercial enterprises. As indicated in Table 23 and shown on Map 29, 25 personal interviews were completed in the City of West Allis, 102 in the City of Milwaukee, and 45 in the City of Cudahy. With respect to major streams within the Kinnickinnic River watershed, 92 personal interviews were completed with owners or tenants of structures located along the Kinnickinnic River, 26 along Lyons Park Creek, and 54 along Wilson Park Creek.

Results of the personal interview survey as they relate to the historic and existing flood problems are summarized by reach in Table 25 with the location of the reaches being shown on Map 29. For each of the seven reaches, Table 25 includes such information as the total number of structures for which interviews were completed, the number of structures in which flood and flood-related problems have been observed one or more times, and the types of flood problems that occurred. Types of flood problems identified in Table 25 are: overland flooding onto the structure site, overland flooding onto the site and into the crawl space or basement of the structure, first floor flooding, sanitary sewer backup into a crawl space or basement, and seepage through walls or floor into a crawl space or basement. A given residential or commercial structure could incur one or more types of flooding over a period of time or even during a particular flood event. For a given property, each type of reported flood problem was counted only once for purposes of Table 25 even if it occurred two or more times.

The principal findings of the personal interview survey with respect to historic and existing flood problems in the Kinnickinnic River watershed and probable future problems in this basin may be summarized as follows:

- Of the 172 structures included in the survey and located within the selected riverine areas as described above, owners or tenants of 62 structures, or 36 percent of the total, reported one or more incidences of some type of flood problem. By civil division, one or more flood problems were reported for about one-tenth of the structures surveyed in the City of West Allis, about one-third of the structures surveyed in the City of Milwaukee, and about one-half of the structures surveyed in the City of Cudahy.

- Of those owners or tenants reporting one or more incidences of the various types of flood problems, the dominant type of problem was sanitary sewer backup into basements or crawl spaces. Of the 66 reported incidences of flood problems, 36 or about one-half were attributed to sanitary sewer backup. By civil division, sanitary sewer backup into basements or crawl spaces accounted for all of the reported flooding problems in the City of West Allis and three-fourths of those in the City of Milwaukee, but less than 10 percent of those in the City of Cudahy. With respect to stream reach, sanitary sewer backup into basements and crawl spaces accounted for about 35 percent of the reported flooding problems along the Kinnickinnic River, three-fourths of those along Lyons Park Creek, and about 25 percent of those along Wilson Park Creek.

- The second most common type of flood problem reported to have occurred one or more times by owners or tenants of residential or commercial buildings was seepage through walls or floors into basements or crawl spaces. Of the 66 reported incidences of flood problems, 28, or approximately 40 percent, involved seepage through walls or floors into basement crawl spaces. By civil divisions, seepage through walls or floors accounted for one-fifth of the reported incidences of flooding problems in the City of Milwaukee and about 90 percent of those reported in the City of Cudahy. With respect to stream reach, seepage through walls or floors into basements or crawl spaces accounted for about one-tenth of the reported flooding problems along the Kinnickinnic River, about one-fourth of those reported along Lyons Park Creek, and over two-thirds of those reported along Wilson Park Creek.

- Only two incidences of overland flooding onto a building site were reported, and there were no reports of first floor flooding.

- About half of the structures for which personal interview surveys were completed are equipped with sump pumps. By civil divisions, about 80 percent of the structures included in the survey within the City of Cudahy have sump pumps, about 40 percent of those in the City of Milwaukee are so equipped, and only about 10 percent of those in the City of West Allis have sump pumps.

- While about one-third of the owners or tenants of structures included in the personal interview survey reported one or more incidences of having water in the basement as a result of either sanitary sewer backup or seepage through basement walls, the quantity or depth of water in the basements was generally very minor. For example, 23 incidences of water in basements were reported in the City of Cudahy but in all but two cases the water consisted of a mere trickle on the basement floor. The two exceptions consisted of reports of up to one-half foot of water in the basement as a result of sump pump failures.

It is important to reiterate that the personal interview surveys conducted by the Commission staff during the early part of 1977 were not carried out along the Kinnickinnic River between S. 6th Street to S. 16th

Street. Although the analysis of the sequence of historic flood events suggested that serious flood problems existed in this reach, it was excluded from the personal interview survey as well as from all other inventory and analysis phases of the Kinnickinnic River watershed planning program. As noted earlier, the Milwaukee-Metropolitan Sewerage Commission and the City of Milwaukee were committed, prior to the beginning of the watershed planning program, to resolve this problem through a combination of channel modification and bridge alteration or removal.

Concluding Statement: Historic Flood Events and Findings of the Personal Interview Survey

Seven major floods have occurred in the Kinnickinnic River watershed. Each of these floods has caused damage and disruption in riverine areas as a result of primary and secondary flooding. Most of these flood events have been accompanied by scattered storm water inundation problems only indirectly related to the flood problems along the major stream. Flood problems have been concentrated along the 3.70 mile-long-reach of the Kinnickinnic River bounded at the downstream end by S. 6th Street and at the upstream end by S. 43rd Street and scattered less severe flood problems have been reported along the Wilson Park Creek and other tributaries.

Extensive channel modifications have been carried out along the Kinnickinnic River, Wilson Park Creek, Lyons Park Creek, and other tributaries in the watershed since 1952 and the historic record through the April 1973 flood experience suggests that these efforts have substantially reduced the flood hazards. Although relatively severe in terms of flood discharge, the April 1973 flood caused damage and disruption primarily along the S. 6th Street to S. 16th Street reach of the Kinnickinnic River. However, the Milwaukee-Metropolitan Sewerage Commission and the City of Milwaukee are committed to resolve this problem by means of a combination of bridge removal and channel modification.

Research findings on the historic flood problems supplemented by results of the personal interview survey, considered in light of completed channel improvements and the commitment to resolve the flood problem along the S. 6th Street to S. 16th Street reach of the Kinnickinnic River, may lead to the erroneous conclusion that major flood problems have been or soon will be eliminated in the Kinnickinnic River watershed. It is important to note, however, that the design flood selected for the Kinnickinnic River watershed planning program is the 100-year recurrence interval flood event as it would occur under year 2000 plan land use and floodland development conditions. A flood of this magnitude has probably not occurred in the watershed under existing or recent development conditions—the most recent severe flood which occurred in April 1973 is estimated to have had a discharge of 4,600 cfs and a recurrence interval of 60 years on the Kinnickinnic River near the watershed outlet at S. 7th Street. Therefore, it is imperative that the hydrologic-hydraulic-flood risk analyses be carried out under the watershed planning program to determine whether flood problems are likely to occur in the watershed under year 2000 plan land use and floodland development conditions. If serious flood problems are likely to occur, the analyses will serve to identify the location of such problems and to quantify their severity in terms of flood depth, area of inundation, and monetary risk. The manner in which this analysis was conducted and the results in terms of flood discharge, stages, and monetary damages are described in Chapter XII.

HISTORIC FLOODING: SOME OBSERVATIONS

One of the uses of historic flood information is to support public educational and informational activities after completion of the watershed plan. Much can be learned and several conclusions can be drawn from the record of historic flooding in the Kinnickinnic River watershed. Some observations based on information obtained during the research on historic flooding are discussed below. The intent is that these observations may be useful to public officials and interested citizens when they face decisions directly or indirectly related to development or redevelopment in the riverine areas, particularly decisions related to flood problems.

Variety of Damage and Disruption

The historic record clearly demonstrates that floodwaters can cause physical damage to many different kinds of structures and facilities in a variety of ways. As a result of that damage, and sometimes even in the absence of actual physical damage, major floods can cause significant disruption of social and economic activities throughout much of the watershed.

The principal type of damage experienced in the Kinnickinnic River watershed has been damage to structures—private residences and commercial buildings—and to their contents as a result of overland and attendant secondary flooding. Bridges and culverts and sections of roadways and sidewalks have been damaged by the erosive action of rapidly moving floodwaters so as to require extensive repair or complete rebuilding.

A common and costly type of disruption associated with major flood events in the Kinnickinnic River watershed has been interruption of business activities not only during flood events but also during the postflood cleanup and repair period. In the public sector, the routine operations of governmental units usually are disrupted during flood events as public officials attempt to provide immediate relief to affected areas. Another form of disruption directly attributable to major flood events is the temporary closure of highways and railroads that have been inundated at a relatively low place, such as an underpass, or as a result of damage to a river crossing. Although floodland recreational areas and facilities such as ballfields, golf courses, and picnic grounds typically incur little physical damage as a result of flooding, their use is temporarily curtailed by inundation.

In summary, then, the historic flood record assembled for the Kinnickinnic River watershed indicates that floods cause physical damage to many types of structures and facilities in a variety of ways, and that floods directly or indirectly disrupt the normal activities of many watershed residents. While the physical damage caused by major flood events is limited to the riverine areas, the attendant costs and disruption may be more widely borne.

Dominance and Significance of Rainfall-Induced Flood Events

Chapter V of this report presents data which clearly indicate that rainfall, as opposed to either snowmelt or a combination of rainfall and snowmelt, has been the dominant cause of annual flood events in the Kinnickinnic River watershed. This conclusion is further substantiated by the historic record for the six major floods that have occurred in the watershed in that four of these were exclusively rainfall events, one was a combination rainfall-snowmelt event, and one resulted solely from snowmelt.

The dominance of rainfall event floods in the Kinnickinnic River watershed is significant for two reasons. First, with the possible exception of the winter season, major floods can occur any time of the year. Second, rainfall floods, as opposed to either snowmelt or combination rainfall-snowmelt floods, will exhibit rapid increases in stream discharge and stage, especially in the typical hydraulically efficient urban environment, thereby providing little opportunity for communicating flood warnings to occupants of riverine areas.

The Risk to Human Life and Health

There is a tendency to consider and evaluate the damage and disruption normally accompanying flooding without due regard to the risk to human life and health that exists during every major flood event. Public officials and interested citizens should be aware of this danger as one factor to be weighed in making decisions that are directly or indirectly related to riverine areas. The historic flood record for the Kinnickinnic River watershed contains several accounts of near loss of life during flood events and of successful rescues by police and fire department personnel.[5]

Regardless of the rural or urban nature of a watershed, flood events are potentially hazardous to people in or near the riverine areas primarily because normally shallow, narrow, slowly moving rivers and streams become deep, wide, rapidly moving torrents that can readily entrap even an adult. For example, floodwaters at a depth of four feet and moving at a velocity of four feet per second, a condition that would be expected over much of the floodlands of the Kinnickinnic River during a major flood event, would exert a dynamic force of approximately 110 pounds on an adult. If the velocity were doubled to eight feet per second, which is still a common condition near the channel during a major flood event, the dynamic force would increase by a factor of four to about 440 pounds.[6] Not only are these forces large, but they probably would be applied abruptly and unexpectedly to persons entrapped in the floodwaters.

The threat to human life is relatively more severe in the Kinnickinnic River watershed for three reasons. First, most of the watershed is highly urbanized and, therefore, many people—and particularly many children who are naturally drawn to surface waters—may be expected to be close to the stream system. Second, as a result of the extensive storm and floodwater conveyance system that has been developed to serve most of the watershed, flood discharges and stages in the watershed stream system rise rapidly with little advance warning. Third, most of the watershed stream system has been subjected to major channelization. These hydraulically efficient sections will exhibit very high, and therefore potentially dangerous, channel velocities during flood events. Results obtained with the hydrologic-hydraulic model described in Chapter VIII of this report indicate that channel velocities in channelized sections may be expected to be substantially higher than channel velocities in natural riverine areas under major flood conditions.

The effect of channel modification on flow velocity is readily demonstrated with hydraulic information developed under the watershed planning program.

The 1.5-mile reach of the Kinnickinnic River bounded by S. 43rd Street at the downstream end and S. 60th Street at the upstream end has a natural channel-floodplain cross section. Hydrologic-hydraulic calculations under year 2000 plan land use-floodland development conditions indicate that the median channel velocity for cross sections in this natural reach under 10-year recurrence interval flood event conditions would be about four feet per second and under 100-year recurrence interval flood event conditions would be about five feet per second.

[5] *In addition to the accounts of near loss of life during the six flood events described in this chapter, other risks to human life occurred on June 19, 1971. A 17 year old youth fell down the embankment and into the rain swollen Kinnickinnic River after a heavy thunderstorm and, while attempting to rescue him, a second youth also was swept downstream by the heavy current. Fire department personnel were called and the first youth was rescued by extending a ladder down to him near S. 9th Street crossing of the Kinnickinnic River. After clinging to the underpinnings of the S. 10th Street bridge, the second youth was rescued by a patrolman who tied himself to a rope held at shore and waded into the River.*

[6] *The dynamic force or drag may be computed using the equation force =* $C_D A p V^2/2$ *where* C_D *= dimensionless drag coefficient = 1.2, A = area of submerged surface perpendicular to flow = 4.0 feet x 1.5 feet = 6.0 square feet, p = mass density of water = 1.94 slugs per cubic feet and V = velocity of the water = 4 and 8 feet per second.*

The 0.5-mile-long reach of the Lyons Park Creek bounded at the downstream end by W. Cleveland Avenue and at the upstream end by W. Oklahoma Avenue has been extensively channelized for flood control purposes. Hydrologic-hydraulic computations indicate that, under year 2000 plan land use-floodland development conditions, the 10-year recurrence interval flood event would produce a median velocity in this reach of about 10 feet per second whereas the 100-year recurrence flood event will result in a median velocity in this reach of about 12 feet per second. Inasmuch as these two stream reaches are similar for channel bottom slopes and flood discharges, the high channel velocity in the channelized section, compared to the natural channel-floodplain cross section, is largely attributable to the hydraulic effect of channelization. Not only are velocities higher in channelized reaches, compared with the conditions that exist in the channel and on the floodplain under more natural conditions, but human escape from the channelized reaches is more difficult because of the relatively smooth, steep sidewalls of the improved channels.

With the exception of increasing public awareness of the danger, little can be done to mitigate the above mentioned threat to human life. That threat is one of the intangible, but nevertheless significant negative aspects of an urban development pattern that encroaches into the wide, natural floodlands of the surface water system thereby necessitating the construction of narrow, deep, and straight artificial channels designed to effect a rapid removal of runoff during major rainfall and snowmelt events.

In summary, then, historic evidence accumulated for the Kinnickinnic River watershed, supplemented with hydraulic analyses completed under the watershed study, indicate that major flood events can pose a serious threat to human life. This risk is heightened in highly urbanized watersheds like the Kinnickinnic River watershed because of the proximity of people to the riverine areas, the "flashy" nature of the streams, and the high velocities and steep sidewalls characteristic of channelized reaches.

While the threat of flooding to human life can be readily illustrated by reference to historic accounts of flood-related rescues and deaths, the threat to health is not so apparent. Nevertheless, it does exist. Floodwaters can be the medium for transporting potentially harmful substances, such as toxic materials, from industrial operations and pathogenic (disease-producing) bacteria from sanitary and combined sewers to residential areas where there is the possibility of contact with and harm to the residents.

In addition to potential physiological harm, the occurrence of floods as well as the ever-present threat of flooding can adversely affect the psychological health and well-being of riverine area residents. Owners or tenants of flood-prone structures and properties are burdened with the need to be in a constant state of readiness, particularly in the Kinnickinnic River watershed where major floods can occur almost any time of the year and with little warning. These owners or tenants occasionally must contend with the unpleasant task of cleaning flood-borne, contaminated sand, silt, and other materials and debris from their homes and places of business. Finally, even after the flood has passed and the cleanup and repairs have been completed, lingering odors and other evidence of the recent inundation will impose an additional psychological stress on the occupants of riverine area property.

MONETARY FLOOD LOSSES AND RISKS

Flood damage is defined herein as the physical deterioration or destruction caused by floodwaters. The term flood loss refers to the net effect of historic flood damage on the regional economy and well-being with the tangible components of the loss being expressed in monetary units. Flood risk is the probable damage, expressed either on a per flood event basis or on an average annual basis, that will be incurred as a result of future flooding with the tangible portion of the risk expressed in monetary terms. All losses resulting from historic flooding or the risk attendant to future flooding can be classified into one of three types of damage categories—direct, indirect, and intangible. Such damages can also be classified according to whether the private or the public sector incurs the losses or risks. This two-way classification of flood losses and risks is set forth in Table 26.

Flood Losses and Risks Categorized by Type

In order to promote compatibility with the policies and practices of such federal agencies as the U. S. Army Corps of Engineers and U. S. Soil Conservation Service, which may be asked to assist in the implementation of the recommended watershed plan, the following three categories of flood losses and risks were defined for the purpose of the study:

1. Direct flood losses or risks were defined as monetary expenditures required, or which would be required, to restore flood-damaged property to its preflood condition. This includes the cost of cleaning, repairing, and replacing residential, commercial, industrial, and agricultural buildings and contents and other objects and materials located outside of the buildings on the property. Direct losses and risks also encompass the cost of cleaning, repairing, and replacing roads and bridges, storm water systems, sanitary sewer systems, and other utilities, as well as the cost of restoring damaged park and recreational lands.

2. Indirect flood losses and risks were defined as the net monetary cost of evacuation, relocation, lost wages, lost production, and lost sales; the increased cost of highway and railroad transportation because of flood-caused detours; the costs of flood fighting and emergency services provided by governmental units, as well as the cost of postflood floodproofing of individual structures. The costs of postflood engineering and planning studies also are categorized as indirect losses and risks. Although often difficult to determine with

Table 26

CATEGORIES OF FLOOD LOSSES AND RISKS

Type of Damage	Ownership	
	Private Sector	Public Sector
Direct	Cost of cleaning, repairing, or replacing residential, commercial, and industrial buildings; contents and land Cost of cleaning, repairing, or replacing agricultural buildings and contents and cost of lost crops and livestock	Cost of repairing or replacing roads, segments, bridges, culverts, and dams Cost of repairing damage to storm water systems, sanitary sewerage systems, and other utilities Cost of restoring parks and other public recreational lands
Indirect	Cost of temporary evacuation and relocation Lost wages Lost production and sales Incremental cost of transportation Cost of postflood floodproofing	Incremental costs to governmental units as a result of flood fighting measures Cost of postflood engineering and planning studies
Intangible	Loss of life Health hazards Psychological stress Reluctance by individuals to inhabit flood-prone areas thereby depreciating riverine area property values	Disruption of normal community activities Reluctance by business interests to continue development of flood-prone commercial-industrial areas thereby adversely affecting the community tax base

Source: SEWRPC.

accuracy, indirect losses and risks nevertheless constitute a real monetary burden on the economy of the Region.

3. Intangible flood losses and risks were defined as flood effects which cannot be readily measured in monetary terms. Such losses and risks include health hazards, property value depreciation as a result of flooding, and the general disruption of normal community activities. Intangible losses and risks also include the severe psychological stress experienced by owners or occupants of riverine area structures.

Flood Losses and Risks Categorized by Ownership

As already noted, flood losses and risks may also be classified on the basis of ownership into public-sector and private-sector losses and risks. Each of the three categories of flood loss by type-direct, indirect, and intangible—may, therefore, be further subdivided into public-sector losses as shown in Table 26. Within the direct loss category, for example, the cost of cleaning, repairing, and replacing residential buildings and their contents is a private-sector flood loss whereas the cost of repairing or replacing damaged bridges and culverts is a public-sector loss.

Role of Monetary Flood Risks

Previous sections of this chapter identified the major historic flood events known to have occurred within the watershed and described the severity of each flood event in terms of the reaches of the stream system affected, the types of damage and disruption that occurred, the relative magnitude of recorded discharges and observed stages, and the degree to which human life was endangered. While such a qualitative description of flooding is an effective means of communicating the characteristics of flooding, it is not adequate for sound economic analyses of alternative solutions to flood problems. Such analyses require that flood damages for the various stream reaches be quantified in monetary terms on a uniform basis throughout the watershed.

The quantitative, uniform means of expressing flood damages selected for use in the Kinnickinnic River watershed study was the average annual flood damage risk expressed in 1977 dollars. Average annual flood risk was computed for floodprone reaches to provide a monetary value that could be used, wholly or in part, as an annual benefit for comparison to annual costs of technically feasible alternative flood control measures such as acquisition and removal of flood-prone structures, structure floodproofing, channel modification, and construction of earthen dikes, concrete floodwalls, and flood control reservoirs.

Methodology Used to Determine Average Annual Flood Risks

The average annual flood damage risk for a stream reach is defined as the sum of the direct and indirect monetary flood losses resulting from floods of all probabilities, each weighted by its probability of occurrence or exceedance in any year. If a damage-probability curve is constructed, such as the graph of dollar damage versus flood probability as illustrated in Figure 34, the average annual risk is represented by the area beneath the curve. The damage-probability curve for each flood-prone reach is developed by combining the reach stage-probability relationship with the reach stage-damage curve as illustrated in Figure 34. The determination of average annual flood risk for a particular flood-prone reach, therefore, depends upon construction of the stage-probability and stage-damage relationships for the reach.

The ideal way to develop the two required relationships for a particular reach would be from a long series of stage observations which could be analyzed statistically to yield the stage-probability curve and from a similar long series of recorded direct and indirect damages actually experienced by riverine area occupants for a full range of flood stages. Inasmuch as neither the river stage information nor the damage information is generally available, it is necessary to develop the stage-probability and stage-damage relationships by analytical means and then to combine them to form the damage-probability relationship.

Synthesis of Reach Stage-Probability Relationships

The stage-probability relationship for a particular reach is determined by the hydraulic characteristics of the reach, such as the shape of the floodland cross sections, the value of the Manning roughness coefficients and presence of bridges, culverts, and other structures—all of which are to some extent determined by the activities of man—and the magnitude of flood flows expected in the reach. These flood flows are in turn a function of upstream hydraulics and hydrology which are also, because of man's activities, continuously undergoing change or have the potential to do so. It follows, therefore, that each reach does not have a unique stage-probability curve but instead there are many possible stage-probability curves, each of which is associated with a given combination of hydrologic-hydraulic conditions in and upstream of the reach in question.

Figure 34 shows an example of a stage-probability curve synthesized for a reach.

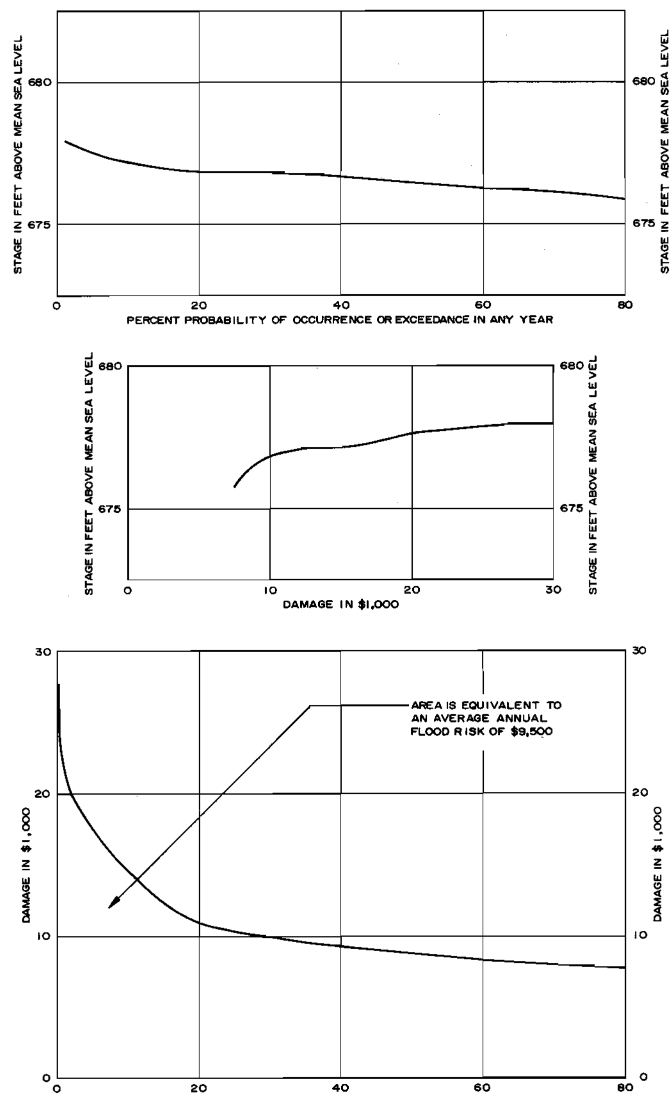
Synthesis of Reach Stage-Damage Relationships

The stage-damage curve for a reach is determined by the nature and extent of flood-prone structures and other property contained within the reach. It follows, therefore, that there is a separate stage-damage curve for each combination of riverine area land uses. Development of the stage-damage relationship for a particular combination of riverine area land uses in a reach begins with computation of the flood losses that may be expected for an arbitrarily selected flood stage slightly above the elevation of the river channel. These flood losses consist of estimates of the direct and indirect monetary flood losses set forth in Table 26. Upon completion of the summation of flood losses at the initial flood stage, a higher stage is considered. This process is repeated so as to consider the full spectrum of flood stages from just above the river bank up to the 500-year recurrence interval flow stage. Figure 34 presents an example of a synthesized stage-damage curve for a reach.

Synthesis of reach stage-damage relationship requires the use of stage-damage relationships for the various type structures, facilities, and activities likely to be present in or to occur in floodlands. A stage-damage relationship for a particular type of structure is a graph of depth of inundation in feet relative to the first floor versus dollar damage to structure and contents expressed as a percent of the total dollar value of the structure and its contents.

Figure 34

EXAMPLE OF DETERMINATION OF AVERAGE ANNUAL FLOOD RISK FOR A RIVER REACH



NOTE: EXAMPLE PERTAINS TO FLOOD DAMAGE FOR THE EDGERTON CHANNEL REACH BETWEEN NICHOLSON AVENUE AND A POINT APPROXIMATELY 100 FEET DOWNSTREAM IN THE CITY OF CUDAHY

Source: SEWRPC.

The stage-damage relationships for five types of structures as used in the Kinnickinnic River watershed study are shown in Figure 35. These stage-damage relationships were developed by the Commission staff using Federal Insurance Administration tables as published in 1970 and revised in 1974 and 1975.

Determination of Indirect Damages: The above stage-damage relationships reflect the direct damage to each of the various types of structures as the function of the depth of inundation. Indirect damages, which can be a significant fraction of the total monetary losses incurred during a flood event, were computed as a percentage of the direct damages to the various types of structures. The direct damages to commercial and industrial structures were increased by 40 percent to account for indirect damages whereas the direct damages to residential and all other types of structures were increased by 15 percent to reflect indirect damages.[7]

Average Annual Flood Risks: The above methodology was used to compute average annual flood risks for selected reaches in the Kinnickinnic River watershed under existing and hypothetical future floodland development-land use conditions. The voluminous computations were carried out with the flood economics submodel of the hydrologic-hydraulic simulation model described in Chapter VIII of this volume. The resulting per event and average annual flood risks for selected reaches under various floodland and nonfloodland development conditions are presented in tabular and graphic form in Chapter XII of this report.

SUMMARY

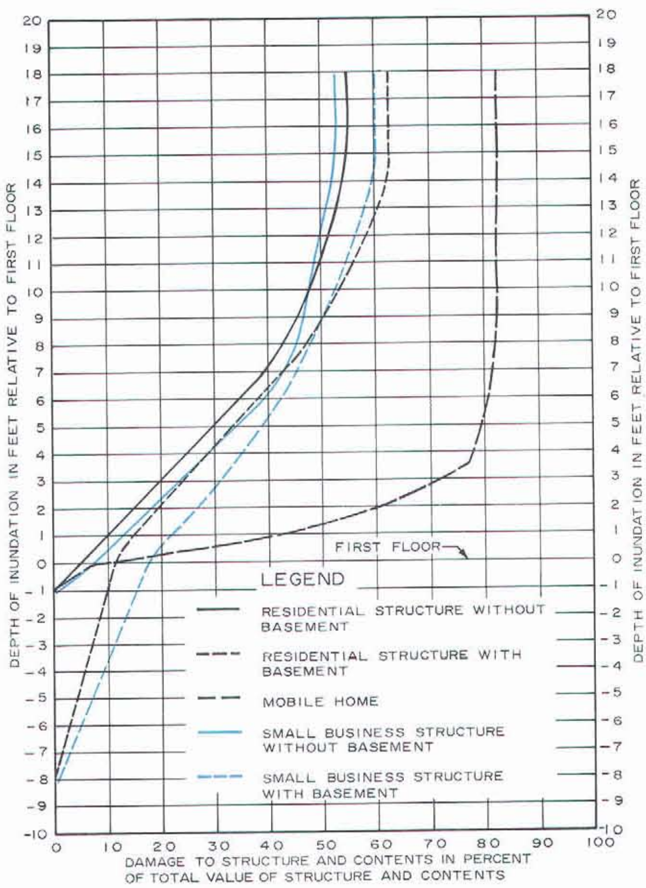
An understanding of the interrelationships that exist between the flood characteristics of the watershed stream system and the uses to which the floodland and nonfloodland areas of the watershed are put is fundamental to any comprehensive watershed study. This understanding is a prerequisite to solving existing flood problems and preventing the occurrence of future flood problems. Flood damage and disruption in the Kinnickinnic River watershed have been largely a consequence of the failure to recognize and account for the relationships which exist between the use of land, both within and outside of the natural floodlands of the watershed, and the flood flow behavior of the stream system of the watershed.

Historic flood information has several key applications during both the plan preparation and plan implementation processes including: 1) identification of problem areas, 2) determination of the causes of flooding, 3) calibration of the hydrologic-hydraulic model, 4) computation of monetary flood risks, 5) formulation of alternative flood control plan elements, and 6) postplan information and education purposes. Synthesized monetary flood risks are utilized during the watershed planning process to conduct cost-benefit analyses of alternative flood control measures such as acquisition and removal of flood-prone structures, structure floodproofing, channel modification and construction of dikes, floodwalls, and flood control reservoirs.

A distinction is drawn between flooding problems, which is the intended concern of this chapter—and one of the major water resource problem areas to be addressed in the watershed planning effort—and storm water inundation problems which are beyond the scope of the Kinnickinnic River watershed planning program. Flood problems are defined, for purposes of this report, as damaging inundation which occurs along well defined

Figure 35

DEPTH-DAMAGE CURVES FOR SELECTED STRUCTURES



Source: Federal Insurance Administration and SEWRPC.

[7] *R. W. Kates, "Industrial Flood Losses: Damage Estimation in the Lehigh Valley," the University of Chicago, Department of Geography, Research Paper No. 98, pp. 15 to 17, 1965.*

rivers and streams as the direct result of water moving out of and away from those rivers and streams, and includes both overland and secondary flooding. In contrast, storm water inundation problems are defined as damaging inundation which occurs when storm water runoff enroute to rivers and streams and other low-lying areas encounters inadequate conveyance or storage facilities and, as a result, causes localized ponding and surcharging of storm and sanitary sewers.

Research of the available historic records indicated the occurrence of seven major floods in the Kinnickinnic River watershed. These major floods, each of which caused significant damage to property as well as disruption of normal social and economic activities in the watershed, were the floods of March 18, 1912; June 22, 1917; January 24, 1938; March 30, 1960; August 3, 1960; September 18, 1972; and April 21, 1973. Information about the cause and effect of each of these floods was derived by a research process consisting of the following sequential steps: initial reconaissance of published reports and data, review of newspaper accounts and newspaper files, examination of library and historical society holdings, contact with community and agency officials and, where warranted, personal interviews with the owners or tenants of riverine area residential, commercial, and industrial structures and property.

Findings of the research into historic flood problems, supplemented by the results of the personal interview survey, and considered in light of completed channel improvements and the decision to resolve the flood problem along the S. 6th Street to S. 16th Street reach of the Kinnickinnic River by bridge removal and replacement and further channel improvement may lead to the erroneous conclusion that flood problems have been or soon will be eliminated in the Kinnickinnic River watershed. It is important to note, however, that the design flood selected for the Kinnickinnic River watershed planning program is the 100-year recurrence interval event as it would occur under year 2000 plan land use and floodland development conditions. A flood of this magnitude has not occurred in the watershed under existing or recent development conditions. Therefore, hydrologic-hydraulic-flood risk analyses were performed to determine if flood problems are likely to occur in the watershed under year 2000 plan land use and floodland development conditions and, if so, to identify flood-prone areas and to quantify the severity of the flood problem.

In addition to the quantitative data derived from the inventory of historic flooding, three observations emerge regarding the characteristics of flooding in the Kinnickinnic River watershed. First, the historic record indicates that flooding has caused physical damage to many different types of structures and facilities in a variety of ways and that the disruption attendant to major floods is experienced by many watershed residents, not just those that actually occupy the floodlands. Second, the inventory of historic flooding indicates that rainfall, as opposed to snowmelt or rainfall-snowmelt combinations, has been the principal cause of major floods. This is particularly significant in the heavily urbanized Kinnickinnic River watershed because it means that, with the exception of the winter season, major floods can occur at any time of the year and, when they do occur, they will be characterized by rapid increases in discharge and stage, thereby offering minimal opportunity for advance warning to occupants of riverine areas. Finally, the risk to human life is illustrated in the historic flood record by several accounts of near drownings, with the threat to human life being more severe in an urban, rather than a rural, watershed.

Flood loss refers to the net effect of historic flooding on the regional economy and well-being with the tangible portions of the loss being expressed in monetary terms. Flood risk is the probable damage, expressed either on a per flood event basis or on an average annual basis, that will be incurred as a result of future flooding with the tangible portion expressed in monetary terms. All flood losses and risks may be classified into one of three categories—direct, indirect, and intangible—or they may be classified by whether the private or public sector incurs the losses or risks.

Average annual flood damage risk expressed in monetary terms was selected as the quantitative, uniform means of expressing flood severity in the Kinnickinnic River watershed. These values were derived from damage-probability curves developed for selected reaches under existing, planned, and other floodland and nonfloodland development conditions.

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Chapter VII

SURFACE WATER QUALITY CHARACTERISTICS AND PROBLEMS

INTRODUCTION

A basic premise of Commission watershed studies is that the activities of man affect, and are affected by, water quality. This is especially true in a highly urbanized area such as the Kinnickinnic River watershed where the effects of human activities on water quality tend to overshadow natural influences. The hydrologic cycle provides the principal linkage between human activities and the quality of surface water and groundwaters in that the cycle transports potential pollutants from man to his environment and from the environment to man.

Water resources planning efforts in general, and the Kinnickinnic River watershed planning program in particular, must include an evaluation of historic, present, and anticipated future water quality conditions and the relationship of those conditions to existing and probable future land and water uses. The purpose of this chapter is to determine the extent to which surface waters in the Kinnickinnic River watershed have been and are polluted and to identify the probable causes for or sources of that pollution. More specifically this chapter discusses the concepts of water quality and pollution; summarizes the adopted water use objectives and supporting water quality standards for the surface water system of the watershed as a benchmark against which historic and recent water quality may be measured; documents current surface water pollution problems in the watershed utilizing field data from a variety of water quality studies, most of which were conducted during the past decade; explores the differences between wet and dry weather water quality phenomena; and indicates the location and type of the numerous and varied sources of wastewaters and other potential pollutants discharged to the surface water system of the watershed, describes the characteristics of the discharges from those sources and, where feasible, quantifies the pollutant contribution of each source. Data and information presented herein provide the basis for development and testing of the alternative water quality control plan elements described in Chapter XII of this report.

The focus of this chapter is surface water quality characteristics and problems. Two related topics addressed in previous Commission comprehensive studies of watersheds are groundwater quality characteristics and problems and water supply from both subsurface and surface sources. The topics of groundwater quality and water supply are treated in this report only to the extent that they provide background information about the watershed or relate to surface water quality problems. This minimal emphasis on groundwater quality and on surface water and groundwater supply is in accordance with the objectives of the Kinnickinnic River watershed planning program which are set forth in Chapter I and, briefly stated, are to: 1) prepare a floodland management plan, 2) prepare a surface water quality management plan, and 3) refine and adjust the regional land use plan to reflect the needs and characteristics of the watershed. These planning program objectives are based on the conclusions set forth in the Kinnickinnic River Watershed Planning Program Prospectus, which identified three water resource-related problems in the watershed; namely, flooding, surface water uses and pollution, and existing and changing land use. The preliminary public hearing conducted on the proposed scope and content of the watershed study[1] as well as the inventory and analysis phases of the Kinnickinnic River watershed planning program did not identify any serious problems in these two water resource-related areas and, therefore, support the conclusion of the Prospectus that groundwater quality and surface water and groundwater supply are not serious problems in the Kinnickinnic River watershed.

The elimination of water supply as a major area of concern in the Kinnickinnic River watershed planning program does not introduce any deficiencies in the systems analysis conducted under the planning program since the water supply-waste water disposal system is largely independent of the watershed hydrologic-hydraulic system. As indicated in Chapter III of this report, almost all of the Kinnickinnic River watershed is served by public water supplies utilizing Lake Michigan as a source. After use, this water is discharged by the user to the sanitary sewerage system through which it is transported back out of the watershed for treatment before being returned to the Lake. Therefore, the water supply and disposal system of the watershed is not an integral part of the hydrologic-hydraulic system of the watershed; the former is essentially physically separate from the latter except to the extent that some of the water supplied from Lake Michigan to the watershed and then discharged to the combined sewer system in the lower portion of the basin is spilled, through combined sewer overflows, to the Kinnickinnic River during rainfall and snowmelt events.

Even if groundwater problems, particularly groundwater quantity problems, do develop in the Kinnickinnic River watershed, it is highly unlikely that the watershed study or an extension of the study would be a sound basis for investigating and resolving those problems. Regardless of whether the groundwater moves in the shallow or deep aquifers, that movement is essentially independent of watershed processes and watershed boundaries—particularly in a basin as small as the Kinnickinnic River watershed—being instead influenced by regional and even extraregional aquifer characteristics, recharge patterns, and groundwater pumpage. Groundwater supply problems beginning to appear in the southeastern Wisconsin area can best be resolved through a comprehensive regional water supply planning program.

[1] *Southeastern Wisconsin Regional Planning Commission Minutes of the Initial Public Hearing on the Kinnickinnic River Watershed Study, March 9, 1977.*

WATER QUALITY AND POLLUTION: BACKGROUND

The term "water quality" refers to the physical, chemical, and biological characteristics of surface water and groundwater. Water quality is determined both by the natural environment and by the activities of man. The uses which can be made of the water resource are significantly affected by its quality, and each potential use requires a certain level of water quality.

Definition of Pollution

Pure water, in a chemical sense, is not known to exist in nature in that foreign substances, originating from the natural environment or the activities of man, will always be present. Water is said to be polluted when those foreign substances are in such a form and concentration so as to render the water unsuitable for any desired beneficial uses such as the following: preservation and enhancement of fish and other aquatic life, water-based recreation, public water supply, industrial water supply and cooling water, and aesthetic enjoyment.

This definition of pollution does not explicitly consider the source of the polluting substance which may significantly affect the meaning and use of the term. For the purpose of this report, the causes of pollution are considered to be exclusively related to human activity and, therefore, the sources are potentially subject to control through alteration of human activity. Examples of potentially polluting discharges to the surface waters that are related to human activities include discharges of treated effluent from municipal and private sewage treatment facilities, discharges of raw sewage from separate and combined sewer overflows and from commercial and industrial establishments, and runoff from urban areas and from agricultural lands. Substances derived from natural sources that are present in such quantities as to adversely affect certain beneficial water uses would not be herein defined as pollution but would constitute a natural condition that impairs the usefulness of the water.

Types of Pollution

As defined above, water pollution is the direct result of human activity in the tributary watershed. Water pollution may be divided into one or more of the following eight types in accordance with the nature of the substance that causes the pollution:

1. Toxic pollution, such as that caused by heavy metals and other inorganic elements or compounds in industrial wastes, domestic sewage, or runoff, some of which may be toxic to humans and other life;

2. Organic pollution, such as that caused by oxygen-demanding organic compounds—carbonaceous and nitrogenous—in domestic sewage and industrial waste, which exerts a high oxygen demand and may severely affect fish life;

3. Nutrient pollution, such as that caused by an overabundance of plant nutrient substances such as nitrogen and phosphorus compounds in urban or agricultural runoff and in domestic sewage; this type of pollution may cause unsightly, excessive plant growths which can deplete oxygen supply in the water through respiratory and decay processes;

4. Pathogenic or disease-carrying pollution, such as that caused by the presence of bacteria and viruses in domestic sewage or in runoff, which may transmit infectious diseases from one person to another;

5. Thermal pollution, such as that caused by heated discharges, which may adversely affect aquatic flora and fauna;

6. Sediment pollution, such as that caused by lack of adequate soil conservation practices in rural areas and inadequate runoff control during construction in urban areas, which results in instream sediment accumulation that has the potential to inhibit life and interfere with navigation;

7. Radiological pollution, such as that caused by the presence of radioactive substances in sewage or cooling water discharges, which may adversely affect human and animal life.

8. Aesthetic pollution, which may be associated with any combination of the other forms of pollution along with floating debris and unsightly accumulations of trash along stream banks and lakeshores.

All of the above eight types of water pollution may occur in surface waters. Groundwater pollution is normally limited to toxic, pathogenic, and radiological pollution. With the exception of thermal and radiological pollution, all of the above types of pollution are known to occur or to have occurred in the Kinnickinnic River watershed as documented in this chapter.

The Relative Nature of Pollution

The determination of whether or not a particular surface water or groundwater resource is polluted is a function of the intended use of the water resource in that the water may be polluted for some uses and not polluted for others. For example, a stream that contains a low dissolved oxygen level would be classified as polluted for the use of sport fishing since the survival and propagation of fish depends upon an ample supply of dissolved oxygen. That same stream, however, would not be considered polluted when its water was used for industrial cooling. Water pollution, therefore, is a relative term, depending on the uses that the water is to satisfy and the quality of the water relative to the minimum requirements established for those uses or needs.

Water Quality Parameters

There are literally hundreds of parameters, or indicators, available for measuring and describing water quality; that is, the physical, chemical, and biological characteristics of water. A list of these parameters would include all of the physical and chemical substances in solution or suspension in water, all of the macroscopic and microscopic organisms in water, and the physical characteristics of the water itself. Only a few of these hundreds of parameters, however, are normally useful in evaluating wastewater quality and natural surface water quality and in indicating pollution. Selected parameters were employed in the Kinnickinnic River watershed planning program to evaluate surface water quality by comparing it to supporting adopted water use standards, which in turn relate to specific water use objectives. These same parameters were also used to describe the quality of point discharges and diffuse source runoff and to determine the effect of those discharges on receiving streams. These parameters are temperature, dissolved solids, suspended solids, specific conductance, turbidity, hydrogen ion concentration, chloride, dissolved oxygen, biochemical oxygen demand, total and fecal coliform bacteria, phosphorus and nitrogen forms, aquatic flora and fauna, heavy metals, pesticides, and polychlorinated biphenyls (PCB's).[2]

Wet and Dry Weather Conditions: An Important Distinction

A distinction is drawn in this chapter between instream water quality during dry weather conditions and during wet weather conditions. A water quality sample is said to represent dry weather conditions if 0.10 inch or less of rainfall was recorded in the 24 hours prior to the time of sampling, assuming that the precise time of sampling is known, or recorded on the day of sampling in those cases where the precise time of sampling is not known. Dry weather instream water quality reflects the quality of groundwater discharge to the stream plus the continuous or intermittent discharge of various point sources; for example, industrial cooling or process waters and leakage and discharge from sanitary or combined sewers. While instream water quality during wet weather conditions includes the above discharges, the dominant influence, particularly during major rainfall or snowmelt runoff events, is likely to be the soluble and insoluble substances carried into the streams by direct storm water runoff. That direct runoff moves from the land surface to the surface waters by overland routes, such as drainage swales and street and highway ditches and gutters, or by the underground storm sewer system and combined sewer system.

Until recently, water quality sampling and monitoring were most often conducted in dry weather, low flow periods such as might be expected in July, August, and September. This practice reflects a period in the development of the state of the art of water quality control when continuous and relatively uniform discharges from point sources—primarily municipal sewage treatment plant and industrial wastewater outfalls—were the major sources of pollution. The impact of these kinds of "point" sources of pollutants on stream water quality was most critical when stream flows were lowest. Accordingly, most of the available water quality monitoring studies for the Kinnickinnic River watershed and, therefore, most of the data presented in this chapter pertain to dry weather, low flow conditions.

In the last decade, significant progress has been made in the control of major point sources of pollution. Consequently, substances carried into the streams by storm water runoff during wet weather conditions are becoming increasingly important in terms of their impacts on water quality. Wet weather conditions are likely to be more critical in terms of adverse water quality conditions than dry weather conditions in the Kinnickinnic River watershed because of the absence of major point sources of pollution. Nevertheless, every effort was made to obtain and report wet weather instream water quality conditions in the Kinnickinnic River watershed in order to present a balanced account of all factors influencing instream water quality.

The frequency of wet weather conditions is defined, for purposes of this chapter, as being equal to the average number of days in a year on which 0.10 inch or more of precipitation occurs. An examination of daily rainfall data for the watershed for the 37-year period from 1940 through 1976 indicates that there are an average of 63 days per year during which 0.10 inch or more of precipitation may be expected. Therefore, wet weather conditions may be expected to occur during about 18 percent of the days in any given year.

WATER USE OBJECTIVES AND SUPPORTING WATER QUALITY STANDARDS

This chapter includes an evaluation, based on field studies, of historic water quality conditions in the Kinnickinnic River watershed. Chapter XIII of this report uses simulation modeling to evaluate existing and hypothetical future water quality conditions in the surface waters of the watershed. Water use objectives and supporting water quality standards are particularly relevant to these two chapters since they provide a scale against which the historic, existing, and probable future water quality of the surface water system of the Kinnickinnic River watershed can be evaluated.

For purposes of the comparative water quality analyses set forth in this chapter and in Chapter XIII, the water quality standards corresponding to the "warmwater fishery and aquatic life, recreational use, and minimum standards" water use objectives established under the

[2] *For a more complete discussion of most of the cited indicators, including their significance in evaluating water quality, see Chapter VII of SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume One, Inventory Findings and Forecasts, October 1976.*

areawide water quality planning program for the Kinnickinnic River system in conformance with the national water quality objectives cited in Public Law 92-500 have been used (see Table 27). The standards are intended to permit use of the surface waters of the Kinnickinnic River watershed for full body contact recreation and to support warm water fish and aquatic life. The water use objectives and supporting water quality standards set forth in Table 27 specify a minimum dissolved oxygen level, a maximum temperature, a fecal coliform count, a total residual chlorine level, an ammonia-nitrogen level, a total phosphorus level; and a pH range. In addition, by explicit and implicit reference to federal and other reports,[3,4] the water use objectives and standards incorporate recommended maximum or minimum levels for other water quality parameters.

While it may not in the final analysis be practicable, or even possible, to achieve the water quality levels required by the federally mandated "fishable-swimmable" water use objectives in the Kinnickinnic River watershed, it was deemed appropriate to use such objectives and corresponding standards as a basis for evaluating the surface water quality in the Kinnickinnic River watershed. The comparative analyses set forth in this and Chapter XIII are intended to provide the information needed to determine if the "fishable-swimmable" water use objectives are achievable and, if not, to recommend establishment of a reasonable lesser set of water use objectives and supporting standards.

Historically, water quality standards were developed for application to specified periods of low flow such as a seven day-10 year low flow conditions in order to determine the effects of point sources. Under this historic approach it was assumed that diffuse sources of pollution had an insignificant effect on water quality conditions and that the worst water quality occurred during periods of low flow. More recent studies, including those conducted by the Commission under its areawide water quality management planning program, however, indicate that the water quality standards may be violated during periods of high flow as well as during periods of low flow, particularly during rainfall events following long periods of dry weather during which a buildup of pollutants takes place on the land surface. This finding requires a new approach to the application of water quality standards, an approach which considers the assessment of the proportion of the total time that water quality conditions can be expected to be in compliance with specified standards. Under this approach, statistical analyses were conducted on the results of the continuous water quality simulation modeling to determine the percent of time a given standard may be expected to be exceeded including during periods of high and moderate flows as well as during periods of low flow. A 95 percent compliance level was selected for those parameters which directly affect aquatic organisms—dissolved oxygen, temperature, ammonia-nitrogen, residual chlorine, and pH. A 90 percent compliance level was selected for those parameters which do not directly affect aquatic organisms, but are primarily related to recreational use—phosphorus and fecal coliforms.

Ideally, a comparative analysis between observed surface water quality and established water quality standards should be done with full knowledge of concurrent hydrologic conditions since the water quality standards are not intended to be satisfied under all streamflow conditions. As noted above, surface water quality should satisfy the standards for specified percentages of time. Unfortunately, available historic water quality data are not sufficient to determine whether such percentages have been met. Therefore, for purposes of comparative analyses the standards were assumed to be applicable to all available water quality samples.

In carrying out the comparative analysis, the water quality at a sampling site was considered substandard for a given parameter if any of the water quality analyses were either above or below specified limits. That is, water quality was assessed on the basis of individual determinations made for each parameter as opposed to using values averaged over a day or period of days.

A precise comparison of observed fecal coliform bacteria concentrations to the specified standards could not be made because of the manner in which the standards are defined. For example, the state-established fecal coliform bacteria standard states that the fecal coliform count shall not exceed a monthly geometric mean of 200 colonies per 100 ml in more than 10 percent of all samples during the month. Inasmuch as the various water quality studies which have been carried out in the watershed did not always include the requisite number of samples taken over a one-month period, the fecal coliform bacteria standard was assumed to be violated during a particular survey at a location if any of the fecal coliform counts obtained at that location exceeded 400 colonies per 100 ml.

Standards have been recommended by the U. S. Environmental Protection Agency (EPA) for heavy metals, polychlorinated biphenyls (PCB's), and pesticides but have not, as yet, been adopted by the federal or state governments. These recommended standards are presented later in this chapter in conjunction with presentation of the limited heavy metals, PCB, and pesticide data available for the Kinnickinnic River watershed.

SURFACE WATER QUALITY STUDIES: PRESENTATION AND INTERPRETATION OF DATA

A variety of data sources, based primarily on field studies and dating back to 1908, are available for use in assessing the historic and existing water quality in the surface waters of the Kinnickinnic River watershed. Each of the

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[3] *U. S. Environmental Protection Agency, Quality Criteria for Water, EPA Report No. 440/9-76-003, Washington, D.C., 1976.*

[4] *National Academy of Sciences, National Academy of Engineering, Water Quality Criteria: 1972, U. S. Environmental Protection Agency, EPA Report No. R3-73-033, Washington, D.C., 1974.*

Table 27

WATER QUALITY STANDARDS CORRESPONDING TO THE "WARMWATER FISHERY AND AQUATIC LIFE, RECREATIONAL USE, AND MINIMUM STANDARDS" OBJECTIVES ADOPTED FOR SOUTHEASTERN WISCONSIN

Parameter	Standard[b]
Dissolved Oxygen	• Shall be greater than or equal to 5.0 milligrams per liter (mg/l)
Temperature	• Shall be less than or equal to 89°F for warmwater fish • No changes that may adversely affect aquatic life • Natural daily and seasonal temperature fluctuations are to be maintained
Fecal Coliform	• Shall not exceed a monthly geometric mean of 200 membrane filter fecal coliform count (MFFCC) per 100 milliliters (ml) based on not less than five samples per month • Shall not exceed a geometric mean of 400 MFFCC per 100 ml in more than 10 percent of all samples during any month • A sanitary survey to assure protection from fecal contamination is the chief criterion in determining suitability for recreation use
pH	• Shall be within the range of 6.0 to 9.0 units • There shall be no change greater than 0.5 unit outside the natural seasonal maximum and minimum
Total Residual Chlorine	• Shall be less than or equal to 0.50 mg/l
Ammonia-Nitrogen	• Shall be less than or equal to 0.4 mg/l in the summer (June, July, and August) and less than or equal to 2.0 mg/l in the fall, winter, and spring
Total Phosphorus	• Shall be less than or equal to 0.1 mg/l
Miscellaneous Parameters and Conditions	• 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 Report No. 440/9-76-003, U. S. Environmental Protection Agency, Washington, D. C., 1976, and Water Quality Criteria-1972, EPA Report No. R3-73-033, 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, of undefined toxicity to fish and other biota shall be resolved in accordance with the methods specified in Water Quality Criteria-1972; Standard Methods for the Examination of Water and Wastewater, 14th Edition, American Public Health Association, New York, 1975; or other methods approved by the Wisconsin Department of Natural Resources • All waters shall meet the following conditions 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

[a] *Perennial and intermittent streams and storm water runoff.*

[b] *Surface water quality is to be such as to satisfy the dissolved oxygen, temperature, pH, total residual chlorine, and ammonia-nitrogen standards 95 percent of the time; fecal coliform and total phosphorus standards 90 percent of the time; and toxic and hazardous substance standards at all times.*

Source: SEWRPC.

sources used in the watershed study is cited and briefly described below in chronological order according to the initiation date of the investigation. Information about each of the water quality studies used in this chapter is set forth in Table 28, and sampling station locations are shown on Map 35. Selected water quality data from these sources are presented below in tabular and graphic form, and conclusions are drawn as to the nature and, to the extent possible, the cause of surface water pollution in the Kinnickinnic River watershed. An understanding of the nature and probable causes of surface water pollution is basic to developing achievable water quality objectives and alternative pollution abatement plan elements.

Some of the data and information presented herein are based on studies conducted up to 70 years ago. These data are presented to demonstrate that some of the types of pollution problems now evident in the watershed are not of recent origin but have existed for many decades. The conclusions drawn on current water quality conditions, however, are based primarily on data obtained over the past decade.

City of Milwaukee Engineer's Reports Concerning the Flushing Tunnel: 1908 and 1954

Construction on the Kinnickinnic River flushing tunnel began in 1898 and was completed in 1907 at a cost of $275,000, including land acquisition, tunnel and building construction, and mechanical and electrical equipment. The tunnel was built to flush pollutants from the Kinnickinnic River estuary. Originally powered by a steam engine, the pumping mechanism, now rated at 264 million gallons per day (410 cfs), was converted to electric power in 1912. A report entitled Kinnickinnic River Flushing Tunnel was prepared for the City Engineer's 1908 Annual Report and describes the operation of the tunnel through 1908. Although the report contains no water quality data, it concludes that the flushing of the Kinnickinnic River as made possible by the tunnel "has thoroughly cleaned the river so that fish will live in it again." The tunnel draws water from Lake Michigan through an intake located inside the harbor breakwater at the foot of E. Russell Avenue in the City of Milwaukee. The location of the tunnel inlet and outlet and the alignment of the tunnel are shown on Map 35.

Water passes through the 12-foot diameter brick tunnel and is discharged to the Kinnickinnic River at the upstream end of the Kinnickinnic River estuary—immediately downstream of the S. Chase Avenue crossing of the Kinnickinnic River. The pumping station is located on the bank of the Kinnickinnic River at the tunnel outlet. The tunnel is operated by the City of Milwaukee Bureau of Engineers, and according to their 1975 Annual Report: "The water added to the river by this pumping operation serves to maintain the dissolved oxygen content of the river water above two parts per million, which is the minimum required to prevent the formation of offensive odors and sustain aquatic plant and fish life." In 1975, the station operated from June through November on a five-day-per-week seven-hour-per-day schedule.

A report entitled Data Pertaining to Milwaukee's Two River Flushing Stations was prepared in 1954 by the City Engineer for the Common Council of the City of Milwaukee and concerns both the flushing tunnel and a similar tunnel located on the Milwaukee River. The report includes a brief description of the Kinnickinnic River flushing tunnel and station, its operation, and the cost of its operation and maintenance from 1949 through 1953, together with statements indicating that J. Greenbaum Tanning Company, under Common Council Resolution No. 40164, was permitted to withdraw water from the flushing tunnel, and that the Milwaukee County Park Commission was permitted to withdraw water from the tunnel to flush a park lagoon once located near S. 27th Street and W. Oklahoma Avenue. Although this report, like the earlier report cited above, does not contain any water quality data, the report does state that operation periods were determined by the dissolved oxygen content of the Kinnickinnic River downstream of the pumping facility, thus implying that the flushing operation was capable of maintaining adequate dissolved oxygen levels in the river.

City of Milwaukee Board of Park Commissioners Study: 1932

In a letter to the Milwaukee Board of Park Commissioners dated October 4, 1932, the Park Engineer set forth his findings with respect to needed improvements in parklands in the Kinnickinnic River watershed including resolution of water pollution problems. Although water quality data are not presented, the letter notes that "the unsanitary conditions along the Kinnickinnic River from the east end of Jackson Park down to the pumping station at S. Chase Avenue have been a terrible nuisance to the locality for many years" and proposes three alternative solutions to the problem: dilution with water from city water supply mains, dilution with well water, and dilution with water pumped upstream from the flushing tunnel outlet. The last alternative was recommended but not implemented.

Wisconsin Department of Natural Resources Basin Surveys: 1952-53 and 1968

As part of a statewide water quality monitoring program, the Wisconsin Department of Natural Resources and its predecessor agencies have conducted two basin surveys that have included the Kinnickinnic River, Wilson Park Creek, and a small tributary entering the river from Jackson Park. The purpose of the surveys was to identify the major point sources of pollution and to determine the effects of these sources on the quality of receiving waterways. The survey findings are documented in the following reports:

- Report of Investigations of Pollution of Surface Waters in Milwaukee County and that portion of the Root River System Draining from Waukesha through Milwaukee County Conducted during 1952 and 1953, Committee on Water Pollution, March 1954. This report included water quality sampling data on the Kinnickinnic River, Wilson

Table 28

SUMMARY OF WATER QUALITY SAMPLING IN THE KINNICKINNIC RIVER WATERSHED: 1952 TO 1977

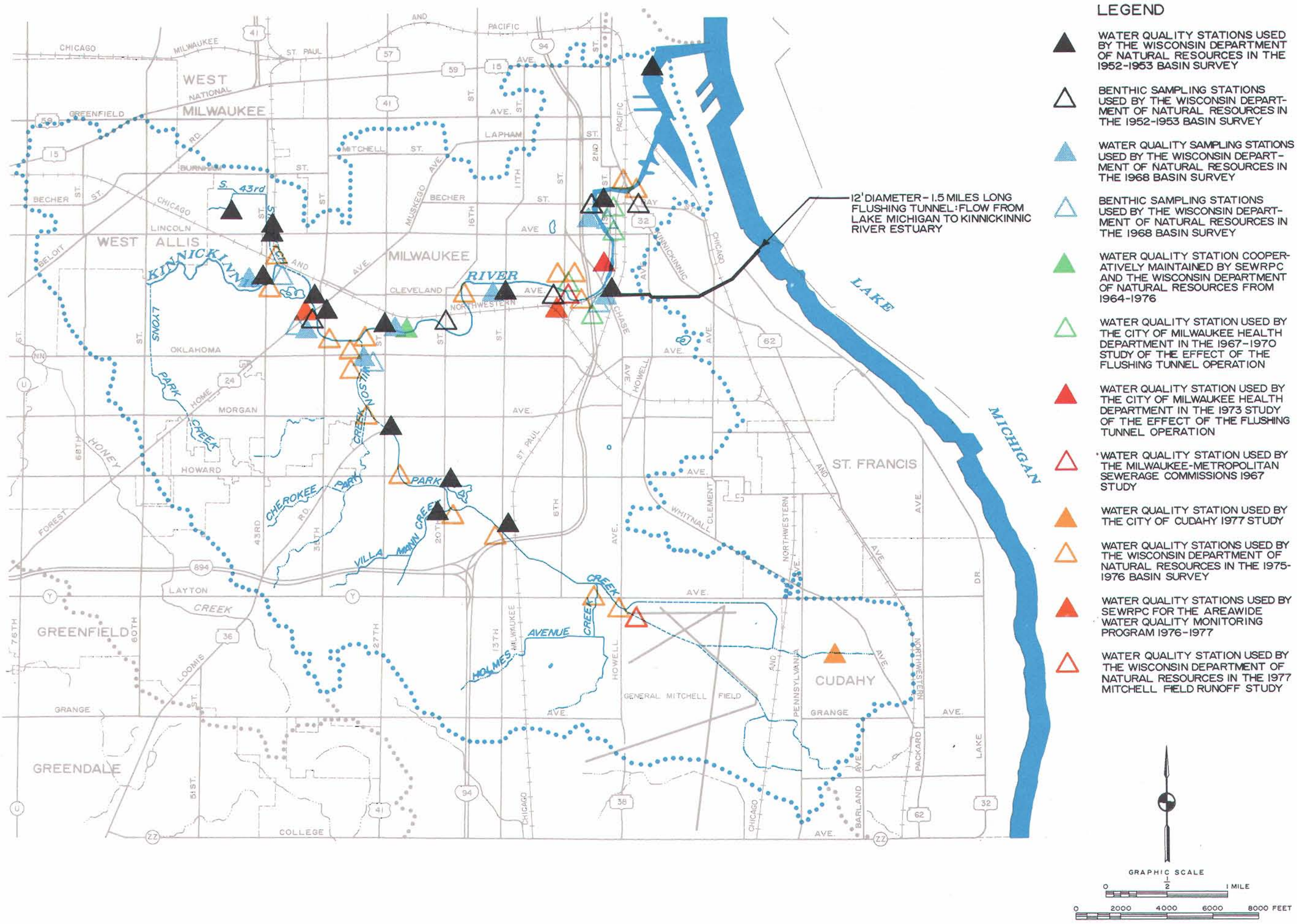
Letter on Map 35	Data Source: Agency Institution	Documentation: Report, Publication, Letter	Date	Objective of Sampling	Streams Sampled	Number of Stations	Sampling Time Period, Frequency	Temperature	Suspended Sediment	Specific Conductance	Biochemical Oxygen Demand	Dissolved Oxygen	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia-Nitrogen	Organic Nitrogen	Total Nitrogen	Dissolved Phosphorus	Soluable Reactive Phosphorus	Total Phosphorus	Phosphate-Phosphorus	Chloride	Total Dissolved Solids	Fecal Coliform	Coliform	pH	Bottom Organisms	Turbidity	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	PCB	DDT	DDE	DDD	Aldrin	Heptachlor	Heptachlor Epoxide	Lindane	Dieldrin	Methoxychlor	Phthalate	Atrazine	Simazine	Remarks
A	Department of Natural Resources	Report of investigation of pollution of surface waters in Milwaukee County and that portion of the Root River system draining from Waukesha through Milwaukee County–conducted during 1952 and 1953.	March 12, 1954	Surveillance	Kinnickinnic River, Main Stem	7	2 to 12 visits; 1 per month, late summer and autumn, 1952-1953	X	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
					43rd Street ditch	4	2 to 3 visits; 1 per month, late summer and autumn, 1953	X	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
					Wilson Park Creek to Kinnickinnic	4	1-2 visits; 1 per month, summer 1953	X	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
B	Department of Natural Resources	Report of investigation of pollution of surface waters in Milwaukee County and that portion of the Root River system draining from Waukesha through Milwaukee County–conducted during 1952 and 1953. (Benthic Sampling Stations)	March 12, 1954	Surveillance	Kinnickinnic River, Main Stem	5	1 visit per station, summer 1953	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
C	Department of Natural Resources	Report on an investigation of the pollution of the Milwaukee River, its tributaries, and Oak Creek–conducted during 1968 and 1969	May 27, 1969	Surveillance	Kinnickinnic River	6	3 visits in 1968, February, August and October	X	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
					Wilson Park Creek	1	3 visits in 1968, February, August and October	X	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
D	Department of Natural Resources	Report on an investigation of the pollution of the Milwaukee River, its tributaries, and Oak Creek–conducted during 1968 and 1969 (Benthic sampling stations)		Surveillance	Kinnickinnic River	4	1 visit per site, February, or March 1968	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
					Wilson Park Creek	1	1 visit, March 1968	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	SEWRPC	Technical Report No. 4, Water Quality and Flow of Streams in Southeastern Wisconsin	November 1966	Assess 1964-1965 conditions and forecast future stream water quality	Kinnickinnic River	1	January 1964, February 1965	X	–	–	–	X	–	–	–	–	–	–	–	–	–	X	X	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
E	SEWRPC, Department of Natural Resources	Transmitted by letter from Department of Natural Resources to SEWRPC	–	Continue monitoring program	Kinnickinnic River	1	October 10, 1966 (Grab)	X	–	X	–	X	X	X	–	–	–	–	–	–	X	X	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			–	Continue monitoring program	Kinnickinnic River	1	April 4, 1967 (Grab)	X	–	X	–	X	X	X	–	–	–	–	–	–	X	X	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			June 25, 1968	Continue monitoring program	Kinnickinnic River	1	April 18, 1968 (Grab)	X	–	X	–	X	X	X	–	–	–	X	–	–	–	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			October 8, 1968	Continue monitoring program	Kinnickinnic River	1	August 14, 1968 (Grab)	X	–	X	–	X	X	X	–	–	–	X	–	–	–	X	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			May 13, 1969	Continue monitoring program	Kinnickinnic River	1	April 1, 1969 (Grab)	X	–	X	–	X	X	X	–	–	–	X	–	–	–	X	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			October 20, 1969	Continue monitoring program	Kinnickinnic Riber	1	August 14, 1969 (Grab)	X	–	X	–	X	X	X	–	–	–	X	–	–	–	X	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			December 14, 1970	Continue monitoring program	Kinnickinnic River	1	August 11 or 12, 1970 (24 hour)	X	–	X	–	X	X	X	–	–	–	X	–	–	–	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
E (cont)	SEWRPC, Department of Natural Resources	Transmitted by letter from Department of Natural Resources to SEWRPC	March 7, 1972	Continue monitoring program	Kinnickinnic River	1	August 8 or 9, 1971 (24 hour)	X	–	X	–	X	X	X	–	–	–	X	–	–	–	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			November 15, 1972	Continue monitoring program	Kinnickinnic River	1	August 14, 1972 (24 hour)	X	–	X	–	X	X	X	X	X	X	X	–	X	–	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			November 28, 1973	Continue monitoring program	Kinnickinnic River	1	August 15, 1973 (24 hour)	X	–	X	–	X	X	X	X	X	X	X	–	X	–	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			December 2, 1974	Continue monitoring program	Kinnickinnic River	1	August 19, 1974 (24 hour)	X	–	X	–	X	X	X	X	X	X	X	–	X	–	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			November 25, 1975	Continue monitoring program	Kinnickinnic River	1	August 25, 1975 (24 hour)	X	–	X	–	X	X	X	X	X	X	X	–	X	–	X	–	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
			February 2, 1977	Continue monitoring program	Kinnickinnic River	1	September 22 and 23, 1976 (24 hour)	X	–	X	–	X	X	X	X	X	X	X	–	X	–	X	–	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
F	Milwaukee Health Department	Report on the operation of the Kinnickinnic River flushing station and its effect on downstream water quality	November 1, 1970	Assess effect of flushing station on downstream water quality	Kinnickinnic River	4	Summers of 1967, 1969, and 1970, 1 to 3 samples per site per week	–	–	–	X	X	–	–	–	–	–	–	–	–	–	X	–	X	X	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
G	Milwaukee Health Department	Report on dissolved oxygen, Kinnickinnic River, September 18 through December 6, 1973	January 11, 1974	Monitor dissolved oxygen levels	Kinnickinnic River	1	Twice per week, September 18 to December 6, 1973	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
H	Milwaukee Metropolitan Sewerage Commission	Transmitted by letter from the Milwaukee-Metropolitan Sewerage Commission to SEWRPC.	November 10, 1975	Surveillance	Kinnickinnic River	1	June 30 to September 4, 1967 (28 days total)	X	–	–	X	X	–	–	–	–	–	–	–	–	–	X	–	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
I	Cudahy Health Department	Transmitted by letter from Cudahy Health Department to SEWRPC	July 29, 1977	Bacterial study	Edgerton Channel	1	Two samples; July 6 and 20, 1977	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
J	Department of Natural Resources	Wisconsin Department of Natural Resources drainage basin study program	To be published in 1978	Surveillance	Kinnickinnic River, Main Stem	3	October 22, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	
						2	May 27, 1975 through April 12, 1976	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	
						1	May 27, 1975 through April 14, 1976	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	
						2	May 27, 1975 through December 8, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	–	–	
						1	May 27, 1975 through December 8, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	X	–	–	–	
						1	February 10, 1976	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	
						1	February 10, 1976	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	
					Wilson Park Creek	1	May 27, 1975 through April 12, 1976	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	
						3	October 23, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	
						1	May 27, 1975 through April 12, 1976	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	
						1	May 27, 1975 through December 8, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	–	–	
						1	May 27, 1975 through December 8, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	X	–	–	–	
						1	February 16, 1976	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	
					S. 43rd Street Ditch	1	October 22, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	
						1	February 10, 1976	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	
					Holmes Avenue Creek	1	October 23, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	
					Villa Mann Creek	1	October 23, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	
					Cherokee Park Creek	1	October 23, 1975	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	
K	SEWRPC, Department of Natural Resources and U.S. Geological Survey	Data obtained under the areawide water quality management planning program	1976	Water quality model calibration	Kinnickinnic River, Main Stem	2	September 7, to October 5, 1976	X	–	X	X	X	X	X	X	X	X	–	X	X	X	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	For one sampling station, SEWRPC conducted one biological sampling each of zooplankton, phytoplankton, and periphyton during this time period
						1	February 10, 1977	–	X	X	X	X	X	X	X	X	X	–	–	X	X	X	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
L	Department of Natural Resources	Storm water quality data - General Mitchell Field Airport–obtained from Department of Natural Resources		Surveillance	Wilson Park Creek	1	July, August 1977 (6 events)	–	X	–	–	–	–	–	–	–	X	–	–	X	–	X	–	–	–	–	–	–	X	X	X	X	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	

Source: SEWRPC, Wisconsin Department of Natural Resources, Milwaukee-Metropolitan Sewerage Commissions, City of Milwaukee Health Department, City of Cudahy Health Department, City of Milwaukee Bureau of Engineers, and U.S. Geological Survey.

Source: SEWRPC.

Map 35

LOCATION OF STREAM WATER QUALITY SAMPLING STATIONS IN THE KINNICKINNIC RIVER WATERSHED: 1952-1977



A variety of data sources are available for use in assessing the historic and existing water quality in the Kinnickinnic River and its tributaries and for identifying the cause of surface water pollution. These data are derived from long-term monitoring studies such as the cooperative effort carried out since 1964 by SEWRPC and the Wisconsin Department of Natural Resources and from special-purpose studies such as those carried out in 1967 and 1970 by the City of Milwaukee Health Department for the purpose of assessing the water quality impact of the flushing tunnel.

Source: SEWRPC.

Park Creek, and the Jackson Park tributary accumulated during the summer and fall of 1952 and 1953. These water quality data were supplemented with benthic animal samples taken along the Kinnickinnic River in 1953.

- Report on an Investigation of the Pollution of the Milwaukee River, Its Tributaries, and Oak Creek Made during 1968-1969, Wisconsin Department of Natural Resources, May 1969. As shown in Table 29, water quality sampling during this survey was conducted on three days—one wet weather day and two dry weather days—at six locations on the Kinnickinnic River and one on Wilson Park Creek in 1968. Benthic organism samples were also taken, as indicated in Table 30, at four locations along the Kinnickinnic River and one on Wilson Park Creek in 1968.

Findings of the 1952-53 Survey: Satisfactory dissolved oxygen levels were reported for Wilson Park Creek and the Kinnickinnic River with the exception of the estuary portion of the river downstream of S. Chase Avenue. Low dissolved oxygen levels in the estuary were attributed to deposition and accumulation of oxygen-demanding organic solids. Undesirably high coliform bacteria levels were reported along Wilson Park Creek and the Kinnickinnic River and were attributed to the probable discharge of sanitary sewage into the surface waters from sewer overflows.

Table 29

WATER QUALITY DATA (DRY AND WET WEATHER) FROM THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES BASIN SURVEY: 1968

Sampling Station				Water Quality Indicators					Concurrent and Antecedent Moisture Conditions as Indicated by Mitchell Field Precipitation Observations		Characterization of Sampling Conditions	
									Daily Precipitation in Inches			
Stream	Location	River Mile	Date[a]	Temperature (°F)	pH (standard units)	Dissolved Oxygen (mg/l)	Biochemical Oxygen Demand (mg/l)	Total Coliform Count (MFCC per 100 ml)	On Day 1 and 1	Before Day 2 Sampling 2	Dry Weather[b]	Wet Weather
Kinnickinnic River	S. 43rd Street	6.51	February 29	32.0	7.8	13.4	1.2	100	0.00	0.01	X	--
			August 8	63.5	7.7	8.4	1.0	10	0.71	0.02	---	X
			October 31	47.3	7.7	10.8	1.0	10	0.00	0.00	X	--
	W. Forest Home Avenue	5.71	February 29	42.8	7.6	10.5	2.2	3,500	0.00	0.00	X	--
			August 8	74.3	7.6	6.5	10.0	40,000	0.71	0.02	--	X
			October 31	60.8	7.2	6.1	2.5	28,000	0.00	0.00	X	--
	S. 27th Street	4.91	February 29	39.2	7.4	11.0	9.8	5,000	0.00	0.01	X	--
			August 8	74.3	7.8	9.5	2.1	50,000	0.71	0.02	--	X
			October 31	59.0	7.4	7.4	2.1	50,000	0.00	0.00	X	--
	S. 13th Street	3.32	February 29	37.4	8.4	12.2	24.0	3,600	0.00	0.01	X	--
			August 8	74.3	8.4	10.8	1.5	37.000	0.71	0.02	--	X
			October 31	59.0	7.8	9.3	1.8	30,000	0.00	0.00	X	--
	S. Chase Avenue	2.40	February 29	35.6	7.4	12.8	4.9	80,000	0.00	0.01	X	--
			August 8	66.2	7.8	8.2	3.4	120,000	0.71	0.02	--	X
			October 31	53.6	6.8	7.5	2.5	100,000	0.00	0.00	X	--
	W. Becher Street	1.67	March 5	37.4	7.6	8.0	7.4	47,000	0.05	0.00	X	--
			August 8	59.9	8.0	11.0	4.9	26,000	0.71	0.02	--	X
			October 31	50.0	7.2	1.3	4.0	24,000	0.00	0.00	X	--
Wilson Park Creek	W. Oklahoma Avenue Bridge	0.05	February 29	32.0	7.6	9.5	18.0	21,000	0.00	0.01	X	--
			August 8	73.4	7.9	6.8	1.2	90,000	0.71	0.02	--	X
			October 31	46.4	7.7	6.9	14.0	120,000	0.00	0.00	X	--

NOTE: Water quality standards are established for temperature, pH, and dissolved oxygen. These standards were not violated with the exception of substandard dissolved oxygen in the estuary on October 31. A total coliform standard does not exist. However, high total coliform counts suggest that the applicable fecal coliform standard was exceeded in many of the samples.

[a] *Sampling time not available.*

[b] *Precipitation of 0.10 inch or less on day of sampling.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Sampling of benthic fauna at locations along the Kinnickinnic River indicated the presence of a pollution-tolerant bottom community.[5] In addition, oil accumulations were noted as were dense growths of green algae. The density of pollution-tolerant bottom fauna was greatest in the estuary area. For example, in the vicinity of Becher Street, the density of sludge worms was estimated to be about one pound per square foot of estuary bottom and the corresponding calculated weight of the living sludge worm population in this portion of the estuary was estimated to be 50,000 pounds per acre.

[5]*An investigation of the bottom community, which includes a qualitative and quantitative examination of the types of organisms represented and their population density in a river, stream, lake, or impoundment, provides a good indication of the prevailing level of water quality. Unlike the relatively rapidly changing physical, chemical, and biological characteristics of the overlying flowing stream, the bottom community responds to and reflects the long-term condition of the aquatic environment. More specifically, the characteristics of the bottom community directly and indirectly reflect the chemical and physical properties within the aquatic environment, the extent and degree of pollution, the degree of self-purification, and the water use potential. Surface waters subjected to excessive loads of oxygen-demanding substances and nutrients are usually characterized by large populations of relatively few pollutant-tolerant species.*

Findings of the 1968 Survey: Table 29 indicates that satisfactory dissolved oxygen levels—6.1 milligrams per liter (mg/l) or higher—were found to occur on all three sampling days at the Wilson Park Creek sampling station and the six Kinnickinnic River stations with the exception of the concentration of about 1 mg/l noted at the Becher Street crossing of the estuary portion of the river during a dry weather day in October. High total coliform counts—in excess of 3,500 colonies per 100 ml—were observed on all three sampling days at all seven sampling stations on the Kinnickinnic River and Wilson Park Creek with the exception of the S. 43rd Street crossing of the Kinnickinnic River, where total coliform counts did not exceed 100 colonies per 100 ml. Although a total coliform standard does not exist, the high total coliform counts suggest that the applicable fecal coliform standard of 400 colonies per 100 ml was probably exceeded in many samples. Table 29 indicates that the temperature and pH standards presented in Table 27 were satisfied on all three sampling days at all three stations.

Benthic organisms collected at the four biological sampling stations along the main stem of the Kinnickinnic River between W. Becher Street in the estuary and S. 43rd Street contained large populations of a single species classified as very tolerant to organic water pollution (see Table 30). No species were found representing either the tolerant or intolerant categories at these four sites. However, bottom samples taken from the sampling site located on Wilson Park Creek included a single

Table 30

BENTHIC ORGANISM DATA FROM THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES BASIN SURVEY: 1968

Sampling Station: Stream	Sampling Station: Location	River Mile	Date	Waste Source	Bottom Type	Current	Benthic Invertebrate Organisms: Intolerant: Number of Species	Intolerant: Total Population	Tolerant: Number of Species	Tolerant: Total Population	Very Tolerant: Number of Species	Very Tolerant: Total Population	Remarks
Kinnickinnic River	S. 43rd Street (100 yards downstream)	6.51	February 29	Storm Sewer	Clay and Gravel	Riffle	–	–	–	–	1	759	Poor sampling site, extensive silt from upstream dredging
	W. Forest Home Avenue	5.71	February 29	Storm Sewer	Concrete and Sand	Moderate to Fast	–	–	–	–	1	1,157	River bottom concrete from this point to Chase Avenue
	S. Chase Avenue	2.40	February 29	Combined Sewer	Sand and Gravel	Sluggish	–	–	–	–	1	6,578	Sample below lift station. Oil slicks on water surface
	W. Becher Street	1.67	March 5	Combined Sewer	Sand and Silt	Stagnant	–	–	–	–	1	3,400	Oil slicks on water surface, gas bubbles. Copious amounts of organic debris on bottom
Wilson Park Creek	W. Oklahoma Avenue Bridge	0.05	March 5	Runoff and Storm Sewer	Rock, Sand, and Silt	Sluggish	–	–	1	1	3	197	Poor sampling site, rocky bottom. Organic debris on bottom

Source: Wisconsin Department of Natural Resources.

species of tolerant form and three species of very tolerant form, with a lower total population than found along the Kinnickinnic River. The greater diversity exhibited in the Wilson Park Creek tributary suggests somewhat better water quality conditions than in the main stem of the Kinnickinnic River. Both of these water courses, however, maintain benthic communities indicative of polluted conditions.

SEWRPC Water Quality Study: 1964-1965

During the 14-month period extending from January 1964 through February 1965, the Commission conducted an extensive stream water quality sampling program during which almost 4,000 water samples were collected at 87 sampling stations established on 43 streams in the Region. Under this program, samples were taken at one location in the Kinnickinnic River watershed—the Kinnickinnic River at S. 29th Street. Stream water samples taken under dry weather conditions on a monthly basis at this station over a period of 11 months—from April 1964 through February 1965—were analyzed for seven chemical, physical, and biological water quality indicators for the purpose of assessing the then-existing condition of stream water quality in relation to pollution sources, land use, and population distribution and concentration. The study procedures and results are described in SEWRPC Technical Report No. 4, Water Quality and Flow of Streams in Southeastern Wisconsin: 1966. Sampling was repeated in the Kinnickinnic River watershed in October 1966 and April 1967 prior to initiation of the SEWRPC continuing water quality monitoring program in 1968. Data for the March 1965 through 1967 period are included with a subsequent discussion of the SEWRPC continuing water quality monitoring program.

Findings of the Study: Table 31 presents a synopsis of dry weather water quality conditions in the Kinnickinnic River at S. 29th Street as determined by the 1964-1965 sampling. Survey results for dissolved oxygen, temperature, total coliform bacteria, pH, specific conductance, and chloride as set forth in Table 31 are discussed below.

Dissolved Oxygen: All 11 measured dissolved oxygen levels at the sampling station were well above the established minimum dissolved oxygen standard of 5.0 mg/l. With all of the combined sewer overflow points being located downstream of the sample site, dissolved oxygen levels in reaches receiving combined sewer overflows during wet weather periods would likely exhibit a considerable reduction during those periods compared to levels at the sampling site, possibly violating the established water quality standard for dissolved oxygen.

Temperature: Temperature variations at the sampling station reflect expected seasonal changes ranging from a low of 32°F in February 1965 to a high of 82°F in July 1964. The temperature standard was not exceeded; however, the discharge of cooling waters into the storm sewer systems tributary to the main stem of the Kinnickinnic River upstream of the sampling station may have contributed to the temperature variations, particularly during low flow conditions.

Total Coliform Bacteria: Between 1964 and 1965, the membrane filter total coliform count ranged from 4,000 to 340,000 MFCC/100 ml with an average value of 77,000 MFCC/100 ml. The highest total coliform counts, 230,000 MFCC/100 ml and 340,000 MFCC/100 ml, occurred during the months of May and September 1964 respectively. Although all sampling was done on dry weather days, these counts may reflect the residual effect of spring runoff and the runoff which occurred in September as a result of a rain which fell during the week prior to the sample collection. The correlation between these runoff periods and the high total coliform counts points to sources such as storm water runoff and a discharge of raw sewage from the sanitary sewer flow relief devices located upstream from the sampling station. During wet weather conditions, total coliform counts will likely increase downstream from the sampling station where the stream passes through the combined sewer overflow area. Although a total coliform standard does not exist, very high total coliform counts—4,000 MFCC/100 ml and more—suggest that the

Table 31

WATER QUALITY (DRY WEATHER) FOR THE KINNICKINNIC RIVER AT S. 29th STREET: 1964-1965

Parameter	Units	Sampling Dates											Maximum	Average	Minimum	Number of Analyses	Comparison to Standards			Remarks
		1964									1965						Water Quality Standard	Analyses Not Meeting Water Quality Standards		
		April 9	May 15	June 18	July 16	August 6	September 23	October 21	November 4	December 10	January 7	February 3						Number	Percent of All Analyses	
		0.00[a]	0.00	0.10	0.00	0.00	0.02	0.00	0.00	0.09	0.01	0.00								
Dissolved Oxygen	mg/l	11.8	9.3	7.3[b]	11.6	10.4	8.3	12.9	9.8	13.3[c]	10.3	11.6	13.3	10.6	7.3	11	5.0 (minimum)	0	0	–
Temperature	°F	41.0	59.0	68.0	82.0[c]	77.0	64.0	69.0	54.0	37.0	42.0	32.0[b]	82.0	57.0	32.0	11	89 (maximum)	0	0	–
Total Coliform	MFCC/100 ml	75,000	230,000	49,000	10,000	8,000	340,000[c]	21,000	80,000	12,000	19,000	4,000[b]	340,000	77,000	4,000	11	N/A	–	–	A total coliform standard does not exist. However, very high total coliform counts suggest that the applicable fecal coliform standard was exceeded in almost all samples
pH	Standard Units	8.0[c]	–	–	–	–	7.3[b]	–	–	–	–	–	8.0	7.7	7.3	2	6.0 to 9.0	0	0	–
Specific Conductance	micro-mhos per cm at 77°F	1,040[c]	–	–	–	–	426[b]	–	–	–	–	–	1,040	733	426	2	N/A	–	–	–
Chloride	mg/l	115[c]	–	–	–	–	20.0[b]	–	–	–	–	–	115	65.0	20.0	2	N/A	–	–	–

Note: NA indicates not applicable.

[a] *Precipitation in inches on day of sampling as recorded at Mitchell Field National Weather Service Station.*

[b] *Day on which minimum value of parameter occurred.*

[c] *Day on which maximum value of parameter occurred.*

Source: SEWRPC and Wisconsin Department of Natural Resources.

applicable fecal coliform standard—400 MFFCC/100 ml—was probably exceeded in many samples collected during the 1964-1965 period.

Hydrogen Ion Concentration (pH): Two pH values were obtained at the Kinnickinnic River sampling station—one in April 1964 and one in September 1964. These two values were within the range of 6.0 to 9.0 standard units prescribed for streams intended to support limited recreational use and a marginal fish and aquatic life community.

Specific Conductance and Chloride: The specific conductance at the Kinnickinnic River sampling station was also analyzed in April and September of 1964, yielding values of 1,040 and 426 micro-mhos per centimeter at 77°F, respectively. The highest specific conductance value was obtained during the month of April at the time of the highest chloride concentration. Specific conductance is an index of the dissolved ions present in water, and the high specific conductance value during the spring months may indicate the residual effect of street salting.

Finally, chlorides were analyzed from two samples, again taken in April and September 1964, at the single sampling station. The chloride concentration of 115 mg/l, obtained in the April dry weather sampling, was high when compared to expected dry weather concentrations. A significant decrease in the chloride concentration to 20 mg/l was noted in the September sample. The high chloride level in the Kinnickinnic River during April is probably due to the street salting operations conducted during the winter. The residual chemicals are flushed from the streets and highways by snowmelt and spring rains and carried to the surface waters either directly by surface runoff during wet weather conditions or indirectly by groundwater discharge during dry weather conditions. The low chloride level in September reflects the background chloride concentration expected during low flow conditions after the bulk of the chemicals applied to the streets during the winter period has been flushed from the groundwater system.

Concluding Statement: The 1964-1965 dry weather survey indicated water quality satisfying the dissolved oxygen, temperature, and pH standards presently established for the surface waters in the Kinnickinnic River watershed whereas the fecal coliform bacteria standard was probably often violated. High spring dry weather chloride levels are probably attributable to the residual effects of street salting for deicing purposes.

SEWRPC Continuing Water Quality Monitoring Program: 1968-1976

In 1968 the Commission entered into a cooperative agreement with the Wisconsin Department of Natural Resources for the execution of a continuing stream water quality monitoring program within the Region. The objective of the program was to provide, on a continuing basis, the water quality information necessary to assess the long-term trends in water quality within the rapidly urbanizing seven-county Region.

The continuing monitoring program was designed to build upon the benchmark stream water quality data base established by the Commission in the initial 1964-1965 SEWRPC stream water quality study and, accordingly the monitoring network included the single Kinnickinnic River watershed sampling station. During 1968 and 1969, the SEWRPC stream water quality monitoring program involved twice-yearly sampling at all stations during the periods of high and low flow, with the samples being analyzed for dissolved oxygen, temperature, fecal and total coliform, nitrate-nitrogen, nitrite-nitrogen, dissolved phosphorus, pH, chloride, and specific conductance.

To provide additional information on the diurnal fluctuations of stream water quality, the monitoring program was revised in 1970 to provide for the collection of six stream water samples over a 24-hour period once yearly during the period of low streamflow at each sampling station, with each sample being analyzed for the following five parameters: dissolved oxygen, temperature, pH, chloride, and specific conductance. In addition, once during the 24-hour period the following four parameters would be analyzed: fecal coliform, nitrate-nitrogen, nitrite-nitrogen, and dissolved phosphorus.

In order to obtain regional information on additional water quality indicators, the Commission and the Department of Natural Resources agreed to a further revision of the program beginning with the 1972 survey. The overall continuity of the sampling program was maintained by continuing to monitor those parameters included in previous surveys with the following changes: a decrease from six to four per day in the frequency of dissolved oxygen, temperature, and specific conductance measurements; a decrease from six to two per day in the frequency of chloride determinations; an increase from one to two per day in the frequency of fecal coliform, nitrate-nitrogen, nitrite-nitrogen, and dissolved phosphorus measurements; and the addition of two determinations per day of organic-nitrogen, ammonia-nitrogen, and total phosphorus. The addition of these latter three parameters was prompted by the need for more regional information on nutrients and increased interest in both oxygen demand exerted by ammonia-nitrogen and the toxic effect of ammonia-nitrogen.

Thus, the stream water quality monitoring program, as revised in 1972 and as continued through 1976, provided for four measurements over a 24-hour period once yearly. Four measurements were made during the period of low flow at each of the 87 stations for each of the following three parameters: dissolved oxygen, temperature, and specific conductance. Two determinations were made at each station over the same 24-hour period for each of the following nine parameters: pH, chloride, fecal coliform, nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, organic-nitrogen, dissolved phosphorus, and total phosphorus.

Findings of the Study: Data resulting from October 1966 sampling and the 1968-1976 sampling program at the Kinnickinnic River station at S. 29th Street are set forth in Table 32. These data, all of which were collected under dry weather conditions during August, September, or October, were analyzed under the planning program and are discussed below.

Dissolved Oxygen: Only three, or 9 percent, of 35 measured dissolved oxygen levels at the sampling station were below the established 5.0 mg/l minimum standard. With all 23 combined sewer overflows being located downstream of the sample site, dissolved oxygen levels in reaches receiving combined sewer overflows during wet weather periods would likely exhibit a considerable reduction compared to those at the sampling site, possibly violating the dissolved oxygen standard.

Temperature: Temperature variations at the sampling station reflect expected monthly changes ranging from a low of 54°F in October 1966 to a high of 86°F in August 1969. The temperature standard of 89°F was not exceeded. The discharge of cooling waters into the storm sewer systems tributary to the main stem of the Kinnickinnic River upstream of the sampling station may have contributed to temperature variations.

Fecal Coliform Bacteria: During the 1966 through 1976 period, the membrane filter fecal coliform count (MFFCC) ranged from 30 to 72,000 MFFCC/100 ml, with an average value of 7,000 MFFCC/100 ml. Of the total of 14 fecal coliform analyses, 11 exceeded the applicable fecal coliform standard of 400 MFFCC/100 ml. Under wet weather conditions, total coliform counts may be expected to increase downstream from the sampling station where the Kinnickinnic River passes through the combined sewer overflow area.

Hydrogen Ion Concentration (pH): All but one of the 27 pH values were within the range of 6.0 to 9.0 standard units prescribed to support limited recreational use and a marginal fish and aquatic life community.

Specific Conductance and Chloride: The 35 specific conductance observations averaged 787 micro-mhos per centimeter. A maximum level of 2,271 micro-mhos per centimeter occurred on September 22, 1976. This peak specific conductance measurement coincided with a peak chloride concentration of 598 ml/l and may be the result of an accidental spill or intentional discharge of a chloride compound.

During the 1966-1976 period, 27 chloride analyses were performed on samples taken during the months of August, September, and October. Chloride concentrations ranged from 31 to 598 mg/l and averaged 77 mg/l. As noted above, the peak chloride concentration of 598 mg/l occurred on September 22, 1976 and appears to be the cause of the coincident peak specific conductance observation. Excluding the extremely high September 22, 1976 chloride observation, the average summer dry weather chloride concentration for the Kinnickinnic River at S. 29th Street is 57 mg/l. Chloride levels in the Kinnickinnic River watershed appear to be higher than those found in more rural watersheds of southeastern Wisconsin. This may reflect a combination of factors such as the long-term residual affect of winter street salting operations and accidental spills or industrial discharges of chloride compounds.

Phosphorus Compounds: Orthophosphate ranged from 0.011 to 0.253 mg/l as phosphorus and averaged 0.10 mg/l as phosphorus. Total phosphorus concentrations ranged from 0.010 to 0.340 mg/l as phosphorus and averaged 0.12 mg/l as phosphorus. The average ratio of soluble orthophosphate to a total phosphorus was 0.56. Five of the 11 total phosphorus analyses exceeded the standard of 0.10 mg/l.

Nitrogen Compounds: Ammonia-nitrogen concentrations varied widely from a minimum of about 0.03 to a maximum of about 0.630 mg/l as nitrogen with an average value of 0.25 mg/l as nitrogen. Only one, or 10 percent of the ammonia-nitrogen values, exceeded the summer standard of 0.4 mg/l. Nitrite-nitrogen, nitrate-nitrogen, and organic-nitrogen averaged, respectively, 0.05, 0.35, and 0.58 mg/l. Total nitrogen concentrations ranged from 0.37 to 2.04 mg/l with an average of 1.26 mg/l.

Concluding Statement: The October 1966 sampling and the 1968 through 1976 August and September dry weather surveys indicated water quality satisfying the temperature standard all of the time and the dissolved oxygen and ammonia-nitrogen standards 90 percent or more of the time. The fecal coliform bacteria standard was violated about 80 percent of the time and the total phosphorus standard was violated about one-half of the time.

Milwaukee-Metropolitan Sewerage Commissions Survey: 1967

Estuary water quality data collected by the Milwaukee-Metropolitan Sewerage Commissions are available for the late spring and summer periods of 1965 through 1969. In addition, the Sewerage Commissions sampled the Kinnickinnic River at S. 6th Street, which is above the influence of the estuary, during the summer of 1967. Water quality parameters analyzed the 1965 through 1969 survey and the 1967 survey include temperature, dissolved oxygen, biochemical oxygen demand, fecal coliform, pH, chloride, and turbidity. Concurrent discharge measurements for the Kinnickinnic River are not available.

Data for the S. 6th Street stations, which are presented in Table 33, were analyzed since they reveal some of the summer characteristics of the Kinnickinnic River under both wet and dry weather conditions. Sewerage Commissions estuary data were not analyzed under the watershed study since estuary water quality phenomena were considered to be adequately represented by a special sampling program conducted by the City of Milwaukee Health Department and described in a subsequent section of this chapter.

Findings of the Study: As indicated in Table 33, water quality samples were taken from the Kinnickinnic River at S. 6th Street on 28 days in July, August, and early September of 1967. All of these were dry weather samples with the exception of that taken on July 26, on which 0.43 inch of precipitation was recorded.

Temperature and dissolved oxygen standards were satisfied in all analyses conducted during this study. The fecal coliform standard of 400 MFFCC/100 ml was exceeded in 12, or 43 percent, of the 28 samples, and the specified pH range of 6.0 to 9.0 standard units was not met in three of the 28 analyses. Chloride concentrations averaged 60 mg/l but reached an extreme high of 405 mg/l on July 5.

Some indication of the effect of wet weather conditions on instream water quality is obtained by contrasting water quality conditions on July 26—the one wet weather day in this study—with water quality conditions on other days. As indicated in Table 33, on that day dissolved oxygen levels dropped to 6.7 mg/l—well below the 11.5 mg/l average—while biochemical oxygen demand rose to a relatively high 28.0 mg/l, well above the 8.4 mg/l average. These fluctuations probably reflect the washoff of oxygen-demanding organic material into the surface waters as a result of the wet weather conditions. In addition, on the wet weather day turbidity rose to a value of 300 standard units—the maximum value recorded—and was 250 units above the aveage of 50 units.

Concluding Statement: The 1967 summer survey of Kinnickinnic River water quality at S. 6th Street indicated water quality satisfying the temperature and dissolved oxygen standards. About 10 percent of the samples failed to meet the pH standards while about 60 percent of the samples contained excessive fecal coliform counts. The one wet weather day in the records suggests that wet weather conditions tend to significantly depress dissolved oxygen concentrations of the surface waters while markedly increasing biochemical oxygen demand and turbidity.

City of Milwaukee Health Department Reports Concerning the Flushing Tunnel: 1970 and 1974

A report entitled Report on Operation of the Kinnickinnic River Flushing Station and Its Affect on Downstream Water Quality was prepared by the City of Milwaukee Health Department and submitted to the Common Council of the City on November 1, 1970. The report includes an analysis of the quality of water discharged from the flushing tunnel outlet—which is located immediately east of S. Chase Avenue; water quality conditions in the Kinnickinnic River upstream of the flushing tunnel at S. 6th Street; and water quality conditions downstream of the flushing tunnel at the W. Lincoln Avenue and W. Becher Street crossings of the Kinnickinnic River estuary. Sampling was carried out during the summers of 1967, 1969, and 1970, and the following water quality parameters were measured: temperature, dissolved oxygen, biochemical oxygen demand, chloride, total and fecal coliform bacteria, pH, and turbidity.

In addition to the above report, a letter dated January 11, 1974 from the City of Milwaukee Health Department to the City Engineer of the City of Milwaukee transmits dissolved oxygen data for the Kinnickinnic River at S. First Street bridge, just downstream from the flushing station. The dissolved oxygen values were taken at one- to seven-day intervals for the period September through December 1973.

Findings of the Study: The report on the flushing station provided an opportunity to compare Kinnickinnic River water quality in the estuary downstream of the flushing tunnel with that in the Kinnickinnic River upstream of the flushing tunnel. Furthermore, because the tunnel was not in operation during the 1969 sampling period, the water quality investigations provided an opportunity to evaluate the effectiveness of the tunnel in enhancing estuary water quality.

Table 32

WATER QUALITY (DRY WEATHER) FOR THE KINNICKINNIC RIVER AT S. 29TH STREET: AUGUST, SEPTEMBER, AND OCTOBER, 1966-1976

Sampling Dates and Military Times (1966–1971)

Parameter	Units	1966	1968	1969	1970						1971					
		October 10	August 14	August 14	August 11				August 12		August 8	August 9				
		09:25	10:50	11:40	01:40	04:50	08:35	10:30	04:20	12:45	23:55	03:55	08:15	11:50	15:55	19:45
		0.00[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dissolved Oxygen	mg/l	10.30	10.70	10.20	14.10	12.00	5.80	12.70	6.30	6.00	5.30	5.00	8.70	11.70	9.20	4.50[b]
Temperature	°F	54.00	70.00	86.00	82.00	82.50	78.00	77.00	71.50	76.00	71.50	71.00	72.50	78.50	82.50	78.50
Fecal Coliform	MFFCC/100 ml	–	900[b]	600[b]	–	–	–	200	–	–	1,500[b]	–	–	–	–	–
pH	Standard Units	7.40	8.00	8.00	8.80	8.60	7.90	8.50	5.80[b]	8.00	7.70	7.70	7.90	8.30	7.70	7.30
Specific Conductance	micro-mhos per cm at 77°F	715	722	600	650	670	640	700	560	720	853	842	810	687	665	693
Chloride	mg/l	45	64	64	35	37	32	44	31	44	61	54	46	41	38	32
Soluble Orthophosphate	mg/l as P	–	0.067	0.083	–	–	–	0.093	–	–	0.187	–	–	–	–	–
Total Phosphorus	mg/l as P	0.160[b]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ammonia	mg/l as N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nitrite	mg/l as N	0.030	0.033	0.023	–	–	–	0.011	–	–	0.036	–	–	–	–	–
Nitrate	mg/l as N	1.100	0.151	0.100	–	–	–	0.090	–	–	0.360	–	–	–	–	–
Organic Nitrogen	mg/l as N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Nitrogen	mg/l as N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Sampling Dates and Military Times (1972–1974)

Parameter	Units	1972				1973				1974			
		August 14				August 15				August 19			
		02:20	06:20	14:05	18:15	00:01	04:00	12:00	16:00	00:01	04:00	12:05	16:00
		0.07	0.09	0.09	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dissolved Oxygen	mg/l	6.40	6.60	8.30	6.20	5.30	5.70	13.10	11.40	3.40[b]	3.70[b]	8.30	8.00
Temperature	°F	75.00	74.00	78.00	73.00	73.00	71.50	77.00	78.50	72.00	70.00	77.50	80.50
Fecal Coliform	MFFCC/100 ml	–	30	–	2,200[b]		810[b]		160[b]		72,000[b]		17,000[b]
pH	Standard Units	–	8.10	–	7.70	–	7.60	–	8.00	–	7.70	–	8.20
Specific Conductance	micro-mhos per cm at 77°F	937	962	743	663	795	851	696	717	840	840	800	800
Chloride	mg/l	–	103	–	70	–	50	–	33	–	72	–	58
Soluble Orthophosphate	mg/l as P	–	–	–	0.253	–	0.027	–	0.030	–	0.183	–	0.118
Total Phosphorus	mg/l as P	–	0.130[b]	–	0.340[b]	–	0.070	–	0.100	–	.230[b]	–	.120[b]
Ammonia	mg/l as N	–	0.110	–	0.120	–	0.340	–	0.170	–	.630	–	0.230
Nitrite	mg/l as N	–	0.018	–	0.079	–	0.010	–	0.014	–	0.155	–	0.109
Nitrate	mg/l as N	–	0.130	–	0.660	–	0.250	–	0.250	–	0.350	–	0.390
Organic Nitrogen	mg/l as N	–	0.630	–	0.750	–	0.330	–	0.250	–	0.870	–	0.720
Total Nitrogen	mg/l as N	–	0.890	–	1.610	–	0.930	–	0.680	–	1.995	–	1.451

Sampling Dates and Military Times (1975–1976) and Summary

Parameter	Units	1975				1976				Maximum	Average	Minimum	Number of Analyses	Water Quality Standards[b]	Comparison to Standards: Analyses Not Meeting Water Quality Standards	
		August 25				September 22		September 23								
		00:01	04:01	11:00	15:00	15:20	19:00	03:15	07:00							
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						Number	Percent of All Analyses
Dissolved Oxygen	mg/l	6.60	6.40	8.20	8.60	9.30	6.80	5.60	6.80	14.10	7.70	3.40	35	5.0 (minimum)	3	9
Temperature	°F	75.00	73.00	74.00	77.00	69.00	65.50	63.00	58.00	86.00	73.90	54.00	35	89 (maximum)	0	0
Fecal Coliform	MFFCC/100 ml		600[b]		1,400[b]		1,000[b]		480[b]	72,000	7,063	30	14	400 (maximum)	11	79
pH	Standard Units	–	7.80	–	7.80	7.80	7.80	7.70	7.60	8.60	7.80	5.80	27	6.0 - 9.0	1	4
Specific Conductance	micro-mhos per cm at 77°F	697	740	710	713	2,271	579	798	868	2,271	787	560	35	N/A	–	–
Chloride	mg/l	–	135	–	26	598	43	107	127	598	77.40	31	27	N/A	–	–
Soluble Orthophosphate	mg/l as P	–	–	–	–	–	0.011	–	0.013	0.263	0.10	0.011	11	N/A	–	–
Total Phosphorus	mg/l as P	–	0.030	–	0.010	–	0.020	–	0.070	0.340	0.12	0.010	11	0.1 (maximum)	5	45
Ammonia	mg/l as N	–	0.250	–	0.300	–	0.03	–	0.35	0.630	0.25	0.03	10	0.4 (maximum)	1	10
Nitrite	mg/l as N	–	0.031	–	0.019	–	0.003	–	0.148	0.155	0.048	0.003	15	N/A	–	–
Nitrate	mg/l as N	–	0.480	–	0.360	–	0.16	–	0.75	0.660	0.35	0.090	12	N/A	–	–
Organic Nitrogen	mg/l as N	–	0.780	–	0.440	–	0.19	–	0.80	0.870	0.58	0.19	10	N/A	–	–
Total Nitrogen	mg/l as N	–	1.540	–	1.110	–	0.37	–	2.04	2.04	1.26	0.37	10	N/A	–	–

NOTE: NA indicates not applicable.

[a] *Precipitation in inches on day of sampling prior to time of sampling as recorded at Mitchell Field National Weather Service*

[b] *Underlining indicates substandard water quality based on standards indicated in table.*

[c] *Maximum of 2.0 mg/l in fall, winter, and spring.*

Source: SEWRPC and Wisconsin Department of Natural Resources.

Table 33

WATER QUALITY (DRY AND WET WEATHER) FOR THE KINNICKINNIC RIVER AT S. 6TH STREET: SUMMER 1967

Sampling Dates and Military Times (June–July)

Parameter	Units	June	July											
		30	3	5	7	10	12	14	17	19	21	24	26	28
		08:37	11:07	13:34	08:14	11:01	12:58	07:59	11:00	08:20	10:45	08:40	13:10	08:05
Precipitation at Mitchell Field on Day before Sampling	Inches	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.71	0.00	0.00
Precipitation at Mitchell Field on Day of Sampling before Time of Sampling	Inches	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00
Sampling Conditions[a]		Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Wet	Dry
Temperature	Air: °F	79	70	65	71	69	77	67	75	67	79	81	64	64
	Water: °F	63	70	75	66	73	81	61	75	64	70	72	75	68
Dissolved Oxygen	mg/l	9.80	19.50	21.50	13.20	11.10	13.40	11.70	13.70	10.10	11.40	10.50	6.70	9.60
Biochemical Oxygen Demand	mg/l	3.00	6.20	13.80	5.60	9.60	2.80	3.80	28.50	3.50	5.80	6.60	28.00	3.20
Fecal Coliform	MFFCC/100 ml	85	260	130	80	280	170	16	66	110	30	800[b]	800[b]	1000[b]
pH	Standard Units	8.40	9.10[b]	9.20[b]	8.40	8.50	8.00	–	8.90	8.40	8.50	8.10	6.60	7.70
Chloride	mg/l	80	90	405	70	55	–	58	50	46	54	33	–	–
Turbidity	Standard Units	31	27	34	25	25	25	–	87	25	29	28	300	25

Sampling Dates and Military Times (August–September) and Summary

Parameter	Units	August													September		Maximum	Average	Minimum	Comparison to Standards[b]: Water Quality Standards	Analyses Not Meeting Water Quality Standards	
		2	4	7	9	11	14	16	18	21	23	25	28	30	1	4					Number	Percent of All Analyses
		08:55	10:30	07:55	12:20	08:05	11:05	08:00	10:30	08:10	12:40	08:10	11:00	08:40	08:00	12:55						
Precipitation at Mitchell Field on Day before Sampling	Inches	–	–	0.18	–	–	–	–	–	–	–	–	0.01	0.79	0.00	–	0.79	.06	0.00	N/A	–	–
Precipitation at Mitchell Field on Day of Sampling before Time of Sampling	Inches	0.05	–	–	–	–	–	–	0.03	–	–	–	–	–	–	–	0.43	.02	0.00	N/A	–	–
Sampling Conditions[a]		Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	–	–	–	N/A	–	–
Temperature	Air: °F	80	73	73	72	64	73	77	71	66	68	74	70	55	65	71	81	71	55	N/A	–	–
	Water: °F	73	75	70	77	64	77	72	77	64	64	66	64	64	63	66	81	70	61	89 (maximum)	–	–
Dissolved Oxygen	mg/l	4.90[b]	15.40	7.00	14.60	10.60	15.10	9.00	9.60	8.30	7.90	8.70	10.50	8.30	9.60	10.00	21.50	11.10	4.90	5.0 (minimum)	–	–
Biochemical Oxygen Demand	mg/l	29.60	4.70	10.20	5.80	6.60	13.20	5.70	6.80	10.40	3.90	3.90	4.30	5.00	1.90	3.00	29.60	8.40	1.90	N/A	–	–
Fecal Coliform	MFFCC/100 ml	440[b]	220	2300[b]	340	1100[b]	530[b]	110	1460[b]	2000[b]	1200[b]	900[b]	700[b]	270	30	200	2300	558	16	400 (maximum)	12	43
pH	Standard Units	8.60	8.70	7.70	8.50	8.10	9.20[b]	7.90	8.10	7.60	7.60	7.70	8.10	8.00	7.40	7.90	9.20	8.20	6.60	6.0 to 9.0	3	11
Chloride	mg/l	62	3	8	–	43	37	47	–	43	42	36	33	32	36	43	405	60	3	N/A	–	–
Turbidity	Standard Units	221	25	33	25	25	25	25	25	25	25	25	25	110	25	–	25	50	300	N/A	–	–

NOTE: N/A indicates not applicable.

[a] *Dry weather is defined as 0.10 inch or less of precipitation on day of sampling and before sample was taken.*

[b] *Underlining indicates substandard water quality based on standards indicated in table.*

Source: Milwaukee-Metropolitan Sewerage Commissions and SEWRPC.

A summary of all of the physical, chemical, and biological analyses conducted during the three summers at the four locations is set forth in Table 34. Dissolved oxygen levels for all locations during the summers of 1967 and 1969 are presented in graphic form in Figure 36. The July and August 1967 data used in Figure 36 are for samples collected after a minimum of three hours operation of the flushing tunnel and when no rainfall had been recorded at the Milwaukee-General Mitchell Field weather station during the preceding 24-hour period. The July-August 1969 data are for samples preceded by at least 24 hours without recorded precipitation at the Milwaukee-General Mitchell Field weather station. Based on the data presented in the report, some of which is presented in Table 34 and Figure 36, certain conclusions may be drawn concerning the effectiveness of the flushing tunnel in enhancing estuary water quality.

- When the flushing tunnel is in operation:

    1. estuary water quality approximates that of the water being pumped from Lake Michigan into the estuary.

    2. estuary water quality is superior to that of the Kinnickinnic River upstream of the estuary for biochemical oxygen demand, chlorides, and total and fecal coliform bacteria.

    3. the dissolved oxygen concentration in the estuary is less than that of the Kinnickinnic River immediately upstream of the estuary; however, the dissolved oxygen levels in the estuary are well above the established 5.0 mg/l minimum standard.

- When the flushing tunnel is not operating, the most significant water quality effects are low to substandard dissolved oxygen levels in the estuary and increased chloride levels with the latter approximating that of the Kinnickinnic River immediately upstream of the estuary.

The 1967 through 1970 City of Milwaukee Health Department investigation did include an examination of relationships between wet weather flow and water quality in the lower Kinnickinnic River. However, the report concludes that "no significant or invariable relationship between wet weather flow and downstream water quality was established.

The City of Milwaukee Health Department performed dissolved oxygen determinations in the Kinnickinnic River estuary at the S. First Street bridge at one- to seven-day intervals during the period September 18, 1973 to December 6, 1973. Dissolved oxygen values ranged from a low of 4.8 mg/l to a high of 9.7 mg/l, with an

Table 34

DRY WEATHER WATER QUALITY IN THE KINNICKINNIC RIVER UPSTREAM AND DOWNSTREAM OF THE FLUSHING TUNNEL WITH AND WITHOUT OPERATION OF THE FLUSHING TUNNEL: SUMMERS OF 1967, 1969, AND 1970

Sampling Station			Arithmetic Mean of All Analyses							
Location	River Mile	Number of Samples	Temperature (°F)	Dissolved Oxygen (mg/l)	Biochemical Oxygen Demand (mg/l)	Chloride (mg/l)	Total Coliform (MFCC per 100 ml)	Fecal Coliform (MFFCC per 100 ml)	pH (standard units)	Turbidity (standard units)
Summer 1967—Flushing Station Operated										
S. 6th Street	2.81	26	69.8	10.8	8.7	59.7	395,200	<u>58,700</u>	7.88	50.8
Flushing Station Outlet . .	2.35	26	62.8	8.5	4.1	20.5	73,300	<u>1,900</u>	7.98	25.4
W. Lincoln Avenue	1.96	26	63.9	8.0	5.5	23.6	244,900	<u>22,000</u>	7.89	30.8
W. Becher Street	1.67	26	64.9	7.3	5.0	24.3	352,900	<u>15,500</u>	7.92	46.1
Summer 1969—Flushing Station Not Operated										
S. 6th Street	2.81	14	70.0	9.4	8.0	44.5	833,600	<u>57,000</u>	8.00	27.8
Flushing Station Outlet . .	2.35	14	68.5	5.1	6.1	43.9	214,700	<u>22,300</u>	7.71	21.2
W. Lincoln Avenue	1.96	14	71.2	<u>2.6</u>	6.2	44.6	293,500	<u>14,200</u>	7.70	26.5
W. Becher Street	1.67	14	70.2	<u>1.3</u>	6.4	38.3	361,700	<u>8,200</u>	7.61	30.0
Summer 1970—Flushing Station Operated										
S. 6th Street	2.81	13	77.9	12.8	6.5	62.1	154,900	<u>18,800</u>	8.53	15.1
Flushing Station Outlet . .	2.35	13	63.5	9.9	4.1	20.4	48,400	<u>4,200</u>	8.16	16.1
W. Lincoln Avenue	1.96	13	61.7	10.1	3.6	19.9	36,900	<u>2,400</u>	8.18	15.2
W. Becher Street	1.67	13	65.3	9.8	3.9	19.1	50,800	<u>3,900</u>	8.05	16.9

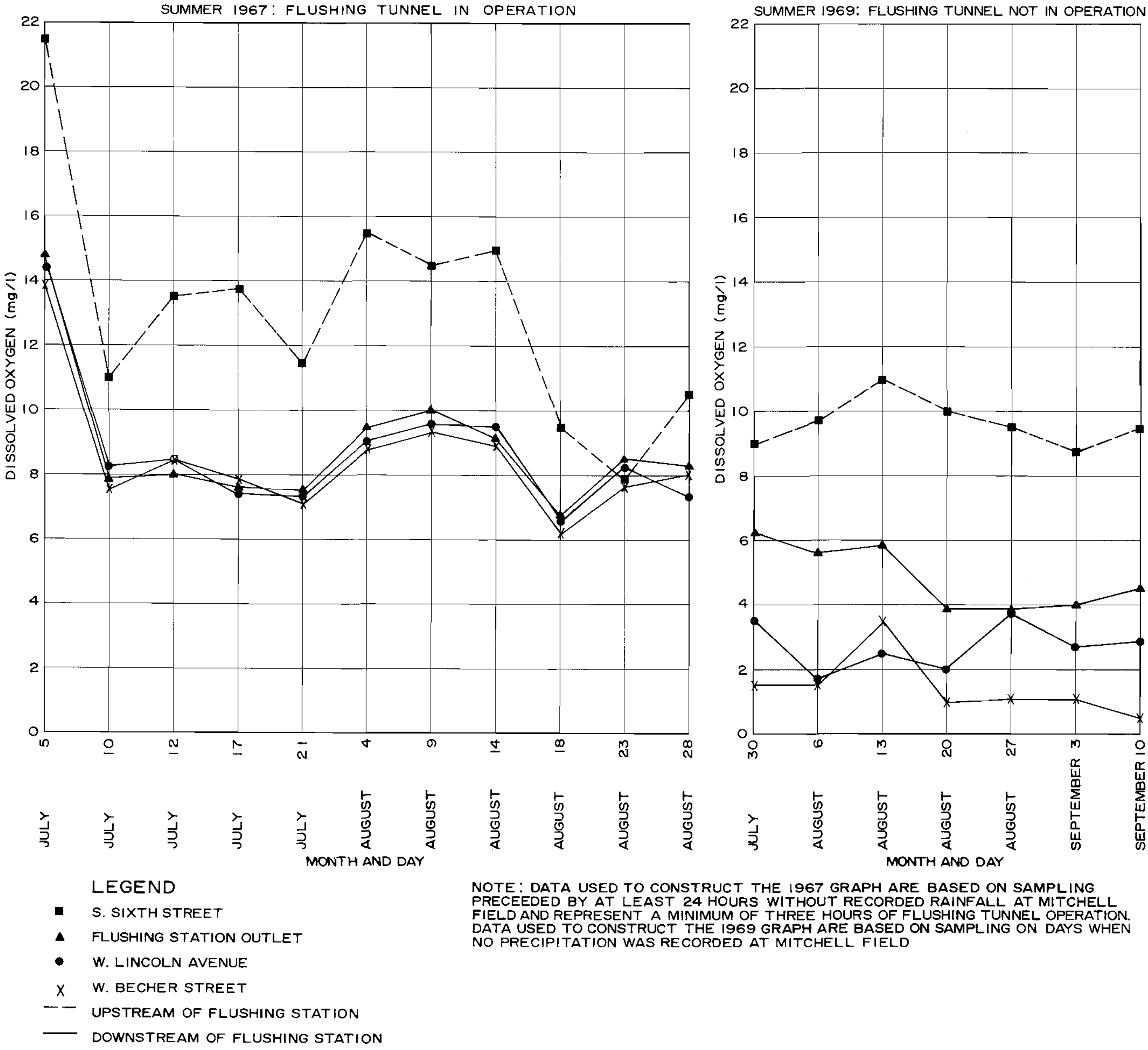
NOTE: Underlining indicates substandard water quality based on the following applicable standards:

Temperature—maximum of 89°F.
Dissolved Oxygen—minimum of 5.0 mg/l.
Fecal Coliform—maximum of 400 MFFCC per 100 ml.
pH—6.0 to 9.0.

Source: City of Milwaukee Health Department.

Figure 36

DISSOLVED OXYGEN IN THE KINNICKINNIC RIVER UPSTREAM AND DOWNSTREAM OF THE FLUSHING TUNNEL WITH AND WITHOUT OPERATION OF THE TUNNEL: SUMMER OF 1967 AND 1969



Source: City of Milwaukee Board of Health.

average of 7.5 mg/l. Thus the range and the average are generally well above the minimum concentration of 5.0 mg/l specified by the standard. The flushing tunnel was in operation intermittently during most of this sampling period, having been shut down permanently for the season on November 21, 1973. The principal objective used to establish the operating schedule of the flushing tunnel is maintenance of a minimum dissolved oxygen concentration of 2.0 mg/l in the estuary at the S. First Street crossing. The City of Milwaukee Health Department data suggest that the tunnel operation was successful in satisfying this dissolved oxygen standard.

Wisconsin Department of Natural Resources Basin Surveys of Toxic and Hazardous Substances: 1975-1976

There is a growing awareness on the part of scientists, engineers, and the general public of the potentially harmful affects on animal and human life of toxic and hazardous substances not formerly considered in water quality management studies. Because of this growing awareness, the available data on the levels of toxic and hazardous substances in the streams and lakes of the Region as obtained under the Wisconsin Department of Natural Resources drainage basin study program were assembled by the Commission under the areawide water quality management program. Data extracted from that inventory for the Kinnickinnic River watershed are presented and their significance is discussed herein.

Toxic and Hazardous Substances—Background: The general category of toxic and hazardous materials consists of the three subcategories: heavy metals, pesticides, and polychlorinated biphenyls (PCB's). After their initial production, all of these materials accumjlate in nature as the result of man's activities.[6] Heavy metals such as cadmium, chromium, cobalt, copper, lead, mercury, nickel, and zinc are those metals which have a specific gravity greater than four. Such metals have several oxidation states, and readily form complex ions. Pesticides are organic chemicals utilized by man to control or destroy undesirable forms of plant and animal life. Pesticides encompass all forms of insecticides, herbicides, fungicides, fumigants, nematocides, algicides, and rodenticides. Polychlorinated biphenyls (PCB's) are a class of compounds produced by chlorination of biphenyls and are registered in the United States under the trade name of Arochlor. PCB's are slightly soluble in water, relatively nonflammable, and have desirable heat exchange and dielectric properties. They are used principally in the electrical industry in capacitors and transformers and were formerly used in the production of papers used for printed self-copying forms not requiring carbon paper.

Heavy metals, pesticides, PCB's, and other toxic and hazardous substances generally do not present the gross, aesthetic, or olfactory offense of some other water pollutants, but may present a serious and insidious health hazard to animal and human population. Reported adverse effects of heavy metals, pesticides, and PCB's on humans include liver and kidney disorders, carcinogenic effects, nervous system damage, skin lesions, and disruption of reproductive processes. Not only are these toxic and hazardous materials taken up by rooted plants, but certain of these materials have the innate ability to enter the food chain at the lowest levels of vegetative growth and then gradually move up the food chain and accumulate in the fleshy tissue of fish which in turn are available for human consumption. Other carnivores, such as predatory birds, may be adversely affected by toxic materials.[7]

Heavy metals, pesticides, and PCB's may be transported into the surface waters of the urban Kinnickinnic River watershed directly via groundwater discharge. Potential diffuse sources of heavy metals, pesticides, and PCB's in the urban environment include industrial wastewater discharges; atmospheric fallout and washout; washoff from streets, highways, parking lots, rooftops, lawns, and other pervious and impervious surfaces; organic and inorganic fertilizers for agricultural and lawn and garden purposes; pesticides that have been sprayed or spread; and discharge of sanitary sewerage system flow relief devices.

Findings of the Study: Dry weather heavy metal concentrations and PCB levels found in the selected surface water quality samples were taken by the Wisconsin Department of Natural Resources in the Kinnickinnic River watershed from sampling stations located on the Kinnickinnic River, Wilson Park Creek, S. 43rd Street ditch, Holmes Avenue Creek, Villa Mann Creek, and Cherokee Park Creek from May 1975 through April 1976 (see Table 35). Dry weather pesticide data for surface water quality samples were taken by the Department on the Kinnickinnic River and Wilson Park Creek from May through December 1975 (see Table 36). Finally, Table 37 indicates the concentration of heavy metals and PCB's found in sediment samples taken by the Department from the bottom muds of the Kinnickinnic River, Wilson Park Creek, and S. 43rd Street ditch in February 1976.

The criteria recommended by the U. S. Environmental Protection Agency are noted in Tables 35 and 36 for each substance for which data are available. The notable omission is recommended criteria for certain pesticide compounds for which only very limited data are available. The other categorical omission is recommended levels of any of the substances in the bottom sediments of streams. The recommended criteria were generally established by applying a factor of 0.01 to the concentration of a substance shown to be lethal to 50 percent of the test population of an indicator species after 96 hours.[8]

Surface Waters: Generally, the data presented in Tables 35 and 36 are not indicative of extensive toxicity problems in the water columns of the streams in the Kinnickinnic River watershed. Some localized or unique findings are worthy of note, however, and are described here. These findings should be evaluated carefully because of the very limited number of samples and their associated areas of coverage. As indicated in Table 35, of the seven heavy metals for which data are available, mercury is the only one found to occur in concentrations in excess of the recommended standard. The four available mercury determinations ranged from 0.2 to 0.4 microgram per liter, which is four to eight times the recommended standard of 0.05 microgram per liter.

It is important to note that in the above heavy metal analyses, the lowest level of detection in two cases was higher than the recommended criteria. For example, as shown in Table 35, in many of the analyses conducted for mercury the lowest level of detection of the laboratory conducting the test was 0.2 microgram per liter, whereas the criterion used for comparison is 0.05 micro-

[6] *For a description of a monitoring study showing significant increases in the concentration of copper and lead in Wisconsin lake sediments as a result of man's activities refer to, "Lake Mud Reveals Pollution History," Wisconsin Conservation Bulletin, May-June 1974, pp. 26-27.*

[7] *See Appendix A of SEWRPC Technical Report No. 17, Water Quality of Lakes and Streams in Southeastern Wisconsin, (to be published in 1978).*

[8] *Ibid.*

Table 35

DRY WEATHER HEAVY METAL AND PCB CONCENTRATIONS IN KINNICKINNIC RIVER WATERSHED WATER SAMPLES: 1975 and 1976

Heavy Metal and PCB Concentrations in Micro-Grams per Liter (recommended maximum concentration shown in parentheses)

Sampling Station			Date or Time Period	Cadmium (12)				Chromium (100)				Copper (145)				Lead (4,820)			
				Determinate Samples (average)		Indeterminate Samples[a]		Determinate Samples (average)		Indeterminate Samples[a]		Determinate Samples (average)		Indeterminate Samples[a]		Determinate Samples (average)		Indeterminate Samples[a]	
Stream	Location	River Mile		Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration
Kinnickinnic River	S. 43rd Street	6.51	October 22, 1975	–	–	1	<0.2	–	–	1	<3.0	–	–	1	<3.0	1	264.0	–	–
	S. 35th Street	5.45	May 27, 1975 through April 12, 1976	4	0.9	9	<0.2	7	9.0	6	<3.0	13	98.0	–	–	12	101.0	–	–
	Cleveland Avenue	3.79	October 22, 1975	–	–	1	<0.2	1	3.0	–	–	–	–	1	<3.0	1	18.0	–	–
	S. 7th Street	2.88	October 22, 1975	–	–	1	<0.2	1	3.0	–	–	1	4.0	–	–	1	15.0	–	–
	S. 6th Street	2.81	May 27, 1975 through April 12, 1976	3	0.5	9	<0.2	8	15.0	4	<3.0	10	8.7	2	<3.0	10	34.8	2	<3.0
	Chicago and Northwestern Railway Bridge	0.84	May 27, 1975 through April 14, 1976	4	0.41	8	<0.7	11	7.5	1	<3.0	11	31.9	1	<3.0	12	16.0	–	–
Wilson Park Creek	S. Howell Avenue	3.65	May 27, 1975 through April 12, 1976	1	0.3	11	<0.2	4	3.0	8	<3.0	12	7.0	–	–	10	10.0	2	<3.0
			October 23, 1975	–	–	1	<0.2	–	–	1	<3.0	1	4.0	–	–	–	–	1	<3.0
	S. 13th Street	2.42	October 23, 1975	–	–	1	<0.2	–	–	1	<3.0	–	–	1	<3.0	1	3.0	–	–
	W. Howard Avenue	1.30	October 23, 1975	–	–	1	<0.2	–	–	1	<3.0	–	–	1	<3.0	1	3.0	–	–
	Immediately upstream of confluence with Kinnickinnic River	0.00	May 27, 1975 through April 12, 1976	4	0.4	11	<0.4	7	7.0	7	<3.0	12	6.0	2	<3.0	11	14.0	2	<3.0
S. 43rd Street Ditch	Immediately upstream of confluence with Kinnickinnic River	0.00	October 22, 1975	–	–	1	<0.2	–	–	1	<3.0	1	6.0	–	–	1	35.0	–	–
Holmes Avenue Creek	E. Layton Avenue	0.12	October 23, 1975	–	–	1	<0.2	–	–	1	<3.0	1	5.0	–	–	1	9.0	–	–
Villa Mann Creek	Immediately upstream of confluence with Kinnickinnic River	0.00	October 23, 1975	–	–	1	<0.2	–	–	1	<3.0	1	6.0	–	–	1	7.0	–	–
Cherokee Park Creek	Morgan Avenue	0.00	October 23, 1975	–	–	1	<0.2	–	–	1	<3.0	1	6.0	–	–	1	13.0	–	–
Average: Concentration					0.5				8.5				29.7				37.1		

Sampling Station			Date or Time Period	Mercury[b] (0.05)				Nickel (100)				Zinc (334)				PCB[b] (0.001)			
				Determinate Samples (average)		Indeterminate Samples[a]		Determinate Samples (average)		Indeterminate Samples[a]		Determinate Samples (average)		Indeterminate Samples[a]		Determinate Samples (average)		Indeterminate Samples[a]	
Stream	Location	River Mile		Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration
Kinnickinnic River	S. 43rd Street	6.51	October 22, 1975	–	–	1	<0.2	–	–	1	<20.0	–	–	1	<20.0	–	–	–	–
	S. 35th Street	5.45	May 27, 1975 through April 12, 1976	1	0.3	12	<0.2	–	–	13	<20.0	13	134.0	–	–	1	0.2	2	<0.1
	Cleveland Avenue	3.79	October 22, 1975	–	–	1	<0.2	–	–	1	<20.0	1	60.0	–	–	–	–	–	–
	S. 7th Street	2.88	October 22, 1975	–	–	1	<0.2	–	–	1	<20.0	1	40.0	–	–	–	–	–	–
	S. 6th Street	2.81	May 27, 1975 through April 12, 1976	1	0.2	11	<1.1	–	–	12	<20.0	12	57.0	–	–	–	–	2	<0.1
	Chicago and Northwestern Railway Bridge	0.84	May 27, 1975 through April 14, 1976	1	0.4	11	<0.2	1	50.0	11	<20.0	11	83.0	1	<20.0	–	–	2	<0.1
Wilson Park Creek	S. Howell Avenue	3.65	May 27, 1975 through April 12, 1976	–	–	12	<0.2	–	–	12	<20.0	9	44.0	3	<20.0	–	–	3	<0.1
			October 23, 1975	–	–	1	<0.2	1	20.0	–	–	–	–	1	<20.0	–	–	–	–
	S. 13th Street	2.42	October 23, 1975	–	–	1	<0.2	–	–	1	<20.0	–	–	1	<20.0	–	–	–	–
	W. Howard Avenue	1.30	October 23, 1975	–	–	1	<0.2	–	–	1	<20.0	–	–	1	<20.0	–	–	–	–
	Immediately upstream of confluence with Kinnickinnic River	0.00	May 27, 1975 through April 12, 1976	1	0.3	13	<0.2	1	20.0	13	<20.0	10	57.0	4	<20.0	–	–	3	<0.1
S. 43rd Street Ditch	Immediately upstream of confluence with Kinnickinnic River	0.00	October 22, 1975	–	–	1	<0.2	–	–	1	<20.0	1	70.0	–	–	–	–	–	–
Holmes Avenue Creek	E. Layton Avenue	0.12	October 23, 1975	–	–	1	<0.2	1	20.0	–	–	–	–	1	<20.0	–	–	–	–
Villa Mann Creek	Immediately upstream of confluence with Kinnickinnic River	0.00	October 23, 1975	–	–	1	<0.2	–	–	1	<20.0	–	–	1	<20.0	–	–	–	–
Cherokee Park Creek	Morgan Avenue	0.00	October 23, 1975	–	–	1	<0.2	–	–	1	<20.0	–	–	1	<20.0	–	–	–	–
Average: Concentration					0.3				27.5				77.2				0.2		

[a] *Precise concentration not known. Concentration less than or equal to indicated value.*

[b] *Detectable limit of laboratory analysis is higher than recommended concentration; therefore, it is not known whether criteria were satisfied or violated.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 36

DRY WEATHER PESTICIDE CONCENTRATIONS IN KINNICKINNIC RIVER WATERSHED WATER SAMPLES: 1975

Sampling Station			Time Period	Pesticide Concentrations in Micro-Grams per Liter (recommended maximum concentration shown in parentheses)																							
				DDT (0.001)[b]				DDE (–)[c]				DDD (–)[c]				Aldrin (0.003)[b]				Heptachlor (0.001)[b]				Heptachlor[b] Epoxide (0.001)			
				Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]	
Stream	Location	River Mile		Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration
Kinnickinnic River	S. 35th Street	5.45	May 27, 1975 through December 8, 1975	–	–	3	<.02	–	–	3	<.01	–	–	3	<.02	–	–	3	<.005	–	–	3	<.005	–	–	3	<.01
	S. 6th Street	2.81	May 27, 1975 through December 8, 1975	–	–	2	<.02	–	–	2	<.01	–	–	2	<.01	–	–	2	<.005	–	–	2	<.005	–	–	2	<.02
	Chicago & North Western Railway Bridge	0.84	May 27, 1975 through December 8, 1975	–	–	2	<.02	–	–	2	<.01	–	–	2	<.02	–	–	2	<.01	–	–	2	<.005	–	–	2	<.01
Wilson Park Creek	S. Howell Avenue	3.65	May 27, 1975 through December 8, 1975	–	–	3	<.02	–	–	3	<.01	–	–	3	<.02	–	–	3	<.005	–	–	3	<.005	–	–	3	<.01
	Oklahoma Avenue	0.15	May 27, 1975 through December 8, 1975	–	–	3	<.02	–	–	3	<.01	–	–	3	<.02	–	–	3	<.005	–	–	3	<.005	–	–	3	<.02

Sampling Station			Time Period	Pesticide Concentrations in Micro-Grams per Liter (recommended maximum concentration shown in parentheses)																							
				Lindane (0.01)				Dieldrin (0.003)[b]				Methoxychlor (0.03)[b]				Phthalate (3.0)				Atrazine (–)[c]				Simazime (–)[c]			
				Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]		Determinate Samples		Indeterminate Samples[a]	
Stream	Location	River Mile		Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration	Number	Concentration
Kinnickinnic River	S. 35th Street	5.45	May 27, 1975 through December 8, 1975	–	–	3	<.005	–	–	3	<.01	–	–	3	<.1	–	–	1	<.2	–	–	–	–	–	–	–	–
	S. 6th Street	2.81	May 27, 1975 through December 8, 1975	–	–	2	<.006	–	–	2	<.01	–	–	2	<.04	–	–	–	–	–	–	–	–	–	–	–	–
	Chicago & North Western Railway Bridge	0.84	May 27, 1975 through December 8, 1975	–	–	2	<.003	–	–	2	<.01	–	–	2	<.08	–	–	1	<.2	–	–	–	–	–	–	–	–
Wilson Park Creek	S. Howell Avenue	3.65	May 27, 1975 through December 8, 1975	–	–	3	<.003	–	–	3	<.01	–	–	3	<.08	–	–	2	<.2	–	–	–	–	–	–	–	–
	Oklahoma Avenue	0.15	May 27, 1975 through December 8, 1975	–	–	3	<.005	–	–	3	<.01	–	–	3	<.08	–	–	–	–	–	–	–	–	–	–	–	–

a Precise concentration not known. Concentration less man or equal to indicated value.

b Detectable limit of laboratory analysis is higher than recommended concentration; therefore, it is not known whether criteria were satisfied or violated.

c Recommended criteria not established.

Source: Wisconsin Department of Natural Resources and SEWRPC (KKRW, I.M. 5, Exh. AQ-2).

Table 37

HEAVY METAL AND PCB CONCENTRATIONS IN KINNICKINNIC RIVER WATERSHED SEDIMENT SAMPLES: FEBRUARY 1976

Sampling Station			Date	Heavy Metal Concentration in Micro-grams per Gram of Sediment							PCB Concentration in Micro-grams per Gram of Sediment
Stream	Location	River Mile		Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	
Wilson Park Creek	Entrance to Tunnel	0.35	February 16, 1976	1.25	1.25	16.0	375	0.025	12.0	250	0.11
Kinnickinnic River	0.3 mile downstream of S. 6th Street	2.51	February 10, 1976	3.5	37.5	78.0	650	0.34	25.0	825	9.7
	Confluence with mooring basin	0.80	February 10, 1976	1.2	500	11.8	670	0.55	32.0	850	--
S. 43rd Street Ditch	Immediately upstream of Kinnickinnic River	0.00	February 10, 1976	3.5	22	49.0	670	0.31	15.0	750	2.7

Source: Wisconsin Department of Natural Resources and SEWRPC.

gram per liter. Therefore, the actual mercury concentration present in the sample may be less than 0.2 microgram per liter but greater than the recommended level. Thus, it is impossible to determine the actual number of mercury samples that contain mercury in concentrations above 0.05 microgram but below 0.2 microgram per liter. Also, the single determinante PCB sample from Kinnickinnic River watershed, as shown in Table 35, had a centration of 0.2 microgram per liter—200 times the recommended standard. As with mercury, the sensitivity of most of the tests for PCB's—0.1 microgram per liter—was significantly higher than the recommended level of 0.001 microgram per liter. Therefore, it is difficult to assess actual levels of concentration in the surface waters of this basin.

With regard to observed pesticide concentrations for which criteria have been recommended—namely DDT, Aldrin, Heptachlor, Heptachlor Epoxide, Lindane, Dieldrin, Methoxychlor, and Phthalate—the data indicate that the maximum allowable concentrations of Lindane and Phthalate were not exceeded. Since the level of detection of the laboratory conducting the analyses of the other six pesticides was higher than the standard, it is not possible to determine if the standards were exceeded.

Sediment: Standards have not been established or even recommended for heavy metals and PCB levels in bottom sediments; therefore, the bottom sediment heavy metal and PCB data set forth in Table 37 cannot be evaluated relative to established or recommended criteria. A tendency exists for substances such as heavy metals and PCB's to be moved from the water column to the bottom sediments as a result of the relatively low solubility of these substances, their affinity for particulate matter, and their potential to be consumed by and stored in biota. The tendency of heavy metals and PCB's to accumulate in bottom sediments is reflected in the much higher concentrations of these substances observed in the sediments than in the overlying water. For example, the average concentration of cadmium according to determinate analyses in the Kinnickinnic River watershed surface waters as set forth in Table 35 is 0.54 microgram per liter, or about 0.00054 microgram per gram. The average concentration of cadmium in the Kinnickinnic River watershed bottom sediments, based on four analyses performed on sediment samples as set forth in Table 37, is 2.4 micrograms per gram, or about 4,400 times the concentration of cadmium found in the flowing water. Similarily, the average concentrations of chromium, copper, lead, mercury, nickel, zinc, and PCB in bottom sediments as set forth in Table 37 are, respectively, about 16,400, 1,300, 15,900, 1,000, 750, 8,700, and 21,000 times the average concentrations in the surface waters as set forth in Table 35.

Concluding Statement: The limited data available indicate that excessive mercury and PCB levels have existed recently in the surface waters of the Kinnickinnic River under dry weather conditions. Excessive concentrations of other heavy metals and of pesticides may also have existed during dry weather sampling periods but the data are inconclusive because of sensitivity limits in the laboratory analyses. Conclusions cannot be drawn concerning wet weather-condition heavy metal, PCB, and pesticide levels since the available data pertain only to dry weather conditions. Heavy metals and PCB's tend to accumulate in the bottom sediments of the watershed, and the average concentrations of these substances in sediment range from about 1,000 to 20,000 times the concentrations measured in the flowing streams. During wet weather conditions, some of the substances contained within bottom sediments may be brought into suspension and transported from the watershed.

SEWRPC Monitoring for the Areawide Water Quality Management Planning Program: 1976-1977

In 1976 the Commission entered into a cooperative agreement with the Wisconsin Department of Natural Resources and the U. S. Geological Survey for the execution of a short-term stream water quantity and quality monitoring program within the Region that included two locations within the Kinnickinnic River watershed. The objective of this monitoring program, which was carried out under the areawide water quality management planning program, was to provide discharge and flow data on the selected locations in the Region for a continuous period of time encompassing both low flow, dry weather periods and high flow, rainfall or rainfall-snowmelt events. The data were intended to be used to assess the impact of rainfall and rainfall-snowmelt events on instream water quality and to provide a suitable continuous data series for calibration of the hydrologic-hydraulic-water quality model being used under the areawide water quality management planning program—the same model used under the Kinnickinnic River watershed planning program.

One sampling station was located at the S. 7th Street crossing of the Kinnickinnic River (River Mile 2.88) in the City of Milwaukee, which is also the site of the U. S. Geological Survey continuous stage recorder gage established in September 1976 for the Kinnickinnic River watershed planning program. The second sampling location was at the Kinnickinnic River Parkway Drive crossing of the Kinnickinnic River (River Mile 5.87) within Jackson Park at about S. 37th Street extended in the City of Milwaukee, approximately 0.73 mile upstream of the confluence of the Kinnickinnic River and Wilson Park Creek—the major tributary from the south. Three of the combined sewer overflows in the watershed discharge to the Kinnickinnic River upstream of the S. 7th Street sampling location, whereas no combined sewer outfalls discharge upstream of the Kinnickinnic River Parkway Drive sampling station.

As shown on Figures 37 and 38, stream water quality determinations for both stations were made at approximately one-day intervals for the period beginning September 7, 1976 and extending through October 5, 1976. In addition, on those days in which runoff occurred as the result of rainfall events, several water quality samples were taken for the purpose of defining the instream pollutographs. The major rainfall event occurred on October 4 and 5 when about 1.5 inches of rainfall fell on the watershed during a 28-hour period from about 9:00 p.m. on October 4 to 12:00 p.m. on October 5—a rainfall event that may be expected to occur on the average of one or more times each year.

Water quality determinations were also made on February 10, 1977 at the downstream station during a snowmelt event caused by unseasonably high air temperatures. As indicated by daily meteorologic data shown on Figure 37, no precipitation occurred between February 5 and February 10, and average daily and maximum temperatures for the February 5 through February 8 period were below freezing. About 6 inches of snowpack was reported at the Milwaukee-General Mitchell Field weather station on February 8, 1977. Snowmelt and runoff began on February 9 and extended to about February 12, during which time maximum daily temperatures rose sharply and remained above 40°F, reaching a peak of 47°F on February 11.

The 1976 and 1977 data for the two stations in the Kinnickinnic River watershed as obtained under the areawide water quality management planning program are unusual in comparison to the other monitoring efforts reported herein for two reasons. First, whereas most of the other studies are conducted during dry weather conditions, the 1976-1977 data include water quantity and quality information for rainfall and snowmelt runoff events, thus permitting a characterization of the water quality impact of such events. Second, the 1976-1977 data are for a continuous time period, thus permitting a characterization of water quality changes occurring at a given location over a period of time and in response to varying meteorologic conditions.

Findings of the Study: Figure 37 is a graphic summary of water quantity and water quality conditions in the Kinnickinnic River at S. 7th Street during the period from September 7, 1976 through October 5, 1976 and for the period from February 4 through February 10, 1977. Figure 38 is a synopsis of water quantity and water quality conditions in the Kinnickinnic River at the Kinnickinnic River Parkway Drive for the period September 7, 1976 through October 5, 1976. A summary of dry and wet weather concentration and transport of biochemical oxygen demand, fecal coliform bacteria, chloride, orthophosphate, total phosphorus, and total nitrogen is presented in Table 38 for the downstream station and is limited to that period—September 14, 1976 and later—for which the streamflow recording gage was in operation.

Data presented in Figures 37 and 38 and Table 38 concerning both dry weather and wet weather water quality conditions are discussed below.

Temperature: All of the water temperature measurements made at both the downstream and upstream stations were less than the maximum allowable water temperature standard of 89°F. Air temperature appears to be the primary determinant of water temperature during the dry weather periods in that the water temperature, like the air temperature, exhibits a diurnal fluctuation, with the highest water temperatures occurring during the afternoon hours and the lowest temperatures occurring during the early morning hours. There is a slight lag between water temperatures and air temperatures. For example, air temperatures tend to exceed water temperatures by several degrees in the late morning hours, whereas air and water temperatures are approximately equal in the late afternoon. Air temperatures then drop below water temperatures in the evening and early morning hours. During the October 4, 1976 rainfall event, surface water temperatures were relatively uniform and about 5 to 10 degrees higher than coincident air temperatures.

Dissolved Oxygen: All dissolved oxygen levels at the downstream and more than 90 percent of those at the upstream station exceeded the established minimum dissolved oxygen standard of 5.0 mg/l. The dry weather dissolved oxygen concentration at the downstream station averaged 8.7 mg/l, and at the upstream station averaged 6.1 mg/l. Dissolved oxygen levels were not significantly depressed during rainfall or snowmelt runoff events at the two stations, suggesting that the oxygen demand exerted by organic matter washed from the land surface was offset by oxygen entrained in the

Figure 37

SURFACE WATER QUALITY (DRY AND WET WEATHER) IN THE KINNICKINNIC RIVER WATERSHED AT S. 7TH STREET: SEPTEMBER 7 TO OCTOBER 5, 1976 AND FEBRUARY 4-10, 1977

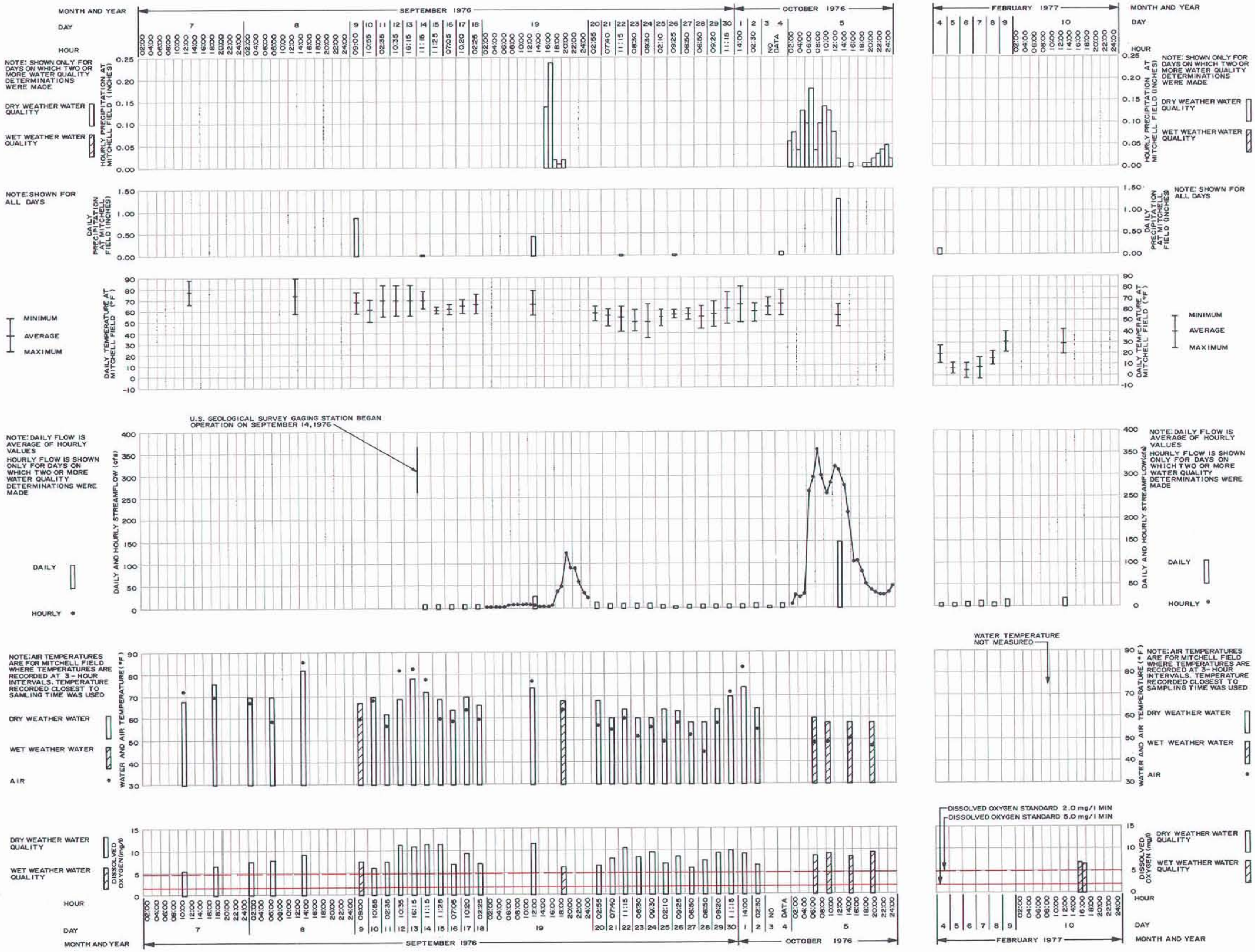
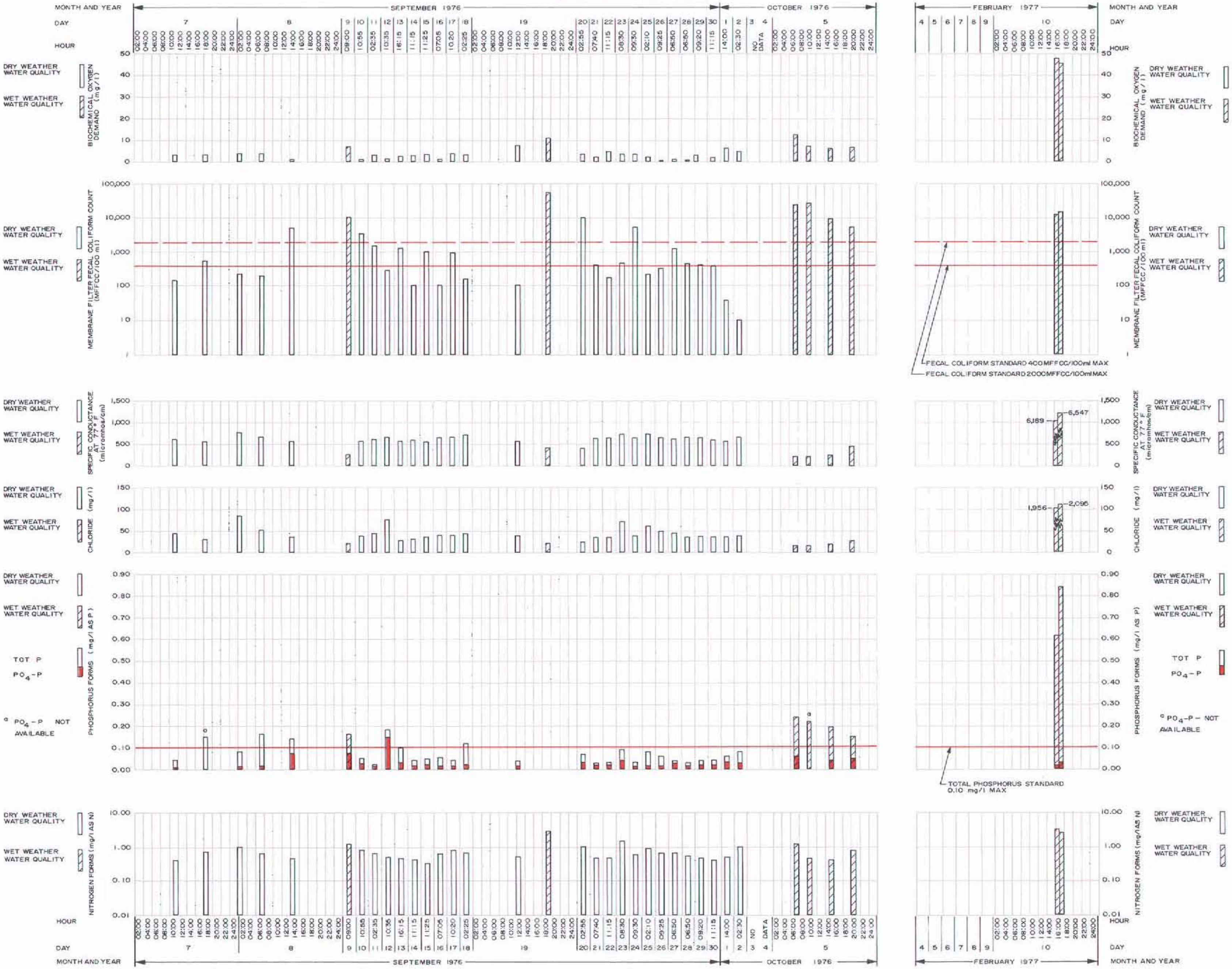


Figure 37 (continued)



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 38

SURFACE WATER QUALITY (DRY AND WET WEATHER) FOR THE KINNICKINNIC RIVER WATERSHED AT KINNICKINNIC RIVER PARKWAY: SEPTEMBER 7 TO OCTOBER 5, 1976

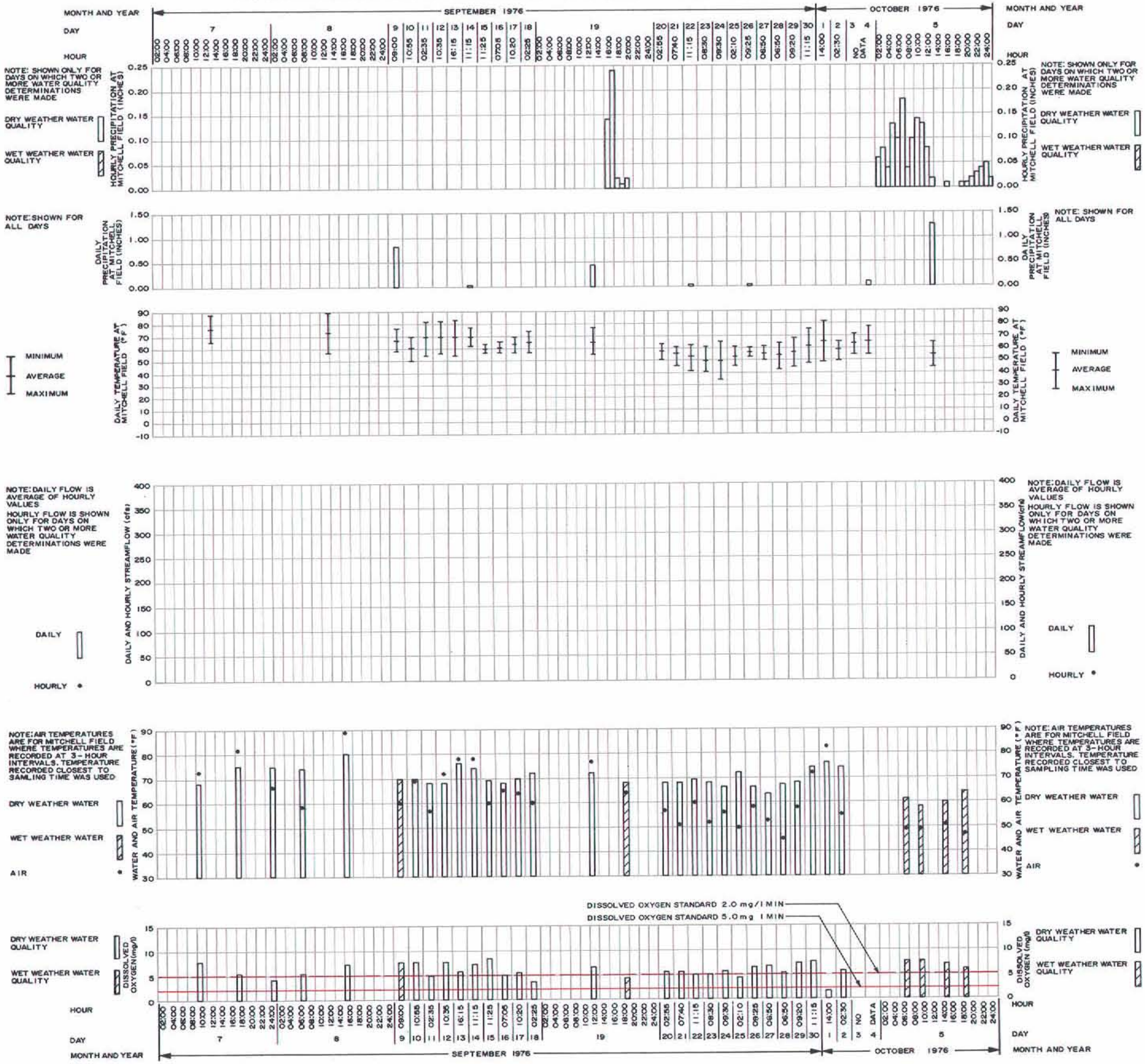
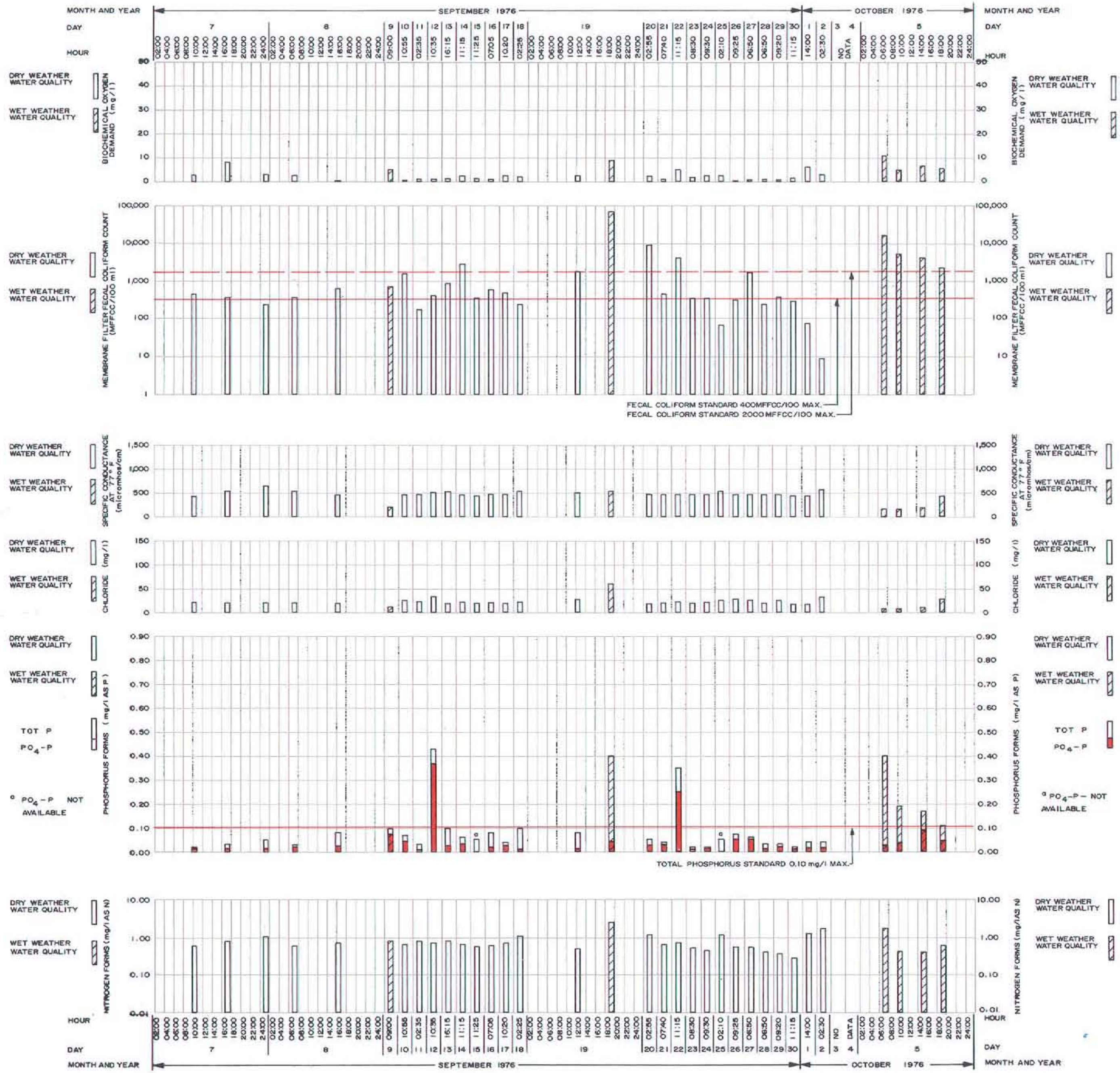


Figure 38 (continued)



Source: Wisconsin Department of Natural Resources and SEWRPC.

storm water runoff. An earlier analysis of the dissolved oxygen content in runoff from various land uses in the Menomonee River watershed indicated near saturation conditions and suggests that wet weather condition runoff is generally rich in dissolved oxygen regardless of land use and antecedent conditions.[9]

Biochemical Oxygen Demand: The dry weather biochemical oxygen demand (BOD) at the downstream station during dry weather periods averaged 2.6 mg/l and at the upstream station averaged 2.5 mg/l. Biochemical oxygen demand in the surface waters at the two stations was significantly influenced by runoff events. For example, the flow-weighted average biochemical oxygen demand of 8.4 mg/l at the downstream station during the October 5, 1977 rainfall event was about three times the average experienced during the dry weather days in the September 14 through October 2 period. Furthermore, the BOD at the downstream station during February 10, 1977 snowmelt event increased to about 45 mg/l, or about 17 times the average dry weather condition level. The latter extremely high biochemical oxygen demand may be attributed to the washoff of organic material—for example, leaves, street litter, and droppings from animals and birds—trapped beneath or accumulated within or on the snow during the winter season.

Fecal Coliform Bacteria: About half of the dry weather fecal coliform counts made at both the upstream and downstream stations exceeded the established standard of 400 MFFCC/100 ml. All of the wet weather—rainfall and snowmelt—fecal coliform counts exceeded the standard.

Specific Conductance and Chloride: Specific conductance is a measure of the concentration of dissolved solids present in water, and specific conductance increases with increasing concentrations of dissolved solids. The monitoring data indicate that during dry weather periods, specific conductance was relatively uniform at the downstream station, averaging 615 micro-mhos. Similarly, at the upstream station during dry weather periods specific conductance averaged 485 micro-mhos per centimeter.

Marked changes in specific conductance occurred during rainfall runoff and snowmelt runoff events at the two stations. For example, at the downstream station during the October 5, 1976 rainfall runoff event, specific conductance and, therefore, the concentration of dissolved substances dropped to about one-fourth to one-half the average dry weather levels, indicating the dilution effect of the runoff water. In contrast, specific conductance concentration at the downstream station increased to about 10 times the average dry weather levels during the snowmelt runoff event which occurred on February 10, 1977. This high specific conductance observation probably reflects the transport by storm water runoff of sodium chloride used for deicing purposes from the melting snowpack, the land surface, and the shallow subsurface into the surface water system. This assumption is substantiated by a comparison of chloride concentration at the downstream station during the snowmelt runoff event to chloride concentrations at that station during rainfall runoff events and dry weather. For example, chloride concentrations of about 2,000 mg/l—about 50 times the average concentration during dry weather flow and about 100 times the concentration recorded during rainfall runoff events—were recorded during the snowmelt runoff event. The high specific conductance, chloride, and biochemical oxygen demand concentrations observed in the surface waters during the snowmelt not only suggest that storm water runoff transports large amounts of pollutants into the surface waters during a short period of time but that concentrations of material and the mass of material transported may be dependent on the cause and nature of the runoff, that is, whether it is rainfall-induced or snowmelt-induced.

Phosphorus: About 10 percent of the dry weather total phosphorus determinations made at both the upstream and downstream stations exceeded the established maximum total phosphorus standard of 0.10 mg/l. All of the wet weather condition samples contained excessive total phosphorus. The average total phosphorus concentration at the downstream station during the February snowmelt event was 0.72 mg/l—3.3 times the flow-weighted average concentration of 0.22 mg/l during the October rainfall event, which was in turn 4.4 times the average dry weather flow concentration of 0.05 mg/l. The data indicate that instream total phosphorus concentration may be expected to significantly increase during both rainfall- and snowmelt-induced runoff events.

Nitrogen: Total nitrogen concentrations during wet weather conditions were observed to be higher than during dry weather conditions. For example, the average total nitrogen concentration at the downstream station during dry weather conditions was about 0.7 mg/l whereas the average total nitrogen concentration at that location during wet weather conditions was about 1.7 mg/l—2.4 times the dry weather level. At the upstream station, the average total nitrogen concentration during dry weather conditions was about 0.8 mg/l, whereas the average total nitrogen concentration at that location during wet weather conditions was about 1.1 mg/l—about 1.4 times the dry weather level. Total nitrogen concentrations observed during runoff caused by the February 10, 1977 snowmelt event were larger than those observed during the September 9 and October 5 rainfall events and approximately the same as those recorded during the September 19, 1976 rainfall event. The data indicate that total nitrogen concentrations may be expected to increase during rainfall or snowmelt events, but not as sharply as other water parameters such as biochemical oxygen demand, fecal coliform bacteria, and total phosphorus.

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[9]*See SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume One, Inventory Findings and Forecasts, October 1976, pp. 249-250.*

Dry and Wet Weather Concentration and Transport: The ever-changing concentration of potential pollutants as measured, for example, in milligrams per liter is the primary measure of the quality of flowing streams; the concentration at any place and time establishes suitability for fish and aquatic life, recreation use, and aesthetic enjoyment. The transport of potential pollutants as measured, for example, in pounds per day at the mouth of a watershed is the primary measure of the long-term quality of relatively static receiving waters such as estuaries, lakes, and reservoirs. The response or sensitivity of such surface water bodies to pollutant loads is likely to be manifested in longer time intervals such as days, weeks, months, or seasons and, therefore, the daily, weekly, monthly, and seasonal loads of pollutants are more important than are the instantaneous concentrations of pollutants in the inflowing water.

Figure 39 provides ratios between the average daily concentration and transport of six parameters—biochemical oxygen demand, fecal coliform, chloride, phosphate-phosphorus, total phosphorus, and total nitrogen—for dry weather days during the period from September 14, 1977 through October 2, 1977 and the concentration and transport for the wet weather day of October 5, 1977. This graphic summary illustrates the significant difference between dry and wet weather surface water quality conditions, as set forth in detail in Table 38, and more particularly, the marked increase in both concentration and transport that occurred during the wet weather period, with the exception of the concentration and transport of chloride.

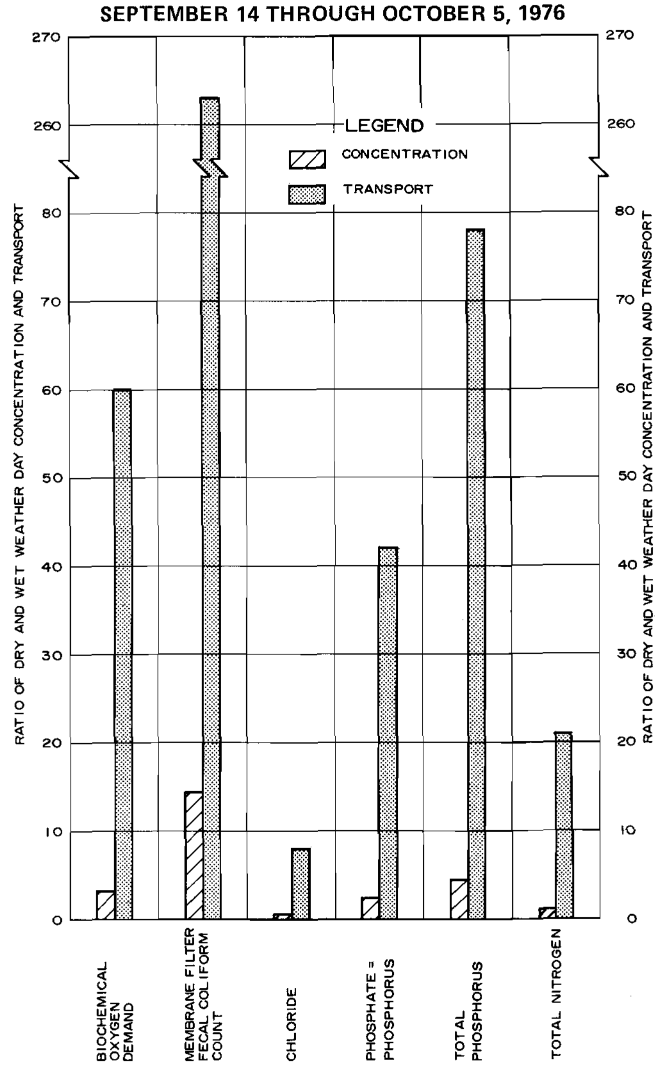
Concentration: The instream concentration of five of the six parameters increased on the wet weather day. The concentrations ranged from 1.1 times the average dry weather concentration for total nitrogen to 14.6 times the average dry weather concentration for fecal coliform bacteria. These concentration levels occurred in spite of the 17-fold increase in average streamflow on the wet weather day—150 cfs as compared to the average for the dry weather days of 18 cfs. Therefore, the substantial increase in the available dilution water was more than offset by the increased quantity of substances carried into the surface waters by direct runoff occurring as overland flow, through the storm sewer system, or from the shallow subsurface.

The single exception to the above pattern is the concentration level for chloride. The wet weather concentration decreased dropped to 40 percent of the dry weather concentration—although as noted below the transport increased significantly. Sampling was carried out in late September and early October 1976, long after the 1975 76th Street deicing season and prior to the 1976-1977 deicing season. While residual chloride may have still been in the shallow subsurface of the watershed, it was diluted by the high streamflows as it was carried into the stream by shallow groundwater during the wet weather event so as to produce a reduction in concentration. That is, of the six pollutants for which data are available, chloride is the only one—because of the seasonal nature of its source—that was probably not added to the land surface or shallow subsurface during the approximately six-month period preceding the October 5, 1977 runoff event and, therefore, chloride was not as readily available for washoff as were the other substances.

Transport: The instream transport of all six parameters increased on the wet weather day to a level ranging from eight times the average dry weather transport for chloride to 263 times the average dry weather transport for fecal coliform bacteria. As shown in Figure 39, the ratios of wet to dry weather transport are much greater than the ratios of wet to dry weather concentration. For example,

Figure 39

RATIO OF DRY AND WET WEATHER CONCENTRATION AND TRANSPORT FOR SELECTED POLLUTANTS IN THE KINNICKINNIC RIVER AT S. 7TH STREET SEPTEMBER 14 THROUGH OCTOBER 5, 1976



NOTE: 1.DRY WEATHER DAY CONCENTRATION AND TRANSPORT LEVELS ARE THE AVERAGE DAILY LEVELS FOR THE DRY WEATHER PERIOD OF SEPTEMBER 14 THROUGH OCTOBER 2, 1976, EXCLUDING SEPTEMBER 19.

2.WET WEATHER DAY CONCENTRATION AND TRANSPORT LEVELS ARE FOR OCTOBER 5, 1976. ABOUT 1.5 INCHES OF RAINFALL FELL ON THE WATERSHED BETWEEN 9:00 P.M. OCTOBER 4 AND 12:00 P.M. OCTOBER 5, WITH 91 PERCENT OCCURRING ON OCTOBER 5. WET WEATHER CONCENTRATION IS FLOW WEIGHTED.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 38

DRY AND WET WEATHER CONCENTRATION AND TRANSPORT FOR SELECTED POLLUTANTS IN THE KINNICKINNIC RIVER AT S. 7TH STREET: SEPTEMBER 14 TO OCTOBER 5, 1976

Parameter	Units (Transport and Concentration)	Sampling Dates[a]																			Summary of Dry Weather Data			Ratio Between Wet Weather and Average Daily Dry Weather Transport and Concentration for Each Parameter
		September																October						
		14	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	1	2	5				
		Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Wet	Maximum	Average	Minimum	
Biochemical Oxygen Demand	Pounds/day	157	135	52	179	142	187	103	223	171	13.40	71	0.56	44	37	117	97	282	190	7,681	282	129	0.56	60
	mg/l	3.00	2.80	1.00	3.40	2.80	2.80	3.00	4.60	3.60	3.00	2.00	0.20	1.00	0.80	2.40	2.00	6.00	4.20	8.40[b]	6.00	2.60	0.20	3.2
Fecal Coliform	colonies/day	1.21×10^{12}	2.19×10^{11}	2.36×10^{10}	2.15×10^{11}	4.16×10^{10}	3.03×10^{12}	9.54×10^{10}	3.30×10^{10}	9.93×10^{10}	1.14×10^{12}	3.23×10^{10}	4.31×10^{10}	2.38×10^{11}	8.10×10^{10}	1.02×10^{11}	8.84×10^{10}	8.53×10^{9}	2.05×10^{9}	9.78×10^{13}	3.03×10^{12}	3.72×10^{11}	2.05×10^{9}	263
	MFFCC/100 ml	5,100	1,000	100	900	180	10,000	410	150	460	5,600	200	340	1,200	410	460	400	40	10	21,850[b]	10,000	1,498	10	14.6
Chloride	Pounds/day	1,520	1,640	1,980	2,000	2,190	1,600	1,850	1,650	3,330	1,700	2,170	1,340	1,880	1,680	1,860	1,750	1,600	1,540	15,260	3,330	1,850	1,340	8
	mg/l	29.00	34.00	38.00	38.00	43.00	24.00	36.00	34.00	70.00	38.00	61.00	48.00	43.00	36.00	38.00	36.00	34.00	34.00	16.00[b]	70.00	40.00	29.00	0.4
Phosphate-Phosphorus	Pounds/day	0.94	1.01	0.73	0.74	1.02	2.27	0.97	1.07	1.90	0.49	0.57	0.47	1.35	.56	0.98	0.92	1.650	1.360	44	2.270	1.060	0.470	42
	mg/l	0.018	0.021	0.014	0.014	0.020	0.034	0.019	0.022	0.040	0.011	0.016	0.017	0.031	0.012	0.020	0.019	0.035	0.030	0.051[b]	0.040	0.022	0.011	2.3
Total Phosphorus	Pounds/day	2.10	2.40	2.60	2.10	6.10	4.70	1.50	1.40	4.30	1.30	2.80	1.70	1.80	1.40	2.00	2.00	2.80	3.60	204	6.10	2.60	1.30	78
	mg/l	0.04	0.05	0.05	0.04	0.12	0.07	0.03	0.03	0.09	0.03	0.08	0.06	0.04	0.03	0.04	0.04	0.06	0.08	0.22[b]	0.12	0.05	0.03	4.4
Total Nitrogen	Pounds/day	23.50	16.90	33.30	42.60	37.10	68.10	25.10	23.70	81.80	28.60	34.60	19.30	33.20	27.60	24.50	20.40	23.90	45.60	725	81.80	33.90	16.90	21
	mg/l	0.45	0.35	0.64	0.81	0.73	1.02	0.49	0.49	1.72	0.64	0.97	0.69	0.76	0.59	0.50	0.42	0.51	1.01	0.81[b]	1.72	0.71	0.35	1.1

[a] *Insufficient data available to estimate transport on September 19 and October 3 and 4, 1976.*

[b] *Flow = weighted concentration*

Source: SEWRPC.

the wet weather concentration of biochemical oxygen demand is 3.2 times the dry weather concentration whereas the wet weather transport is 60 times the dry weather transport.

Concluding Statement: The September and early October 1976 and early February 1977 dry and wet weather surveys indicated water quality conditions satisfying the established temperature standards in all instances, whereas dissolved oxygen standards were exceeded more than 90 percent of the time. About 50 percent of the dry weather fecal coliform and 10 percent of the dry weather total phosphorus concentrations exceeded the established standards, whereas all of the wet weather—rainfall and snowmelt—fecal coliform and phosphorus levels were substandard.

During a rainfall runoff event, the instream concentrations of biochemical oxygen demand, fecal coliform bacteria, phosphate, total phosphorus, and total nitrogen were up to 15 times greater than during dry weather periods. The data suggest that the critical instream water quality conditions in the Kinnickinnic River watershed are more likely to occur during wet weather conditions. During a rainfall runoff event, average daily transports of the above five constituents, plus chloride, to the Kinnickinnic River estuary were up to 263 times greater than during dry weather periods. This suggests that pollutants are more likely to be transported from the Kinnickinnic River watershed to the estuary and Lake Michigan during times of rainfall and snowmelt.

Wisconsin Department of Natural Resources Mitchell Field Runoff Study: 1977

Storm water quality data were collected by the Wisconsin Department of Natural Resources on several storm sewers draining parts of the General Mitchell Field Airport during the period from January 1, 1977 to December 31, 1977. Map 36 shows the 1,355-acre drainage area tributary to the major storm water outfall that was monitored. The area consists of runways, grassed areas, parking lots, an airport terminal, roads, and fuel and deicing storage facilities, as well as portions of the adjacent residential and industrial areas. A variety of water quality parameters were analyzed in this study, including heavy metals, and concurrent discharge measurements were made.

This short monitoring study is unique for three reasons. First, the study focuses on storm water runoff from a single land use, thus permitting an examination of the water quality impacts of that land use separate from the impacts of other upstream land uses. Second, water quality determinations were made at intervals as close as 10 minutes, thus permitting a detailed representation of the variation with time in the concentrations of a variety of potential pollutants as a precipitation event occurs. Third, heavy metals were included in the sampling, thus providing information on a class of potential pollutants for which very little monitoring data are available from other studies.

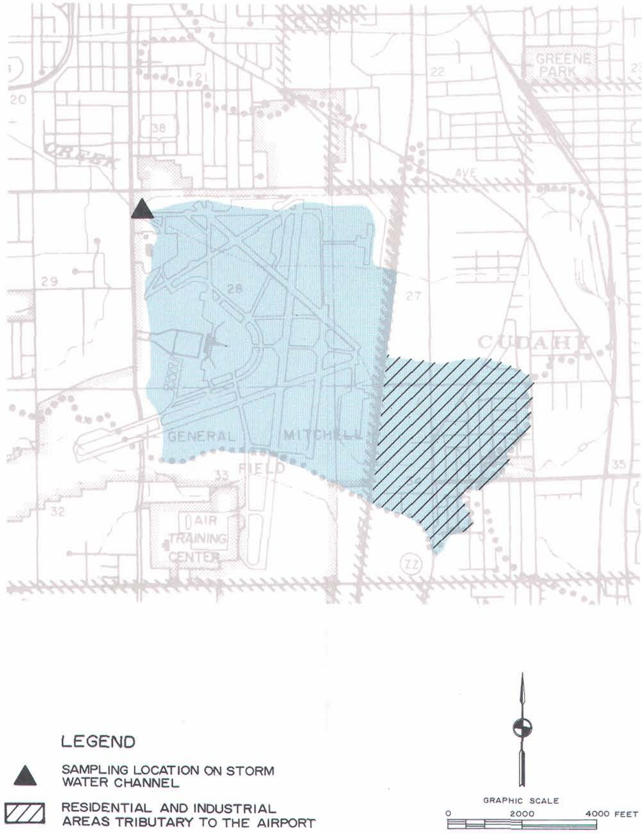
Data for the July 15 and 16, 1977 Mitchell Field storm water runoff sampling are presented in graphic form in Figure 40, which shows the variation with time of precipitation, discharge, and the concentration of selected potential pollutants during the rainfall-runoff event. The transport of selected pollutants from Mitchell Field and environs during each of six rainfall-runoff events which occurred in the summer of 1977 is summarized in Table 39.

Findings of a Preliminary Analysis: Storm water quality data collected by the Wisconsin Department of Natural Resources (DNR) on the major storm water outfall from the Mitchell Field area during the period of July and August 1977 were provided prior to publication of a report by the DNR for analysis by the Commission staff. The findings of the complete report by the DNR are included at the end of this section. The results of the Commission's analysis are as follows:

Reduction in Pollutant Concentration During Runoff Events: A phenomenon exhibited by some sampled constituents—notably suspended sediment, total phosphorus, total nitrogen, and heavy metals—during some rainfall-runoff events is the decrease in concentration of the constituents as the runoff event proceeds. For example, the July 15-16, 1977 rainfall-runoff event illustrated in Figure 40 began at 11:05 p.m. and the first total solids sample was taken during the 10-minute period between 11:15 p.m. and 11:25 p.m., during which time suspended solids were found at a concentration of 600 mg/l. During the next three consecutive 10-minute

Map 36

AREA TRIBUTARY TO MITCHELL FIELD SAMPLING STATION



The Wisconsin Department of Natural Resources monitored the quantity and quality of runoff from General Mitchell Field and tributary areas during the period from January 1, 1977 to December 31, 1977. Storm water runoff at the sampling site was found to contain concentrations of nutrients, biochemical oxygen demand (BOD), and polychlorinated biphenyl levels (PCB's) in excess of state surface water quality standards and EPA recommended criteria. The concentration of heavy metals, total phosphorus, and total nitrogen in the Mitchell Field area runoff were found to be similar to levels reported in other studies for urban roadway and parking lot storm water runoff, even though the concentrations were many times those observed in the receiving stream during dry weather flow conditions. This suggests that these substances accumulate on the land surface between washoff events in such quantities that, even though considerable dilution water is available during runoff events, the resulting average concentration of the substances in the runoff waters significantly exceeds dry weather condition concentrations in the receiving streams. The data suggest that wet weather produces the most adverse instream water quality conditions.

Source: Wisconsin Department of Natural Resources and SEWRPC.

periods, suspended solids concentrations dropped to 430, 350, and 200 mg/l, respectively. By 12:05 a.m. on July 16, the runoff had returned to approximately base flow, and the suspended sediment concentration declined to about 15 mg/l.

The reduction in concentration of various constituents with time during the runoff event reflects, in part, the nature of the washoff process. Various substances accumulate on the land surface during dry weather periods preceding runoff events so that at the beginning of the runoff event the maximum amount of material is available for washoff. As the runoff event continues, more and more material is removed from the surface and, therefore, less is available for washoff. It is generally believed that the rate at which material is carried from the land surface by the storm water runoff process is directly proportional to the amount of material remaining on the land surface—assuming that other factors, such as rainfall intensity, remain unchanged during the runoff event. This conceptual model of the washoff process is supported by suspended solids data from the Mitchell Field study and to a lesser extent by the total phosphorus, total nitrogen, and heavy metals data.

Increase in Pollutant Transport with Precipitation Volume: Another characteristic of the washoff process that is suggested by the Mitchell Field study data is the tendency for the total mass of potential pollutant washed from the land surface by a rainfall event to be proportional to the volume of precipitation that occurs during the event. Consider, for example, the mass of suspended solids washed from the airport surface during the July 17, July 29, and August 5, 1977 rainfall events. Measurable precipitation occurred on the day prior to each of these events, as indicated in Table 39. The smallest volume of precipitation occurred during the July 29, 1977 event, when 0.18 inch of rainfall transported approximately 1.2 tons of suspended sediment from the land surface. During the August 5 event, 0.54 inch of rainfall—three times that which occurred during the July 29 event—transported approximately 2.6 tons of suspended sediment from the airport surface, or two times that washed off during the July 29 event. During the July 17 event, 2.81 inches of rainfall—16 times that which occurred on July 29 and five times that which occurred on August 5—transported approximately 55 tons of suspended solids from the airport and tributary areas—about 44 times that transported during the July 29 event and 21 times that transported during the August 5 event.

Total phosphorus exhibited a similar increase in transport with rainfall volume in that the July 29, August 5, and July 17 rainfall events of, respectively, 0.18 inch, 0.54 inch, and 2.81 inches resulted in a transport of, respectively, 1.67 pounds, 5.60 pounds, and 101 pounds of total phosphorus from the airport and tributary areas. During the same three rainfall events, 10.9 pounds, 31.8 pounds, and 557 pounds of total nitrogen were flushed from the land surface as were 54 pounds, 263 pounds, and 847 pounds of chloride.

Thus, under similar antecedent precipitation conditions, the volume of potential pollutants transported from the basin during the three rainfall events increased with the volume of rainfall. The data also suggest that the rate of increase in the mass of pollutant transported is greater than the rate of increase of the precipitation volume.

Figure 40

QUANTITY AND QUALITY OF RUNOFF FROM MITCHELL FIELD AND TRIBUTARY AREA DURING THE JULY 15 AND 16, 1977 RAINFALL-RUNOFF EVENT

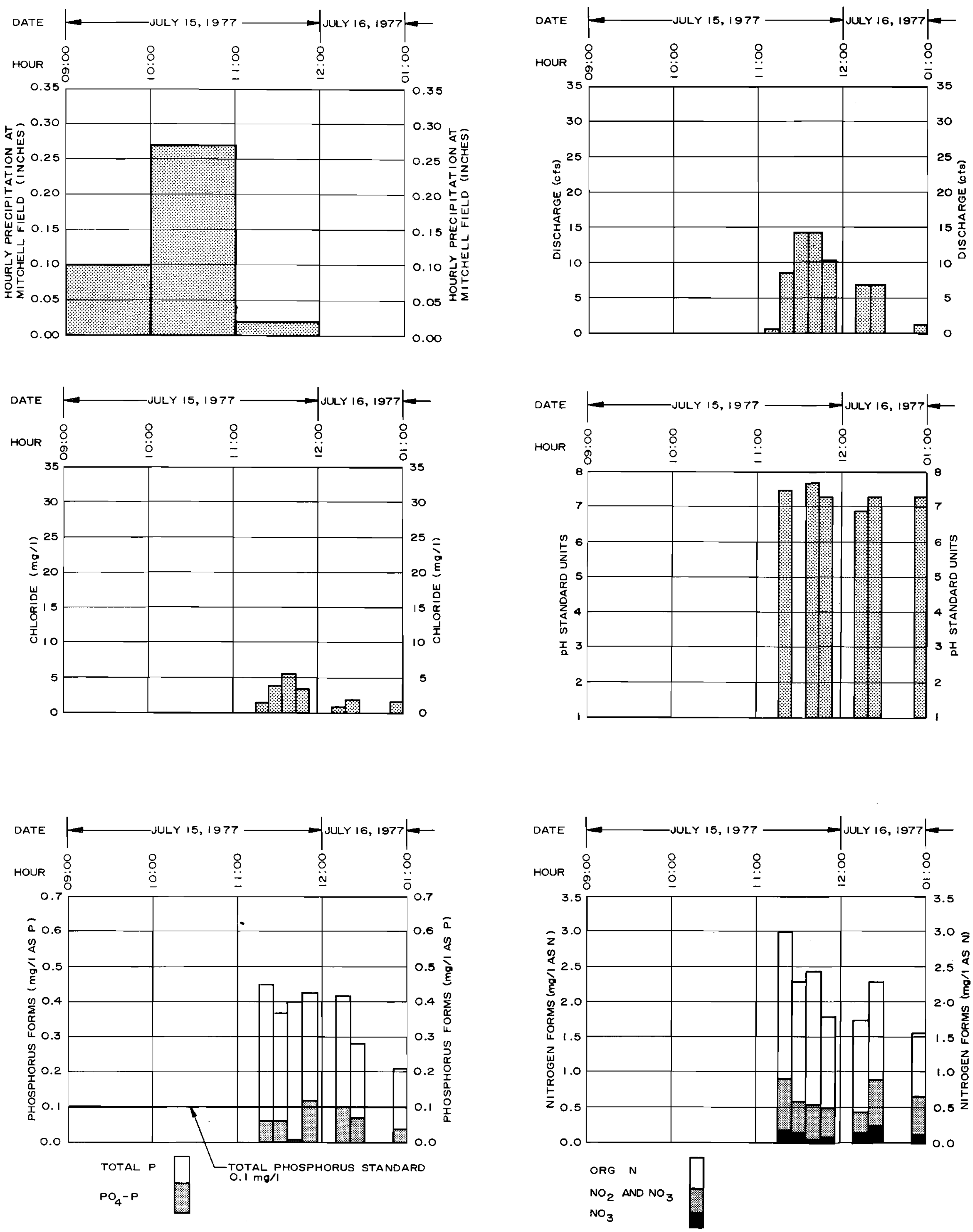
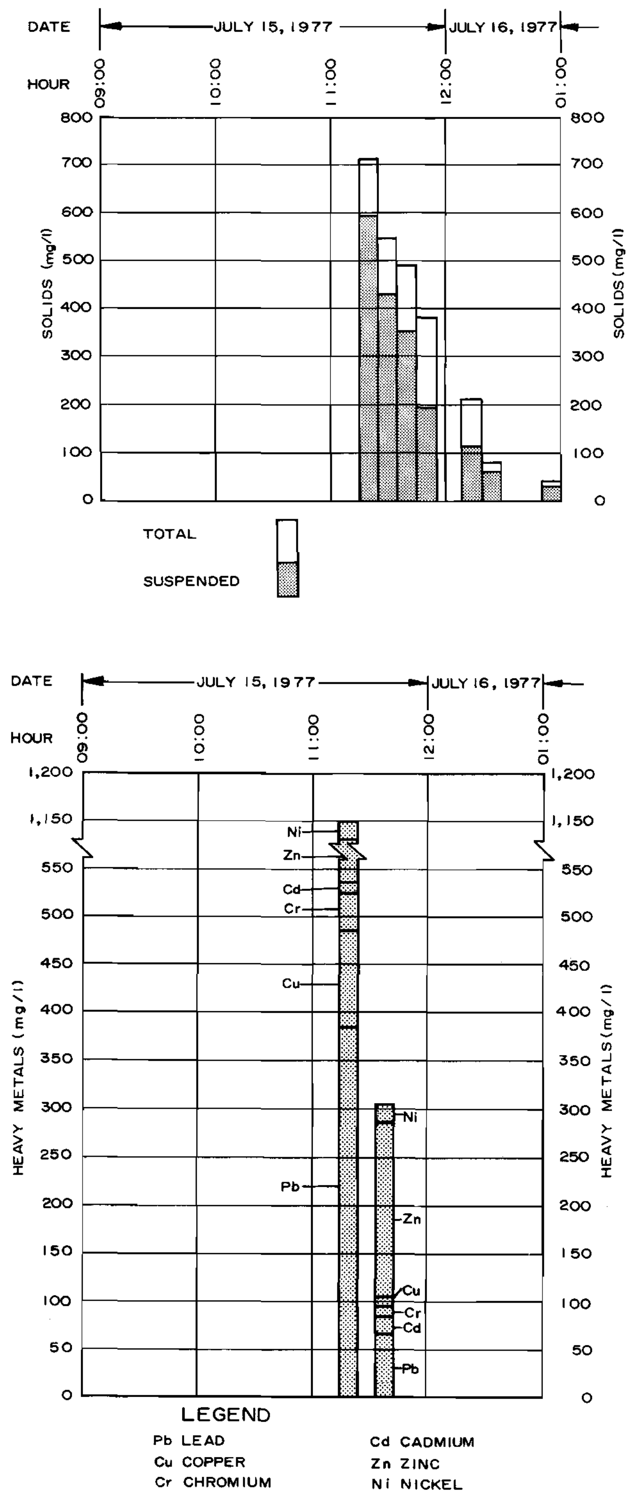


Figure 40 (continued)



Source: Wisconsin Department of Natural Resources and SEWRPC.

That is, pollutant washoff caused by very severe storms appears to be proportionately greater than pollutant transport caused by small events.

Relative Insensitivity of Pollutant Concentration to Precipitation Volume: The total volume of suspended solids, total phosphorus, total nitrogen, and chloride flushed from the airport surface during the six rainfall events was shown to be highly sensitive to the volume of rainfall. The volume of rainfall associated with each of the events ranged from a low of 0.18 inch to a high of 2.81 inches, for a ratio of maximum to minimum rainfall volumes of 16. The mass of suspended solids transported from the airport surface ranged from a low of 1,000 pounds to a high of 109,000 pounds, for a ratio of maximum to minimum values of 109. Similarly, the ratios of maximum to minimum transport of total phosphorus, total nitrogen, and chloride, were, respectively, 78, 74, and 38.

While the flow-weighted concentration of solids, total phosphorus, total nitrogen, and chloride varies from event to event, the variation in concentration is small compared to the variation in mass of pollutants transported. For example, the weighted concentration of suspended solids ranges from a low of 200 mg/l to a high of 550 mg/l for a maximum to minimum ratio of 2.75. Similarly, the ratios of maximum to minimum weighted concentration of total phosphorus, total nitrogen, and chloride were, respectively, 1.85, 2.2, and 4.3. Thus, while the mass of material transported from the Mitchell Field area is highly sensitive to the volume of rainfall that occurs, the weighted concentration of suspended solids, total phosphorus, total nitrogen, and chloride is much less sensitive to the volume of rainfall. Based on the results of these studies, there is no clearly established relationship between the volume of rainfall or runoff volume in a rainfall event and the flow-weighted concentration of various pollutants transported during the event. Because of the first flush effect, more extensive monitoring for similar antecedent conditions would probably indicate a tendency for flow-weighted concentrations to decrease with increasing rainfall or runoff volume.

Quality of Runoff Relative to Standards: Surface water quality standards are applicable to seven of the 11 parameters monitored in the Mitchell Field study; namely, total phosphorus, lead, copper, chromium, cadmium, zinc, and nickel. Based on flow-weighted concentrations, which are used to eliminate high instantaneous concentrations, the maximum allowable total phosphorus concentration of 0.10 mg/l was exceeded in all six rainfall-runoff events, with the ratio of observed concentration to the standard ranging from 2.1 to 3.9. Average observed lead, copper, chromium, cadmium, zinc, and nickel levels were well within the established standards during the five rainfall-runoff events for which heavy metals data are available.

Concentration of Potential Pollutants in Mitchell Field Runoff Compared to Downstream Dry Weather Concentrations: The concentration of heavy metals in Mitchell Field-area runoff during the summer of 1977 is signifi-

Table 39

TRANSPORT OF POTENTIAL POLLUTANTS FROM MITCHELL FIELD AREA FOR SELECTED RAINFALL EVENTS IN THE SUMMER OF 1977

Number	Antecedent Conditions (number of days) without measurable precipitation)	Rainfall Event							Runoff Volume	
		Start		Stop		Duration (hours)	Total Volume			
		Date	Time	Date	Time		(inches)	(acre-feet)	(inches)	(acre-feet)[a]
1	2	July 15	21:00	July 15	24:00	3	0.39	32.82	0.015	1.22 (3.7)
2	0	July 17	22:00	July 18	10:00	12	2.81	236.51	1.32	110.73 (46.8)
3	0	July 29	14:00	July 29	16:00	2	0.18	15.15	0.020	1.65 (10.9)
4	0	August 5	13:00	August 5	18:00	5	0.54	45.45	0.111	9.31 (20.5)
5	1	August 13	14:00	August 13	17:00	3	0.75	63.12	0.098	8.19 (13.0)
6	1	August 28	12:00	August 28	22:00	10	1.08	90.90	0.127	10.67 (11.7)

Number	Transport of Selected Pollutants in Pounds per Event										
	Solids[b]		Total[b] Phosphorus	Total[b] Nitrogen	Lead[c]	Copper[c]	Chromium[c]	Cadmium[c]	Zinc[c]	Nickel[c]	Chloride[b]
	Suspended	Total									
1	1,032 (312)	1,416 (428)	1.29 (0.39)	7.51 (2.2)	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	22 (6.6)
2	103,130 (360)	177,310 (590)	100.9 (0.37)	557.1 (1.8)	6.38 (21 μg/l)	6.60 (22 μg/l)	8.60 (29 μg/l)	0.93 (3.1 μg/l)	63.4 (211 μg/l)	5.81 (23 μg/l)	847 (2.8)
3	2,470 (550)	3,680 (820)	1.67 (0.37)	10.89 (2.4)	0.28 (62 μg/l)	0.10 (22 μg/l)	0.078 (17 μg/l)	0.0068 (1.5 μg/l)	0.96 (214 μg/l)	0.092 (20 μg/l)	54 (12)
4	5,150 (200)	10,960 (430)	5.60 (0.22)	31.79 (1.3)	1.33 (52 μg/l)	1.16 (46 μg/l)	0.28 (11 μg/l)	0.032 (1.2 μg/l)	5.42 (210 μg/l)	0.39 (15 μg/l)	263 (10)
5	9,280 (420)	13,550 (610)	6.78 (0.30)	32.42 (1.46)	0.65 (29 μg/l)	0.30 (13 μg/l)	0.12 (5.5 μg/l)	0.054 (2.4 μg/l)	3.20 (140 μg/l)	0.36 (16 μg/l)	113 (5.1)
6	5,792 (200)	22,380 (770)	6.23 (0.21)	32.60 (1.1)	0.32 (11 μg/l)	0.38 (13 μg/l)	0.11 (3.7 μg/l)	0.024 (0.82 μg/l)	3.49 (112 μg/l)	0.30 (10 μg/l)	119 (4.1)
Average[e]	343	595	0.34	1.7	23	22	24	2.7	198	21	3.6

[a] *Percent of precipitation is shown in parentheses.*

[b] *Average concentration in mg/l, based on total transport and total runoff, is shown in parentheses.*

[c] *Average concentration in μg/l, based on total transport and total runoff, is shown in parentheses.*

[d] *Insufficient sampling data to accurately determine total transport of heavy metals for this event.*

[e] *Average concentration weighted according to runoff volume.*

cantly higher than the dry weather concentration of heavy metals in Wilson Park Creek downstream of Mitchell Field as determined by monitoring between 1975 and 1976. For example, the average concentration of cadmium in Mitchell Field-area runoff from five events is about 2.7 micro-grams per liter, or approximately eight times the average of observed dry weather concentrations of cadmium—0.35 micro-gram per liter as set forth in Table 35—in Wilson Park Creek. Similarly, the average concentrations of chromium, copper, lead, nickel, and zinc in runoff from Mitchell Field and tributary areas vary from just over one to about three times the average concentrations in Wilson Park Creek. The relatively large concentrations of heavy metals in Mitchell Field runoff suggest that these metals accumulate on the watershed land surface between runoff events and are then washed off during these events. The concentration of cadmium in runoff from Mitchell Field and environs is very high compared to the concentration in downstream dry weather flow, suggesting that this heavy metal is peculiar to the Mitchell Field drainage area.

The flow-weighted concentration of total phosphorus in Mitchell Field-area runoff during the summer of 1977 was about 0.34 mg/l—three to six times that observed in recent years in the watershed surface waters during dry weather conditions. Similarly, the flow-weighted concentration of total nitrogen in Mitchell Field-area runoff was about 1.7 mg/l—about twice that observed in the watershed during dry weather conditions. These concentrations suggest that phosphorus and nitrogen compounds accumulate on the surface of Mitchell Field and environs in such quantities that, even though considerable dilution water is available during runoff events, the resulting average concentration of phosphorus and nitrogen in the runoff significantly exceeds dry weather concentrations.

Flow-weighted chloride concentrations in Mitchell Field-area runoff during the summer of 1977 average 3.6 mg/l—about 5 to 10 percent of the concentration observed in the watershed surface waters during summer dry weather conditions. However, the concentrations of heavy metals, total phosphorus, and total nitrogen are larger in storm water runoff than in the receiving stream during flow conditions. The unusual behavior of chloride suggests that the principal source of this substance during the summer is groundwater discharge to the stream, and perhaps industrial discharges and some leakage from sanitary sewers, and that very little chloride accumulates on the land surface between runoff events during the summer seasons. Therefore, the net effect of a runoff event is to dilute the chloride being carried in the stream system. This is in contrast with winter and early spring conditions when, because of recent or current street salting for deicing purposes, instream concentrations of chloride increase during rainfall and snowmelt runoff events.

Concluding Statement: The Mitchell Field study quantity-quality monitoring data for July and August 1978 reveal several phenomena apparently characteristic of the diffuse-source pollution washoff process. The data indicate a reduction in concentration of various constituents in the runoff with time during most of the runoff events, and indicate a tendency for the total mass of potential pollutants washed from the land surface by a rainfall event to be proportional to the volume of precipitation associated with the event. Another characteristic of the washoff process shown by this monitoring study is the relative insensitivity of average pollutant concentration to precipitation volume. Finally, the average concentration of many constituents in the runoff was seen to be much higher than concentrations typically found in receiving streams during dry weather conditions, and some of the average concentrations in the runoff were in excess of that specified in the applicable water quality standards for the receiving streams.

Findings of the Study: A report entitled General Mitchell Field Nonpoint Source Study was published in April 1978 by the Wisconsin Department of Natural Resources and contains the results of the monitoring study which was intended to describe airport land use with respect to water quality relationships, annual and seasonal pollutant yields associated with runoff caused by precipitation events, and similarity to other land use categories. The findings of this report may be summarized as follows:

The storm water runoff from a medium hub airport, such as General Mitchell Field, is a significant source of pollutants in that, at times, the concentrations of nutrients, suspended solids, and five-day biochemical oxygen demand (BOD_5) approximate the levels found in raw domestic sewage. State surface water quality standards and EPA recommended criteria were often exceeded in the storm water runoff samples taken during this study. However, the nutrient, solids, heavy metal, and oxygen-demand concentrations and loadings are similar to those reported in other studies for urban roadway and parking lot storm water runoff.

Analyses of constituent concentrations and loadings and their relationships to discharge indicated similar trends for most constituents. The peak constituent concentrations occur prior to or coincident with the peak discharge and the instantaneous pollutant loadings reach their peak simultaneously with the peak discharge; however, the major portion of total pollutant loading for a runoff event is contributed after the peak discharge occurs. Whereas analyses indicated that the greatest runoff event pollutant loadings are generally in correlation with the storm events that generate the largest runoff volume, a similar relationship does not hold for a seasonal comparison. The greatest seasonal pollutant yield did not occur during the season generating the largest runoff volume—summer—but rather during the season with the least runoff volume—winter—for all constituents except suspended solids. This phenomenon is attributable to the influences of other factors such as accumulation rate and time between runoff events, variation in storm event characteristics, and deicing practices and other grounds maintenance activities.

Within the airport site, sampling and examination of pollutant concentrations of small drainage areas with varying land uses indicate that several sources of pollution exist. The major sources of pollution are paved auto parking areas and airport terminal areas. The runoff from runway and infield areas containing large grass-covered areas, which help to filter the runoff, usually contains much lower pollutant concentrations.

City of Cudahy Health Department Study: 1977

On July 20, 1977 a water sample was taken from Wilson Park Creek—locally known as "Edgerton Ditch"—in the City of Cudahy and analyzed for the presence of coliform organisms. Total coliform bacteria on this dry weather day were found to be present at a concentration of at least 2,400 colonies per 100 ml. These coliform bacteria data—the only such data available for this headwater area of the watershed—suggest that the high total coliform concentrations during low flow periods may not be restricted to the lower reaches of the watershed.

Surface Water Quality Studies

Certain observations may be made and conclusions may be drawn based on the water quality data for the Kinnickinnic River watershed presented in the preceding sections of this chapter. Some characteristics of dry and wet weather water quality processes in the watershed may be identified and an overall assessment may be made as to the degree to which established water quality standards are satisfied within this highly urban watershed. More particularly, the following observations and conclusions are based largely on the historic monitoring studies in the Kinnickinnic River watershed supplemented with analyses of data and information drawn from studies of other urban watersheds.

- Most of the historic water quality monitoring information available for the watershed represents dry weather conditions. Exceptions include the 1976-1977 monitoring for the areawide water quality management planning program and the 1977 Mitchell Field runoff study—both of which focus on water quality processes during wet weather conditions.

- Relatively little information is available on either dry or wet weather-condition concentrations of potential pollutants such as heavy metals, pesticides, and PCB's.

- A marked increase in both the concentration and transport of potential pollutants or of pollution parameters such as fecal coliform bacteria, phosphate-phosphorus and total phosphorus, total nitrogen, and biochemical oxygen demand may be expected during wet weather periods as opposed to dry weather periods.

- Substandard water quality conditions, along with high concentrations of potential pollutants, are more likely to occur during wet weather conditions than during dry weather conditions and are attributable to the accumulation of pollutants on the land surface between rainfall and snowmelt events and the subsequent transport of those pollutants to the stream system by rainfall and snowmelt runoff.

- The substantial increase in available dilution water during a rainfall or snowmelt runoff event is usually more than offset by the increased quantity of potential pollutants carried into the surface water by direct runoff to the stream system occurring as overland flow, through storm sewer and channel systems, or from the shallow subsurface. One known exception is the concentration level for chloride which, because of the seasonal nature of its source—street salting operations—is not available for washoff during some periods of the year as are other substances which appear to be continuously added to the land surface between washoff events.

- The ratio of wet weather to dry weather transport is significantly greater than the ratio of wet weather to dry weather concentration because of the dilution effect in the case of the latter. That is, wet weather conditions generally have a much greater impact on the mass of pollutants transported from the watershed to the harbor-estuary area and to Lake Michigan than on the concentration of pollutants being transported.

- The established temperature standard, which specifies that surface water temperatures be less than or equal to 89°F, appears to be satisfied most of the time in the Kinnickinnic River watershed under both dry weather and wet weather conditions.

- The pH standard, which specifies that pH be within a range of 6.0 to 9.0 standard units, appears to be satisfied most of the time in the watershed during both dry and wet weather conditions.

- The dissolved oxygen standard, which specifies a concentration greater than or equal to 5.0 milligrams per liter, appears to be satisfied most of the time during both dry and wet weather conditions in the watershed. This suggests that the oxygen demand exerted by organic matter washed from the land surface during rainfall and snowmelt runoff events is offset by oxygen entrained in the storm water runoff.

- The fecal coliform standard, which specifies a fecal coliform count not exceeding 400 colonies per 100 ml, appears to be exceeded in the watershed about half the time during dry weather conditions and virtually all of the time during wet weather conditions.

- The total phosphorus standard, which specifies a concentration less than or equal to 0.1 milligram per liter, appears to be satisfied most of the time during dry weather conditions and is violated most of the time during wet weather conditions within the watershed.

- Total nitrogen concentrations may be expected to increase during wet weather conditions relative to dry weather conditions within the watershed, but not as sharply as other parameters such as fecal coliform bacteria, total phosphorus, and biochemical oxygen demand.

- Chloride concentrations in the surface waters of the Kinnickinnic River watershed are at all times well in excess of those found in more rural watersheds of southeastern Wisconsin. Chloride present in the surface waters is attributable to the use of chloride compounds for street deicing purposes during the winter. The highest instream chloride concentrations probably occur during snowmelt conditions. The effect of street deicing salt is felt throughout the year in that dry weather-condition chloride concentrations continuously decline from the end of the winter deicing period to the beginning of the subsequent winter deicing period. At all other times, instream chloride concentrations decrease significantly during wet weather conditions as the result of the dilution affect of the runoff waters. Occasional unusually high specific conductance and chloride levels, particularly when they occur long after the winter deicing period, may be indicative of accidental spills or intentional discharges of soluble substances.

- The concentrations of two heavy metals—mercury and cadmium—are known to have exceeded the established standards of, respectively, 0.05 and 12.0 micrograms per liter in the surface waters of the Kinnickinnic River watershed. During dry weather conditions the concentration of mercury exceeded the standard and during wet weather conditions the concentration of cadmium exceeded the standard.

- Concentrations of other heavy metals and of pesticides in the surface waters of the watershed may exceed established standards, but a definitive determination may not be made from available data since most of the laboratory tests were of insufficient sensitivity.

- The PCB standard, which specifies the maximum concentration of 0.001 microgram per liter, is known to have been exceeded in the surface waters of the Kinnickinnic River watershed during dry weather conditions.

- Heavy metals and PCB's tend to accumulate in the bottom sediments of the watershed, with the average concentrations of these substances in the sediment ranging from 1,000 to 20,000 times the concentrations in the flowing stream. During wet weather conditions, some of the substances contained within the bottom sediments may be brought into suspension and transported from the watershed through the scouring action of storm sewer outfalls and stream flows.

- The benthic community of the Kinnickinnic River watershed is composed of large populations of pollution-tolerant species of fauna that are indicative of polluted conditions.

- The flushing tunnel is located at the upstream end of the Kinnickinnic River estuary and, when it is operating, estuary water quality approximates that of the water being pumped from Lake Michigan into the estuary through the flushing tunnel and is superior to that of the Kinnickinnic River upstream of the estuary with respect to biochemical oxygen demand, chloride, and fecal coliform bacteria. Dissolved oxygen levels in the estuary, although less than in the Kinnickinnic River upstream of the estuary, are well above the 5.0 milligram per liter minimum standard when the flushing tunnel is in operation.

- When the flushing tunnel is not in operation, the most significant water quality effects are low to substandard dissolved oxygen levels and an increase in chloride levels, with the chloride levels approximating those of the Kinnickinnic River upstream of the estuary.

- Of the eight potential types of surface water pollution identified earlier in this chapter—toxic, organic, nutrient, pathogenic, thermal, sediment, radiological, and aesthetic—all but thermal and radiological pollution are known to exist in the Kinnickinnic River watershed.

- The surface waters of the Kinnickinnic River watershed do not meet the established warmwater fishery and aquatic life water use objectives. Although the levels of some critical parameters such as dissolved oxygen and temperature are met most of the time, it is likely that heavy metals and pesticides are at least occasionally present in levels toxic to fish and aquatic life. Furthermore, water quality conditions not withstanding, the propagation of a varied population of desirable fish species is inhibited by the extreme low flow conditions that are likely to occur periodically in the headwater areas of the watershed and by the extensive channel improvements which have virtually eliminated necessary natural habitat.

- The recreational use objective is not satisfied in the Kinnickinnic River watershed, partly because of the high levels of fecal coliform bacteria present in the surface waters and partly because of the potentially harmful effects of heavy metals, pesticides, and PCB's which may be present. In addition, the combination of existing and proposed major channelization, including extensive straightening and use of concrete bottoms and sidewalls, and the close proximity of commercial, industrial, and other urban development are likely to detract from the aesthetic value of surface waters in much of the Kinnickinnic River watershed. Notable exceptions are those portions of the watershed stream system contained within Milwaukee County parklands.

POLLUTION SOURCES

An evaluation of water quality conditions in the Kinnickinnic River watershed must include an identification, characterization, and, where feasible, quantification of known pollution sources. This identification, characterization, and quantification of pollution sources is intended to aid in determining the probable causes and sources of the water pollution problems discussed earlier in this chapter. The following types of pollution sources have been identified in the watershed and are discussed below: sanitary and combined sewer system overflows, industrial wastewater discharges, and diffuse sources.

The schematic representation of the average annual volume of water passing through various paths in the hydrologic cycle of the separate and combined sewer service areas of the Kinnickinnic River watershed and for the entire watershed are shown in Figure 41. The hydrologic budgets were prepared with output from the hydrologic submodel described in Chapter VIII of this report, supplemented with industrial point source discharge data from the Wisconsin Pollution Discharge Elimination System (WPDES). The flow associated with each of the above pollution sources reaches the surface water of the watershed by one or more of the flow paths shown in Figure 41. For example, pollutants discharged from sanitary and combined sewer overflow points will be transported as wet weather flow—surface runoff and interflow—to the stream system. Diffuse source pollutants will move along both the wet weather and dry weather—groundwater—routes from their point of origin to the stream system.

Point Source Pollution

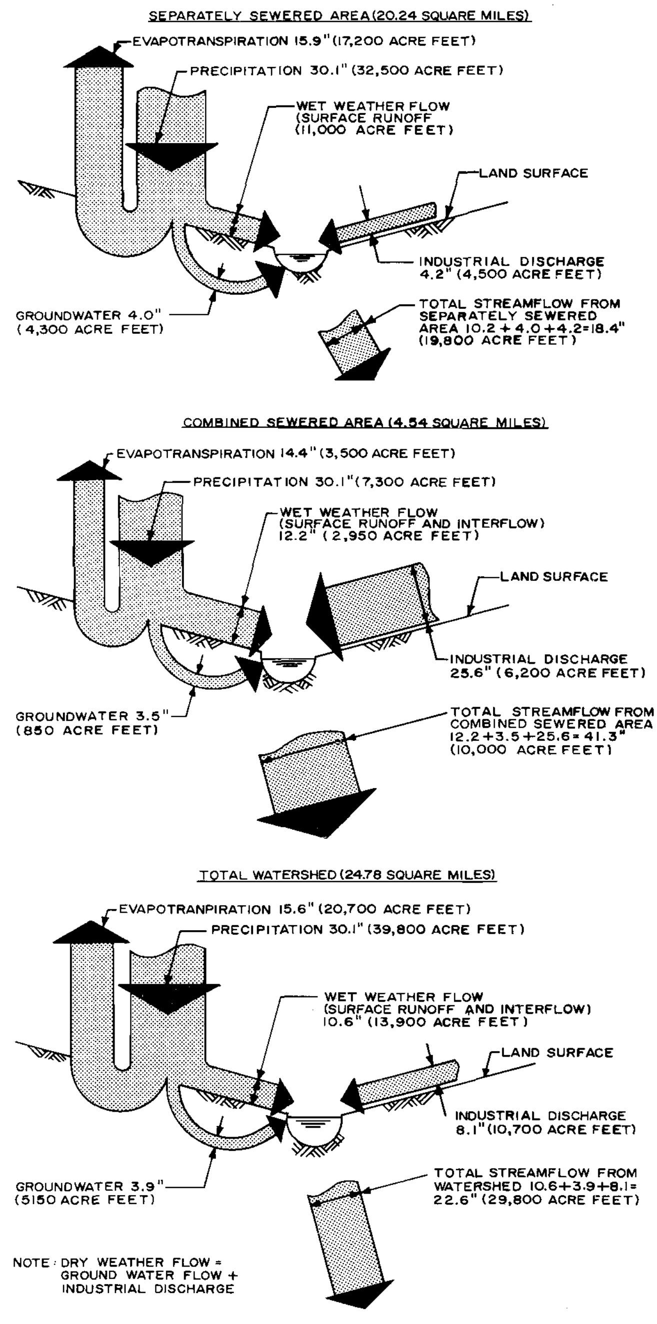
Point source pollution is defined as pollution which is discharged to the surface waters at discrete points. Examples of such discrete discharge points include sanitary sewerage system flow relief devices, sewage treatment plant discharges, and industrial discharges. A discussion of nonpoint, or diffuse, pollution sources is presented later in this chapter in conjunction with the description of diffuse pollution sources in the Kinnickinnic River watershed.

Sanitary Sewerage System Flow Relief Points: Raw sanitary sewage enters the surface water system of the Kinnickinnic River watershed either directly from combined or sanitary sewer overflows or indirectly from such overflows via separate storm sewer systems. This direct or indirect conveyance of sanitary sewage to the watershed's surface water system occurs as a result of the presence of five types of flow relief devices: combined sewer outfalls, and separate sanitary sewer crossovers, bypasses, relief pumping stations, and portable pumping stations.

Flow Relief Devices—Types and Characteristics: A combined sewer is intended to carry sanitary sewage, including domestic, commercial, and industrial wastes, at all times. During periods of rainfall or snowmelt, a combined sewer is intended also to carry storm water runoff from streets and other tributary drainage areas. A combined sewer outfall is an outlet through which a combined sewer discharges directly into a receiving body of surface water during periods of wet weather flow.

Figure 41

AVERAGE ANNUAL HYDROLOGIC BUDGET FOR SEPARATE AND COMBINED SEWER AREAS IN THE KINNICKINNIC RIVER WATERSHED



Source: SEWRPC.

The four other flow relief devices usually found in a municipal sanitary sewerage system—crossovers, bypasses, relief pumping stations, and portable pumping stations—are defined as follows:

- Crossover—A flow relief device by which sanitary sewers discharge a portion of their flow, by gravity, into storm sewers during periods of sanitary sewer surcharge or by which combined sewers discharge a portion of their flow, by gravity, into storm sewers to alleviate sanitary or combined sewer surcharge.

- Bypass—A flow relief device by which sanitary sewers entering a lift station, pumping station, or sewage treatment plant can discharge a portion or all of their flow, by gravity, into a receiving body of surface water to alleviate sewer surcharge. Also, a flow relief device by which intercepting or main sewers can discharge a portion or all of their flow by gravity into a receiving body of surface water to alleviate intercepting or main sewer surcharge.

- Relief Pumping Station—A flow relief device by which flows from surcharged main sewers are discharged into storm sewers or directly into a receiving body of surface water through the use of permanent lift or pumping stations.

- Portable Pumping Station—A point of flow relief at which flows from surcharged sanitary sewers are discharged into storm sewers or directly into a receiving body of surface water through the use of portable pumping units.

Of the five types of sewerage system flow relief devices, the combined sewer outfall and the separate sanitary sewerage system bypass always discharge directly to surface waters and therefore are located near rivers and streams. Crossovers always convey flow from a sanitary sewer to a storm sewer and, therefore, need not be located near rivers and streams but may be found anywhere in the sewered portions of urban areas. Because relief and portable pumping stations may convey flow to either storm sewers or directly to surface waters, these two flow relief devices may be found anywhere in the sewered portions of urban areas. The single most important aspect of the five flow relief devices is that each provides a mechanism whereby raw sanitary sewage can be discharged directly to the surface waters in the urban areas of a watershed, thereby posing a pollution threat in general, and a public health hazard in particular.

Number and Location of Flow Relief Devices in the Watershed: As discussed in Chapter IX, the Wisconsin Pollution Discharge Elimination System (WPDES) has been established by the Wisconsin Department of Natural Resources. This operational permit system provides a good source of data and information concerning the number, type, and location of the five types of municipal sewer system relief points in the Kinnickinnic River watershed.

Table 40 summarizes by receiving stream and sewerage system the type and number of flow relief devices in the watershed. The spatial distribution of these devices is shown on Map 37. A total of 23 combined sewer outfalls and 31 other flow relief devices are known to exist in the Kinnickinnic River watershed. Of this total of 54 known municipal sewer system relief devices, 42, or almost 78 percent, discharge directly or indirectly to the Kinnickinnic River. About 81 percent of all the flow relief devices in the Kinnickinnic River watershed, including all of the combined sewer overflows, are located within the City of Milwaukee.

Quantity and Quality of Flow Release Device Discharges: Combined Sewer Overflows: The estimates of the volume of runoff contributed by the combined sewer overflow devices were based in part on output from the hydrologic submodel, discussed in Chapter VIII of the report, which was used to determine that the average annual surface runoff from the pervious and impervious surfaces in the 4.54-square-mile combined sewer service area of the watershed is about 9.8 inches. Assuming that this runoff constitutes the dominant input to the annual volume of flow transported through the combined sewer system and that essentially all of this spills to the Kinnickinnic River, the average annual discharge from the 4.5-square-mile combined sewer service area is 770 million gallons.

The above discussion implies that: 1) the volume of sanitary sewage carried in the combined sewers and the volume of groundwater infiltration in the combined sewers during combined sewer overflow events are a very small portion of the volume of combined sewage that is discharged; and 2) all direct runoff entering the combined sewers spills to the surface waters. These two assumptions are reasonable and, furthermore, tend to be compensating in that the former would result in a slight underestimate of combined sewer overflows whereas the latter would tend to result in a slight overestimate of combined sewer overflows.

The estimated average annual discharge through the 23 Kinnickinnic River watershed combined sewer overflows to the Kinnickinnic River of 770 million gallons—equivalent to 2.8 inches over the surface of the combined sewer service area—is about 8 percent of the average annual runoff from the watershed. That is, less than one-tenth of the flow that leaves the Kinnickinnic River watershed on an annual basis enters the stream system via combined sewer outfalls.

The concentration of pollutants in discharges from combined sewer overflow devices may, for any given device, be expected to exhibit wide variations with time during the overflow event as the impact of the initial quantity of solid material settled in the combined sewers is flushed through the overflow device and as continuing flow dilutes the remaining substances. In addition, the concentration of pollutants from different combined sewer overflow devices may be expected to exhibit wide variations based on the design and condition of the device and on the characteristics of the tributary area. Estimates of the average annual contribution of selected pollutants

Table 40

KNOWN COMBINED SEWER OUTFALLS AND OTHER FLOW RELIEF DEVICES IN THE KINNICKINNIC RIVER WATERSHED: 1977

Receiving Stream	Sanitary Sewerage System	Combined Sewer Outfalls[a]	Other Flow Relief Devices[a]				Total
			Crossovers	Bypasses	Relief Pumping Stations	Portable Pumping Stations	
Kinnickinnic River	City of Milwaukee	23	10[b]	0	0	0	33
	Milwaukee-Metropolitan Sewerage Commissions	0	0	2	1	0	3
	City of West Allis	0	2	0	0	4	6
Wilson Park Creek	City of Milwaukee	0	6	0	0	0	6
	Milwaukee-Metropolitan Sewerage District	0	0	1	1	0	2
Lyons Park Creek	City of Milwaukee	0	3	0	0	0	3
	Milwaukee-Metropolitan Sewerage District	0	0	1	0	0	1
Total	--	23	21	4	2	4	54

[a] *Based on Wisconsin Pollution Discharge Elimination System Permits as of June 1977.*

[b] *As of December 1976, four of these 10 have been eliminated by the City of Milwaukee.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

from the combined sewer service area of the Kinnickinnic River watershed are presented later in this chapter. More specifically, the average annual contribution of suspended sediment, biochemical oxygen demand, phosphate-phosphorus, total phosphorus, total nitrogen, and dissolved solids from the combined sewer service area are estimated using several analytic techniques.

Quantity and Quality of Other Flow Relief Device Discharges: The average annual discharge from the 21 crossovers, four bypasses, two relief pumping stations, and four portable pumping stations directly or indirectly to the Kinnickinnic River watershed surface waters is very small relative to the volume contributed by the combined sewer overflows. Based on findings of the Commission's areawide water quality planning program, the average annual discharge of a typical flow relief device is about 2 million gallons.[10] Therefore, the average annual flow contributed by the 31 flow relief devices in the Kinnickinnic River watershed, excluding the 23 combined sewer overflows, is approximately 62 million gallons, equivalent to 0.15 inch over the surface of the watershed. This volume is about 8 percent of the average annual contribution of the combined sewer overflows and about 0.6 percent of the average annual discharge from the watershed.

As is the case with combined sewer overflows, discharges from other flow relief devices are likely to exhibit wide variation in quality due to the age, condition, and design of the devices coupled with the natural and man-made characteristics of the tributary area. A review of the limited data available[11,12] on the quality of discharges from crossovers, bypasses, and relief and portable pumping stations supported an assumption that the wastewaters discharged are generally characterized by an average concentration of 30 mg/l of suspended solids, 30 mg/l of biochemical oxygen demand, 1 mg/l of total phosphorus, 3 mg/l of total nitrogen, 5 mg/l of chloride, and 100,000 fecal coliform organisms per 100 ml. Although these concentrations represent average pollutant levels for the entire period that discharge occurs through a flow relief device, much higher concentrations are likely to occur at the beginning of the discharge event because of the first flush of solids accumulated in the sanitary sewers.

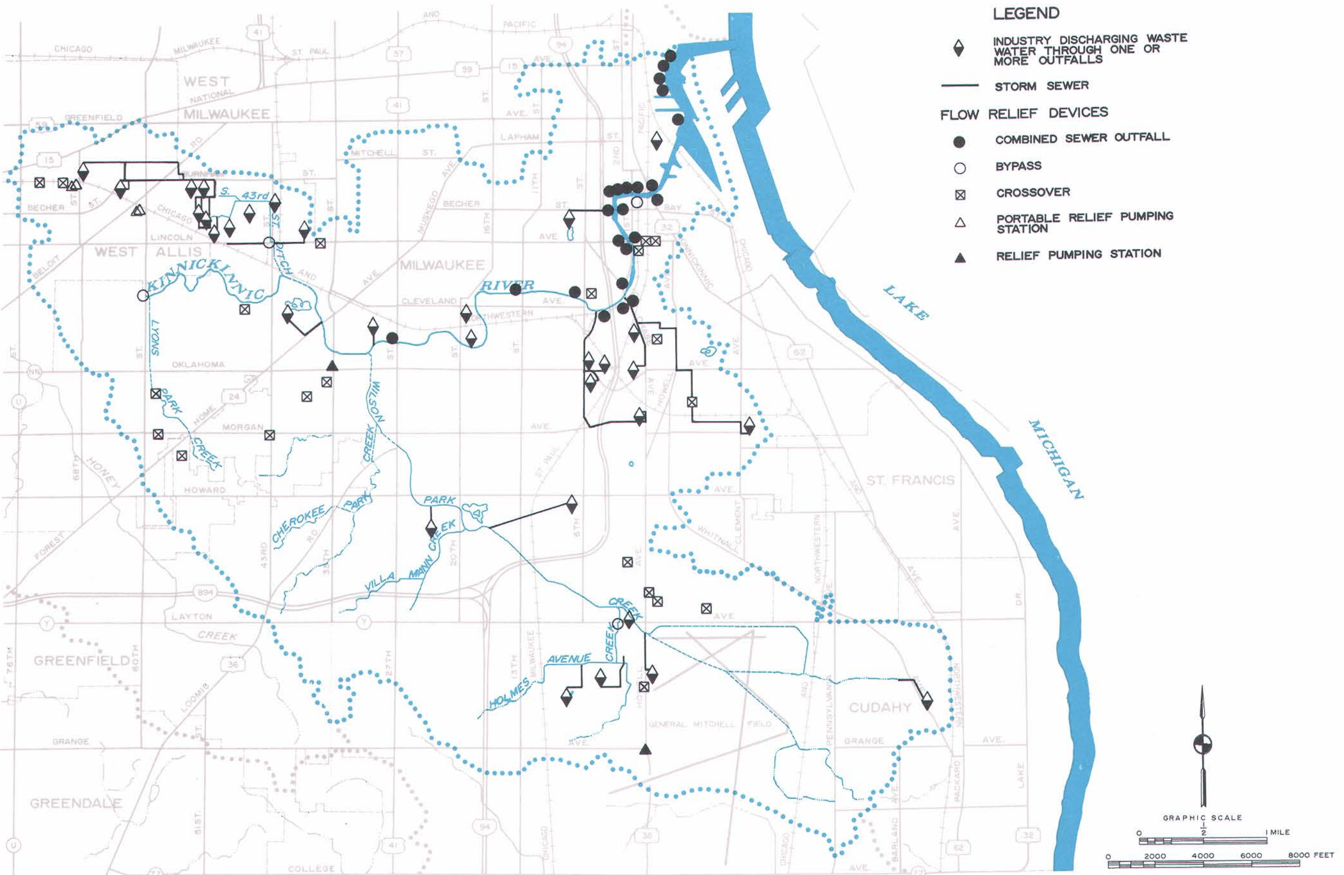
[10] *See Chapter III of SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975.*

[11] *See SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume Two, Alternative Plans and Recommended Plan, October 1976.*

[12] *See SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume One, Point Sources, July 1977.*

Map 37

POINT SOURCES OF WATER POLLUTION IN THE KINNICKINNIC RIVER WATERSHED



A total of 84 known point sources of pollution existed in the Kinnickinnic River watershed in 1977. These consisted of 23 combined sewer outfalls and 31 sanitary sewer relief devices which discharged raw sewage to the river system during periods of wet weather and sewer discharge; and 30 indicates discharging wastewaters through 84 outfalls. These industries discharged primarily cooling and process waters to the river system. There are no sewage treatment plants discharging treated waste water to the watershed stream system since all of the watershed is served by public sanitary sewerage facilities with the sewage being collected and transmitted, for treatment and disposal, to the Jones Island and Southshore treatment plants located outside of the watershed and the shore of Lake Michigan.

Source: SEWRPC.

Applying these concentrations to the above-estimated flow relief device discharge of 62 million gallons per year results in average annual contributions of suspended solids, biochemical oxygen demand, total phosphorus, total nitrogen, and chloride to the surface waters of, respectively, 8, 8, 0.3, 0.8, and 1.3 tons, and an average annual contribution of fecal coliform bacteria of 2.4×10^{14} colonies. A comparison of these loads with the average annual transport of the same substances from the watershed as presented later in this chapter under the subtopic of diffuse source pollution indicates that the annual contribution from crossovers, bypasses, and relief and portable pumping stations of total suspended solids, biochemical oxygen demand, total phosphorus, total nitrogen, and chloride constitutes, respectively, 0.7, 1.7, 1.9, 1.2, and less than 1.0 percent of the average annual transport of these materials from the watershed. Therefore, the pollution load contributed by flow relief devices other than combined sewer overflow devices is very small compared to the pollution load contributed by other sources in the watershed.

Concluding Statement: Significance of Flow Relief Devices: While the above analyses indicate that flow relief devices other than combined sewer overflows contribute relatively small proportions of the total pollution load on the surface waters of the Kinnickinnic River watershed, pollutant concentrations from such flow relief devices may constitute serious local health hazards and create objectionable aesthetic conditions. Therefore, efforts should be continued to eliminate the discharge of sanitary sewage through flow relief devices. Disease-carrying bacteria, viruses, and other organisms are likely to be concentrated in backwater pools or on the ground in the vicinity of flow relief devices during and immediately after precipitation events and these organisms and the diseases they carry could be contacted by unwary individuals, particularly children who may not understand the hazardous situation. Furthermore, health considerations aside, the appearance of and odors associated with feces and other human waste floating on the streams in an urban area constitute a highly objectionable condition from a strictly aesthetic perspective.

It is noteworthy that the identification of flow relief devices has important implications not only for the resolution of health hazards and aesthetic problems as discussed above, but also for the resolution of sanitary sewer surcharge with attendant structure water damage, public health hazards, and operating problems at sewage treatment plants. The presence and frequent operation of flow relief devices are symptomatic of sanitary sewers being surcharged by excess sanitary sewage flows not anticipated in the design of the system; clear water that enters the system during rainfall-snowmelt events as inflow through flooded manhole covers and through downspouts, footing tile drains, and sump pump discharge lines connected directly to the sanitary sewer system; and by groundwater infiltration through cracked or broken joints, pipes, and manhole walls.

The presence of extensive amounts of sewage and/or clearwater in the sanitary sewer system may cause basement flooding as sanitary sewers backup into basements and may also cause hydraulic overloads at sewage treatment plants. The latter necessitates bypassing of untreated sewage and sometimes leads to damage to treatment units and pumping facilities. The first problem—a combination "flood" damage and health hazard problem—is of direct concern to individual property owners while the second is of concern to community officials charged with the responsibility of operating sewage treatment facilities so as to provide adequate treatment while protecting costly equipment from damage.

Consequently, a reduction in the frequency of operation and, to the extent possible, the elimination of flow relief devices is desirable. It is important to note, however, that sound engineering practice requires the existence of a minimum number of flow relief devices at critical points in the sanitary sewerage system to operate as "safety valves" during true emergencies such as power outages at pumping or lift stations or at sewage treatment plants.

In summary, while flow relief devices may not contribute a significant proportion of the total pollution loading on the Kinnickinnic River relative to other pollution sources, the identification and elimination of all but a few selected ones at critical points in the system are important for the following reasons: flow relief devices are likely to constitute health hazards in the immediate vicinity of the discharge point; they may be expected to cause objectionable aesthetic conditions in the receiving streams; and they are symptomatic of excessive clear water entering into the sanitary sewer system and, therefore, of basement flooding and attendant health hazards, and of hydraulic overloads at sewage treatment facilities.

The Combined Sewer System—Previous Studies, Recommendations, and Progress Toward Implementation:

The Combined Sewer System: The 4.54-square-mile combined sewer service area, tributary via the 23 combined sewer outfalls to the Kinnickinnic River, is shown on Map 9 in Chapter III. The Kinnickinnic River watershed combined sewer system is part of a large contiguous combined sewer service area encompassing a total of about 27 square miles and including portions of the City of Milwaukee and the Village of Shorewood in Milwaukee County. During significant rainfall and snowmelt events, this combined sewer service area discharges combined sewage to the Menomonee, Milwaukee, and Kinnickinnic Rivers and to Lake Michigan.

Findings of the Milwaukee River Watershed Study: The entire Milwaukee metropolitan area combined sewer system was inventoried and analyzed under the Milwaukee River watershed planning program conducted by the Commission, the results of which were published in October 1971. In light of this work, the combined sewer service area in the Kinnickinnic River watershed was not subjected to extensive analysis under the Kinnickinnic River watershed planning program. The principal findings of the Milwaukee River watershed plan as they relate to the combined sewer overflow problem are as follows:

- Until the mid-1920's, no treatment of sanitary sewage was provided in the Milwaukee area, with raw sewage being discharged directly to receiving watercourses. Since that time, and partly as a result of severe outbreaks of typhoid fever within the Milwaukee area, the Milwaukee-Metropolitan Sewerage Commissions have constructed two large sewage treatment plants and an extensive system of main, relief, and intercepting sewers. The intercepting sewers in the combined sewer service area generally parallel the Menomonee, Milwaukee, and Kinnickinnic Rivers.

- During dry weather periods, the sanitary sewage from the combined sewer service area is conveyed via the interceptor sewers to the treatment facilities.

- An analysis of the potential effects of overflows from the 2,100-acre combined sewer service area above the North Avenue dam on the Milwaukee River revealed that such overflows have a frequent, severe, adverse impact on river water quality and that in the presence of such overflows the river is unfit for any type of desirable fish and aquatic life and for recreational uses. Similar conclusions may be drawn by inference for other portions of the Milwaukee metropolitan-area combined sewer system.

Recommendations of the Milwaukee River Watershed Plan: After a preliminary screening of 15 alternatives and a more detailed study and analysis of three of those 15 alternatives, it was recommended that a combination deep tunnel mined storage/flow-through treatment alternative be included in the comprehensive Milwaukee River watershed plan as the major water pollution abatement plan element for the lower Milwaukee River. It was further recommended that a preliminary engineering study be undertaken to determine with greater precision and detail the most effective combination of storage and flow-through treatment, and the best configuration of the recommended system as required to serve the entire 27-square-mile combined sewer service area in Milwaukee County.

Progress Toward Implementation: The Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee, acting jointly at a meeting held on April 20, 1973, requested the Southeastern Wisconsin Regional Planning Commission to further explore the means for initiating the above preliminary engineering study and to prepare a prospectus for the study. The Commission, in turn, created a technical advisory committee of knowledgeable and experienced sanitary and public works engineers from within the Region to assist it in the preparation of the prospectus. The Prospectus-Preliminary Engineering Study for Abatement of Pollution from Combined Sewer Overflow in the Milwaukee Metropolitan Area was published by the Southeastern Wisconsin Regional Planning Commission in July 1973. It outlined the general scope and content of the preliminary engineering study required to implement the combined sewer overflow pollution abatement recommendations contained within the adopted Milwaukee River watershed plan, recommended an effective means for organizing and accomplishing the required study, recommended a practical time sequence and schedule for the study, provided sufficient cost data to permit development of an initial budget for the study, and suggested the possible allocation of costs among the various levels and units of government concerned.

In October 1974 the Milwaukee-Metropolitan Sewerage Commissions, using a federal sewerage facilities planning grant, retained the services of a consulting firm to conduct the preliminary engineering study for the abatement of combined sewer overflow in the Milwaukee metropolitan area. The study was intended to provide firm recommendations for construction of sewage conveyance and treatment facilities so as to abate pollution from the entire combined sewer service area. It is important to emphasize that this study includes that portion of the combined sewer service area tributary to the Kinnickinnic River and will culminate in specific recommendations for abatement of the combined sewer overflow in the Kinnickinnic River watershed. As of the end of 1977, the consulting firm conducting the preliminary engineering study concluded that the optimum solution to the combined sewer overflow problem was a system of underground conveyance and storage facilities provided with a means of treatment prior to discharge of the collected combined sewer overflow to Lake Michigan. This recommendation was approved by the Milwaukee-Metropolitan Sewerage Commissions and the consulting firm was proceeding with development of detailed plans for the conveyance-storage-treatment facilities.

The case of the People of the State of Illinois versus the City of Milwaukee was heard by the Honorable John F. Grady during the period January 11, 1977 through July 29, 1977. In his July 29, 1977 Findings of Fact and Conclusion of Law, Judge Grady ordered that "all overflows shall be eliminated." In the Judgement Order approved by Judge Grady on November 14, 1977, the Milwaukee-Metropolitan Sewerage Commissions were ordered to construct, by December 31, 1989, a combined sewer overflow collection and conveyance system having a storage capacity of not less than 2,605 acre-feet. This minimum storage volume is based on an analysis of rainfall events for the 37-year period beginning in 1940. The minimum storage would prevent overflow from the combined sewer system for all rainfall events that occurred during that historic period.

Industrial Discharges: In a number of locations in the Kinnickinnic River watershed, industrial wastewater consisting primarily of cooling and process water is discharged directly or indirectly to the surface water system. This industrial wastewater enters the Kinnickinnic River and its major tributaries as direct discharge or reaches the surface waters via drainage ditches and storm sewers. These discharges are of concern primarily because they may contain toxic substances and high concentrations of suspended solids as well as other pollutants.

Number and Location of Industrial Discharges: As described in Chapter IX, the Wisconsin Pollution Discharge Elimination System (WPDES) has been established by the Wisconsin Department of Natural Resources. Data and information provided by this system were used to determine the type and location of industrial discharges in the Kinnickinnic River watershed.

Table 41 summarizes by receiving stream and civil division the type and number of industrial discharges in the watershed and Map 37 illustrates their spatial distribution. Of the total of 30 industries discharging wastewaters through the 60 outfalls known to exist in the watershed, Table 41 indicates that only half of the outfalls discharge of cooling water. About 65 percent of the industrial wastewater outfalls discharge directly or indirectly to the Kinnickinnic River. More than half of the known industrial discharges in the watershed are located in the City of Milwaukee, with the remainder being located in the Cities of West Allis and Cudahy and the Village of West Milwaukee.

Quantity and Quality of Industrial Discharges: Data are only now becoming available on the quantity and quality of water discharged from industries as a result of the initiation of the Wisconsin Pollution Discharge Elimination System described in Chapter IX of this report. Table 42, which was prepared using that data base, indicates that the average annual total volume of dis-

Table 41

KNOWN INDUSTRIAL WASTEWATER OUTFALLS IN THE KINNICKINNIC RIVER WATERSHED BY RECEIVING STREAM AND CIVIL DIVISION: 1977

Receiving Stream	Civil Division	Number of Outfalls by Type of Discharge[a]									
		Cooling Water	Process Water	Cooling and Process Water	Cooling, Process, and Boiler Blowdown Water	Test and Cooling Water	Swimming Pool Overflow and Emptying	Filter Backwash	Auto Wash Water	Oil Contaminated Storm Water	Total Outfalls
Kinnickinnic River	City of Milwaukee	7	4	6	3	3	2	1	1	0	27
	City of West Allis	5	0	0	2	0	0	0	0	0	7
	Village of West Milwaukee	5	0	0	0	0	0	0	0	0	5
Wilson Park Creek	City of Milwaukee	0	0	0	0	0	1	0	0	1	2
	City of Cudahy	2	0	0	0	0	0	0	0	0	2
43rd Street Ditch	City of Milwaukee	1	0	0	0	0	0	0	0	0	1
	Village of West Milwaukee	2	0	0	0	0	0	0	0	0	2
	City of West Allis	7	1	4	0	0	0	0	0	0	12
Holmes Avenue Creek	City of Milwaukee	1	0	0	0	0	1	0	0	0	2
Total	--	30	5	10	5	3	4	1	1	1	60

[a] *Based on Wisconsin Pollution Discharge Elimination System Permits as of June 1977.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 42

CHARACTERISTICS OF INDUSTRIAL DISCHARGES IN THE KINNICKINNIC RIVER WATERSHED: 1977

Characteristic	Units	Separately Sewered Area (20.24 square miles)	Combined Sewered Area (4.54 square miles)	Total Watershed (24.78 square miles)
Total Discharge	Cubic Feet per Second	6.29	8.55	14.84
	Inches	4.2	25.6	8.1
	Acre-Feet	4,500	6,200	10,700
Biochemical Oxygen Demand (ultimate[a])	Tons per Year	1.8	7.5	9.3
Phosphate-Phosphorus	Tons per Year	0.0	1.1	1.1
Total Phosphorus	Tons per Year	0.1	1.6	1.7
Total Nitrogen	Tons per Year	0.3	1.5	1.8
Chloride	Tons per Year	10.6	2.4	13.0
Dissolved Solids	Tons per Year	315	8	323

[a] *To approximate the five-day biochemical oxygen demand (BOD), multiply by 0.80.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

charge contributed by industrial sources to the surface waters of the Kinnickinnic River watershed is 10,700 acre-feet, or 3,500,000,000 gallons—equivalent to 8.1 inches over the land surface of the watershed. The table also sets forth estimated average annual contributions of six water quality parameters.

As indicated in Figure 41, the average annual total flow from the watershed—wet weather flow plus dry weather flow including point source discharge—is equivalent to 22.6 inches over the land surface of the watershed and the average annual dry weather flow—3.9 inches of groundwater and 8.1 inches of industrial point source discharge—is 12.0 inches. Therefore, industrial sources constitute an important component of the hydrologic budget of the Kinnickinnic River watershed—one-third of the total average annual flow and about two-thirds of the dry weather flow.

The concentration of pollutants and discharges from industrial point sources may be expected to exhibit a wide variation from source to source, and in some cases, with time at a given source. Table 42 indicates the average annual contributions of biochemical oxygen demand, phosphate and total phosphorus, nitrogen compounds, chloride, and total dissolved solids from industrial point sources to the surface waters of the watershed for the separate and combined sewer service areas. A comparison of these loads with the average annual total transport of the same substances from the watershed as presented later in this chapter under the subtopic of diffuse source pollution indicates that the average annual contribution of biochemical oxygen demand, phosphate-phosphorus, total phosphorus, total nitrogen, chloride, and total dissolved solids from industrial point sources constitutes, respectively, only 2, 14, 11, 3, 1, and 3 percent of the average annual transport of these materials from the watershed. Therefore, the annual pollution load contributed by the 60 industrial point sources in the Kinnickinnic River watershed is very small compared to the annual pollution load contributed by other sources in the basin.

While the industrial point sources are not major contributors of pollutants to the surface waters of the Kinnickinnic River watershed on an average annual basis, they are important sources of some forms of pollution during dry weather conditions, which encompass about 82 percent of the days in an average year and during which streamflow consists of industrial discharge and groundwater flow. The average annual dry weather condition contributions from industrial point sources to the surface waters of the watershed are estimated to be as follows: five-day biochemical oxygen demand (BOD_5), 5.9 tons; phosphate-phosphorus, 0.9 tons; total phosphorus, 1.4 tons; total nitrogen, 1.5 tons; chloride, 10.5 tons; and total dissolved solids, 270 tons. A comparison of these loads with the average annual dry weather condition transport of the same substances from the watershed as presented later in this chapter under the subtopic of diffuse source pollution indicates that the average annual dry weather condition contribution from industrial point sources of biochemical oxygen demand, phosphate-phosphorus, total phosphorus, total nitrogen, chloride, and total dissolved solids constitutes, respectively, 8, 100, 100, 10, 5, and 4 percent of the average annual transport of these materials from the watershed. Therefore, the relative pollution load contributed by the 60 industrial point sources in the Kinnickinnic River watershed is more significant during dry weather conditions than on an annual basis when dry and wet weather conditions are combined. This is particularly true for phosphate and total phosphorus in that the total dry weather load of these substances is attributed to point sources.

Diffuse Source Pollution

Definition and Characteristics of Diffuse Source Pollution: Diffuse source pollution, also referred to as nonpoint source pollution, consists of various discharges of pollutants to the surface waters which cannot be readily identified as point sources. Diffuse source pollution is transported from the rural and urban land areas of a watershed to the surface waters by means of direct runoff from the land via overland routes, via storm sewers and channels, and by interflow during and shortly after rainfall or rainfall-snowmelt events. Nonpoint source pollution also includes pollutants conveyed to the surface waters via groundwater discharge—baseflow—which is a major source of streamflow between runoff events.

The distinction between point and nonpoint or diffuse sources of pollution is somewhat arbitrary since a diffuse source pollutant, such as sediment being transported in overland rainfall runoff, can be collected in open channels or in storm sewers and conveyed to points of discharge, such as a storm sewer outfall. Thus, for purposes of this report, diffuse source pollution includes substances washed from the land surface or subsurface by rainfall and snowmelt runoff and then conveyed to the surface waters by that runoff, even though the entry into the surface waters may be through a discrete location such as a storm sewer outfall.

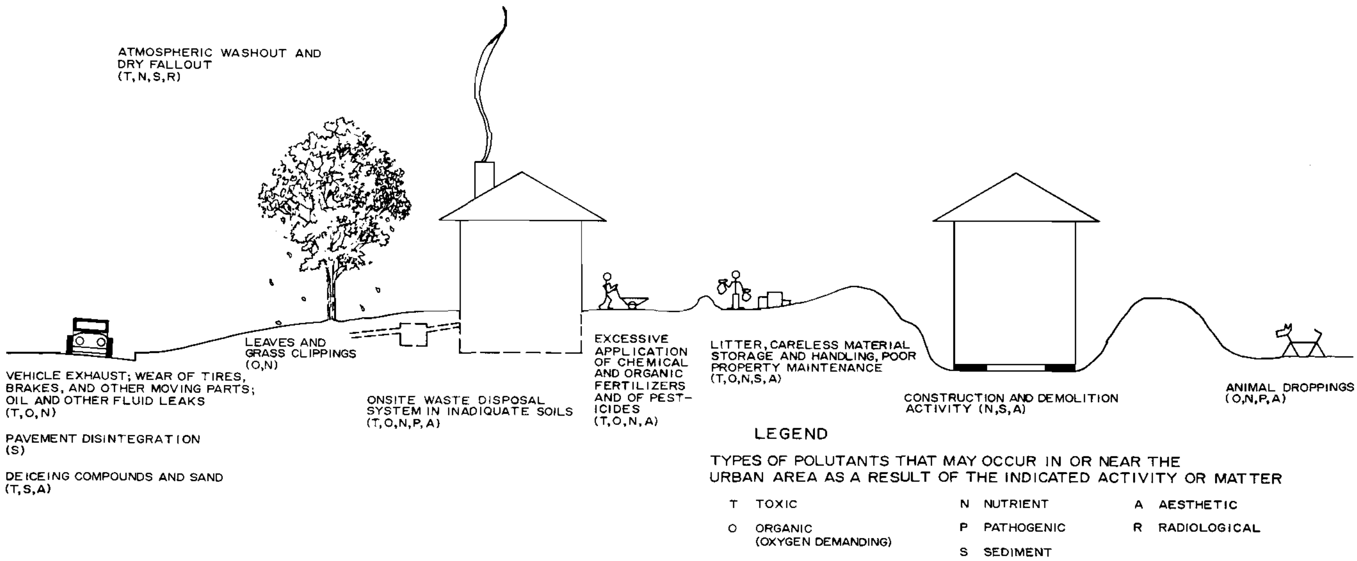
For purposes of this chapter, combined sewer outfalls are considered to be point sources of pollution. The designation of combined sewer outfalls as point sources is another example of the somewhat arbitrary nature of the distinction between point and nonpoint sources of pollution in urban areas. For example, although combined sewer outfalls may be considered point sources of pollution since the entry of the pollutants into the surface waters is at a discrete location, discharge from combined sewer outfalls exhibits behavior characteristic of nonpoint source pollution; namely, flow and pollutant loads occur primarily during and immediately after rainfall or snowmelt events; most of the water discharged is derived directly from rainfall or snowmelt; both discharge rate and pollutant concentration vary markedly with time; and most analytic tools and techniques available for estimating pollutant loads from combined sewer service areas are dependent on areal characteristics rather than on the number and location of outfalls. Thus, in order to provide consistency between the Kinnickinnic River watershed study and the areawide water quality study, combined sewer outfalls are categorized as point sources of pollution.

Diffuse source pollution is similar in content to point source pollution in that it can cause toxic, organic, nutrient, pathogenic, sediment, radiological, and aesthetic pollution problems. Nonpoint source pollution is becoming of increasing concern in water resources plannin and engineering as efforts to abate point source pollution become increasingly successful. The control of diffuse source pollution is a necessary second step in the two-step process of improving surface waters to render such waters suitable for full recreational use and a healthy fishery.

Diffuse source pollution generally differs from point source pollution in one important respect: diffuse source pollution is transported to the surface water at a highly irregular rate in that large portions of the overall transport occur during rainfall or snowmelt events. In the dry period after washoff events, potential diffuse source pollutants gradually accumulate on the land surface as a result of man's activities, becoming available for transport to the surface waters during the next runoff event (see Figure 42). The following activities of man, or effects

Figure 42

IMPACT OF URBANIZATION ON THE AVAILABILITY OF POTENTIAL POLLUTANTS ON OR NEAR THE LAND SURFACE



Source: SEWRPC.

of man's activities, result in diffuse source pollution: 1) dry fallout and washout of atmospheric pollution; 2) vehicle exhaust and lubricating oil and fuel leakage; 3) the gradual wear and disintegration of tires, pavements, structures, and facilities; 4) improper disposal of grass clippings and leaves; 5) improperly located and maintained onsite wastewater disposal systems; 6) poor soil and water conservation practices; 7) excessive use of fertilizers and pesticides; 8) debris, careless material storage and handling, and poor property maintenance; 9) construction and demolition activity; and 10) application of deicing salts and sand. It should also be pointed out that domestic and wild animal litter is also a source of diffuse pollution.

With respect to spatial distribution, the potential source of diffuse pollution in the Kinnickinnic River watershed consists of its entire 24.78-square-mile surface. The characteristics and impact of that potential pollution cannot be readily or completely determined, however, because of the lack of necessary qualitative and quantitative data for the watershed. The results of examination of the available data sources and application of several analytic techniques are presented below to illustrate some characteristics of diffuse source pollution and to indicate its importance relative to point source pollution in the Kinnickinnic River watershed.

Existing Storm Water Drainage Systems: Storm water drainage facilities are defined, for purposes of this report, as conveyances—including but not limited to subsurface pipes and conduits, ditches, channels, and appurtenant inlet, outlet, storage, and pumping facilities—located in urbanized areas and constructed or improved and operated for purposes of collecting storm water runoff from tributary drainage areas and conveying such runoff to natural water courses for disposal. In the larger and more intensely developed urban communities such as those found in the Kinnickinnic River watershed, these facilities generally consist of complete, largely piped, storm water drainage systems which have been planned, designed, and constructed as systems in a manner similar to sanitary sewer and water utility systems. In other smaller and less intensely developed urban communities of southeastern Wisconsin, these facilities tend to consist of fragmented or partially piped systems incorporating open surface channels to as great a degree as possible.

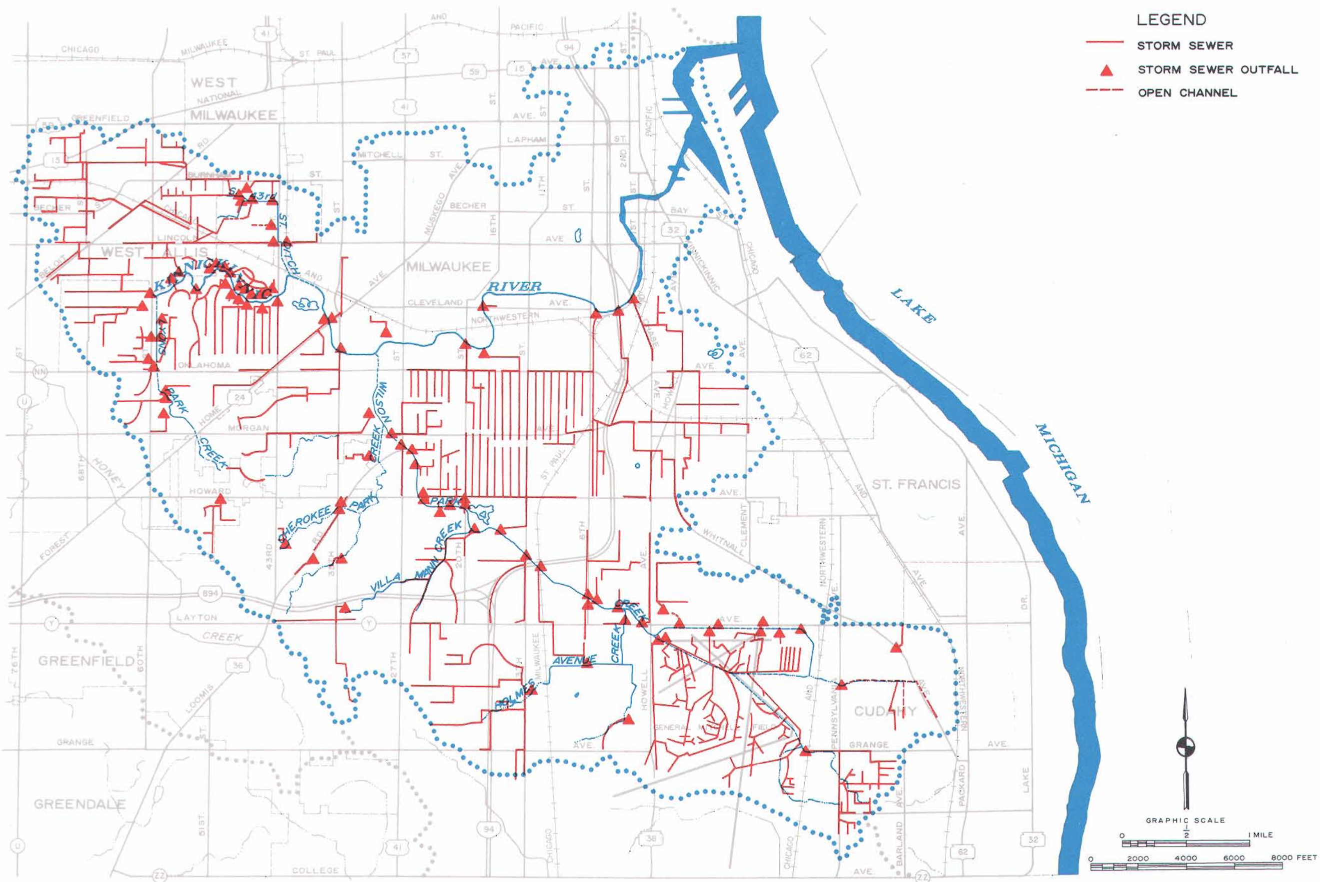
In the Kinnickinnic River watershed, the storm water drainage systems provide means by which much of the diffuse source pollutants reach the surface water system. Therefore, the extent and characteristics of the existing storm water drainage system are pertinent to an understanding of, and the ultimate solution to, the diffuse source pollution problem. Because of the direct relationship between urban storm water drainage systems and surface water quality, the Commission's areawide water quality management planning program includes an inventory of the existing urban storm water drainage systems within the Region. The results of that inventory for the Kinnickinnic River watershed are presented in summary form below.[13]

[13] *For a detailed description of the procedure used to inventory urban storm water drainage systems under the areawide water quality management planning program see Chapter IV of SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin.*

Inventory Findings: There are a total of seven known existing urban storm water systems which provide service to the subareas of the Kinnickinnic River watershed. These include the systems operated by the Cities of Cudahy, Greenfield, Milwaukee, St. Francis, and West Allis, and the Village of West Milwaukee, and Milwaukee County at Mitchell Field. The location and configuration of major storm water drainage conduits as well as of the outlets and the estimated tributary drainage areas of the seven storm water drainage systems within the Kinnickinnic River watershed are shown on Map 38. Together these systems have a tributary drainage area of about 16.6 square miles, or about 67 percent of the total area of the watershed. Included within the urban storm water systems of the Kinnickinnic River watershed are a total of 92 known storm water outfalls ranging in size from 12 inches in diameter to a 142 inch by 89 inch box culvert. There are no known storm water pumping or storage facilities in the watershed. In addition, 4.54 square miles, or 18 percent of the watershed, are served by combined sanitary and storm sewers as described above and in Chapter III of this report. The remainder of the watershed, consisting primarily of scattered, undeveloped tracts of land and some small

Map 38

THE STORM SEWER SYSTEM IN THE KINNICKINNIC RIVER WATERSHED: 1977



About 16.6 square miles, or approximately 67 percent of the total area of the Kinnickinnic River watershed, are served by seven storm sewer systems operated by the Cities of Cudahy, Greenfield, Milwaukee, St. Francis, and West Allis; by the Village of West Milwaukee; and by Milwaukee County. Another 4.54 square miles, or 18 percent of the total area of the watershed, are served by a combined sanitary and storm water system. The remainder of the watershed, consisting of many scattered, undeveloped tracts of land and some small developed tracts, is not served by a piped storm water drainage system, but drainage is instead carried overland and by roadside ditches and natural swales to the major stream system of the watershed.

Source: Cities of Cudahy, Greenfield, Milwaukee, St. Francis, and West Allis; the Village of West Milwaukee; Milwaukee County; and SEWRPC.

developed tracts, is not served by a piped storm water drainage system. In these areas, drainage is conveyed to the major stream system of the watershed by overland routes and by roadside ditches and natural swales.

Diffuse Source Pollution Loads from Land Use-Cover Combinations as Developed under the Areawide Water Quality Management Planning Program: A preliminary analysis of the relative magnitude of diffuse source pollutant loadings from the various land use-cover combinations comprising the Kinnickinnic River watershed was completed under the areawide water quality management planning program.[14] This analysis was based on unit loading rates for various pollutants and land use-cover combinations. Many assumptions were required to develop the loading rates. To the maximum extent possible, these assumptions were based upon data collected from within the Region. The analysis provides an estimate of gross pollutant loads from the land surface of the Kinnickinnic River watershed as well as a means of identifying the most likely important sources of each pollutant.

The results of this analysis are summarized in Table 43. In examining the table, it should be recognized that the loading rates used in the loading analysis are not precise quantifications of pollutant loadings from all specific pollutant sources within the watershed, but rather estimates of pollution runoff from general land uses.

It should also be emphasized that the pollutant loads set forth in Table 43 are based on loading rates computed on the basis of small-scale studies. When runoff loading rates

[14] *See Chapter V of SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin.*

Table 43

WATER QUALITY RELATED LAND USE-COVER COMBINATIONS AND ESTIMATED AVERAGE ANNUAL LOADS OF SELECTED POLLUTANTS IN THE KINNICKINNIC RIVER WATERSHED: 1975

	Area		Average Annual Unit and Total Loads for Selected Pollutants[c]									
			Suspended Sediment		Five-Day Biochemical Oxygen Demand		Total Phosphorus		Total Nitrogen		Fecal Coliform	
Urban Land Use[a]	Square Miles	Percent of Watershed	Pounds/Acre/Year	Tons	Pounds/Acre/Year	Tons	Pounds/Acre/Year	Tons	Pounds/Acre/Year	Tons	Counts Acre/Year	Counts
Residential	12,61	50.74	545	(5.4) 2,200	24	(31.6) 97	0.32	(11.5) 1.3	4.0	(27.9) 16	1.6×10^{10}	(40.2) 1.2×10^{14}
Commercial	2.07	8.33	745	(1.2) 490	98	(21.2) 65	0.75	(4.4) 0.5	9.0	(10.4) 6	3.3×10^{10}	(14.8) 4.4×10^{13}
Industrial	2.31	9.30	975	(1.8) 720	37	(8.8) 27	0.70	(4.4) 0.5	8.4	(10.4) 6	6.2×10^{10}	(30.9) 9.2×10^{13}
Extractive	0.02	0.08	150,000	(2.4) 960	120	(0.3) 0.8	45	(2.6) 0.3	60	(0.7) 0.4	–	–
Transportation	2.86	11.51	2,900-43,000	(32.0) 13,000	18-159	(28.1) 86	1.40-2.70	(16.8) 1.9	12-23	(24.3) 14	$0.0\text{-}6.7 \times 10^{10}$	(13.1) $3.9\ 10^{13}$
Recreation	1.45	5.84	420	(0.5) 195	1.30	(0.2) 0.6	0.06-0.2	(0.3) 0.03	2.30-4.40	(1.7) 1	$0.0\text{-}3.6 \times 10^{9}$	(1.0) 3.0×10^{12}
Construction	0.45	1.81	150,000	(53.2) 21,600	120	(5.6) 17	45	(57.4) 6.5	60	(15.7) 9	–	–
Subtotal	21.77	87.61	–	(97.9) 39,765	–	(95.8) 293	–	(97.4) 11.03	–	(91.1) 524	–	(100.0) 29.8×10^{13}
Rural Land Use[a]												
Cropland, Pasture and Unused Rural Land	3.00	12.07	420-10,000	(2.0) 830	2.1-30	(3.3) 10	0.09-0.64	(2.6) 0.3	0.9-23	(8.7) 5.0	–	–
Silviculture	0.03	0.13	250	(0.0) 2.4	4.6	–	0.14	–	2.3	–	6.6×10^{8}	(0.0) 1.3×10^{10}
Surface Water	0.05	0.20	665	(0.0) 11	162	(0.8) 2.6	0.50	–	8.9	(0.2) 0.1	–	–
Subtotal	3.08	12.39	–	(2.1) 843	–	(4.1) 12.6	–	(2.6) 0.3	–	(8.9) 5.1	–	(0.0) 1.3×10^{10}
Total	24.85[b]	100.00	–	(100.0) 40,608	–	(100.0) 306	–	(100.0) 11.33	–	(100.0) 57.5	–	(100.0) 29.8×10^{13}

[a] *Special land use-cover categories defined under the areawide water quality management planning program for the purpose of establishing unit loads of diffuse source pollution.*

[b] *The 24.85-square-mile area of the watershed is 0.07 square mile larger than the 24.78-square-mile total used in this report. The 24.85-square-mile total was obtained by a digitizing technique under the areawide water quality management planning program and supercedes the watershed study area of 24.78 square mile.*

[c] *Numbers in parentheses indicate percent of watershed total to the nearest 0.1 percent.*

Source: SEWRPC.

developed from studies of very small basins are applied to a larger watershed, such as the Kinnickinnic River watershed, the resulting loads may be different from the actual transport from the watershed because the land and stream processes which retard or remove pollutants or change their form during transport over land surface or within the stream system may not be reflected in the studies of small catchment areas. These removal processes include particle deposition or entrapment on the land surface or on floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The unit loads and, therefore, the total loads set forth in Table 43 are representative of the annual quantities of potential pollutants moved from small homogeneous areas of relatively uniform slope in the Kinnickinnic River watershed and are not intended to reflect the total amount of the pollutants moving from those sources through the hydrologic-hydraulic system and to the watershed outlet.

Several observations can be made based on the information in Table 43:

- Unit loads of a given pollutant may be expected to vary markedly according to land use and cover. For example, the representative unit load of suspended solids from an established residential area is about 550 pounds per acre per year, whereas areas under development may be expected to generate up to 150,000 pounds per acre per year—270 times as much.

- As a result of the variations in unit loads, some land use-cover combinations may generate a disproportionate amount of the total quantity of a given pollutant produced in the watershed. For example, construction activity comprises only about 2 percent of the Kinnickinnic River watershed, but accounts for about half of the suspended solids and total phosphorus generated within the basin.

- Using total annual loads as an index, the land uses and cover combinations that are most critical as potential contributors of suspended solids, biochemical oxygen demand, total phosphorus, total nitrogen, and fecal coliform bacteria in the Kinnickinnic River are construction sites, transportation facilities, and residential areas.

Sediment Yield of the Watershed: Sediment yield, which is defined as the average annual quantity of sediment transported from the watershed land surface by rainfall and snowmelt to and perhaps through the estuary, was estimated for the Kinnickinnic River watershed using two techniques. These techniques, each of which is described below, are: 1) the sediment rating curve-flow duration curve method, and 2) the U. S. Environmental Protection Agency (EPA) preliminary screening procedure.

Sediment Rating Curve-Flow Duration Curve Method: Three steps are involved in estimating sediment yield for a watershed by applying the sediment rating curve-flow duration curve method. The first and second steps are construction of a suspended sediment rating curve and development of a flow duration curve for the watershed. The third step is combining the information embodied in the above two curves to obtain annual sediment yield, and applying an appropriate adjustment for bed load.

Development of Sediment Rating Curve: A suspended sediment rating curve is a graphic representation of the relationship of the daily average discharge from a watershed, expressed in cubic feet per second per square mile, to the daily transport of suspended sediment from the watershed, expressed in tons per day per square mile. The resulting relationship is similar to a discharge rating curve—stage as a function of discharge—in that it depicts the sediment transport capacity of an urban stream as a function of discharge.

Lacking sufficient coincident discharge and sediment data for the Kinnickinnic River watershed, a suspended sediment rating curve was developed for application to the watershed using suspended sediment and discharge data from three similar-sized urban catchments in the Milwaukee urbanized area. These three catchments consist of the gaged portions of the Noyes Creek, Honey Creek, and Underwood Creek subwatersheds, all of which are located within the Menomonee River watershed. All three urban catchments have been the subject of intensive sediment and discharge monitoring under the International Joint Commission's Menomonee River pilot watershed study in which the SEWRPC has been a participant. Table 44 summarizes the natural and man-made characteristics of the gaged portions of these three watersheds, and includes information on the size of tributary area, hydrologic soils group classifications, the area weighted slope, and land use distribution. The three subwatersheds are similar to the Kinnickinnic River watershed in that the drainage areas involved are of the same order of magnitude, the dominant soils are all classified in hydrologic soils group C, the land surface is relatively flat, and urban land uses are predominant. Suspended sediment and discharge data for the three subwatersheds were available for the 19-month period of March 1975 through September 1976.[15]

A total of 268 pairs of daily suspended sediment transport-daily discharge values were used to construct the sediment ratings curve for Noyes Creek, whereas 272 and 230 pairs, respectively, were used to develop the Honey Creek and Underwood Creek sediment rating curves. The data for all three catchments are presented in graphic form in Figure 43, as is an equation for each of the three catchments as obtained by the method of least squares. The equations corresponding to data for Noyes Creek, Honey Creek, and Underwood Creek are seen to be very similar, indicating that there are probably

[15] *U. S. Geological Survey, Water Resources Data for Wisconsin—Water Year 1975, October 1976, and U. S. Geological Survey, Water Resources Data for Wisconsin—Water Year 1976, 1977.*

Table 44

SELECTED INFORMATION ON URBAN SUBWATERSHEDS FROM WHICH DISCHARGE SEDIMENT TRANSPORT DATA WERE USED TO DEVELOP A SEDIMENT RATING CURVE

Subwatershed[a]		Identification Number and Period of Record Available for U. S. Geological Survey Storm Gaging and Sediment Sampling Station				Area Tributary To Gage (square miles)	Hydrologic Soil Group (percent of gaged area)					Area Weighted Slope (feet/100 feet)		1975 Land Use (percent of gaged area)							
Name	City	Number	From	To	Months		A	B	C	D	Other		Residential	Retail Sales and Service	Industrial	Transportation	Communications and Utilities	Government and Institutions	Recreational	Agricultural	Natural Areas and Other Open Lands
Underwood Creek	Wauwatosa	04087088	March 1975	September 1976	19	19.20	--[c]	5.69 (5.80)[c]	60.58 (61.47)[c]	18.02 (18.26)[c]	15.71 (14.46)[c]	3.30	43.60 (5.47)[d]	2.19	2.52	16.06	1.14.	6.23	5.85	5.49	16.96
Honey Creek	Wauwatosa	04087119	March 1975	September 1976	19	10.74	--[c]	0.00 (0.00)[c]	25.69 (81.66)[c]	2.87 (9.12)[c]	71.42 (9.16)[c]	2.89	50.46 (1.66)[d]	2.29	1.72	22.95	1.82	6.74	6.67	0.88	6.40
Noyes Creek	Milwaukee	04087060	March 1975	September 1976	19	2.13	--[c]	1.31	58.39	7.50	32.77	2.19	36.63 (2.72)[d]	2.37	3.44	24.11	7.00	4.24	8.62	1.19	12.40

[a] *All are located within the Menomonee River watershed and within Milwaukee County.*

[b] *Includes man-made land, quarries, dumps, gravel pits, water surfaces, and areas where soil types are unknown.*

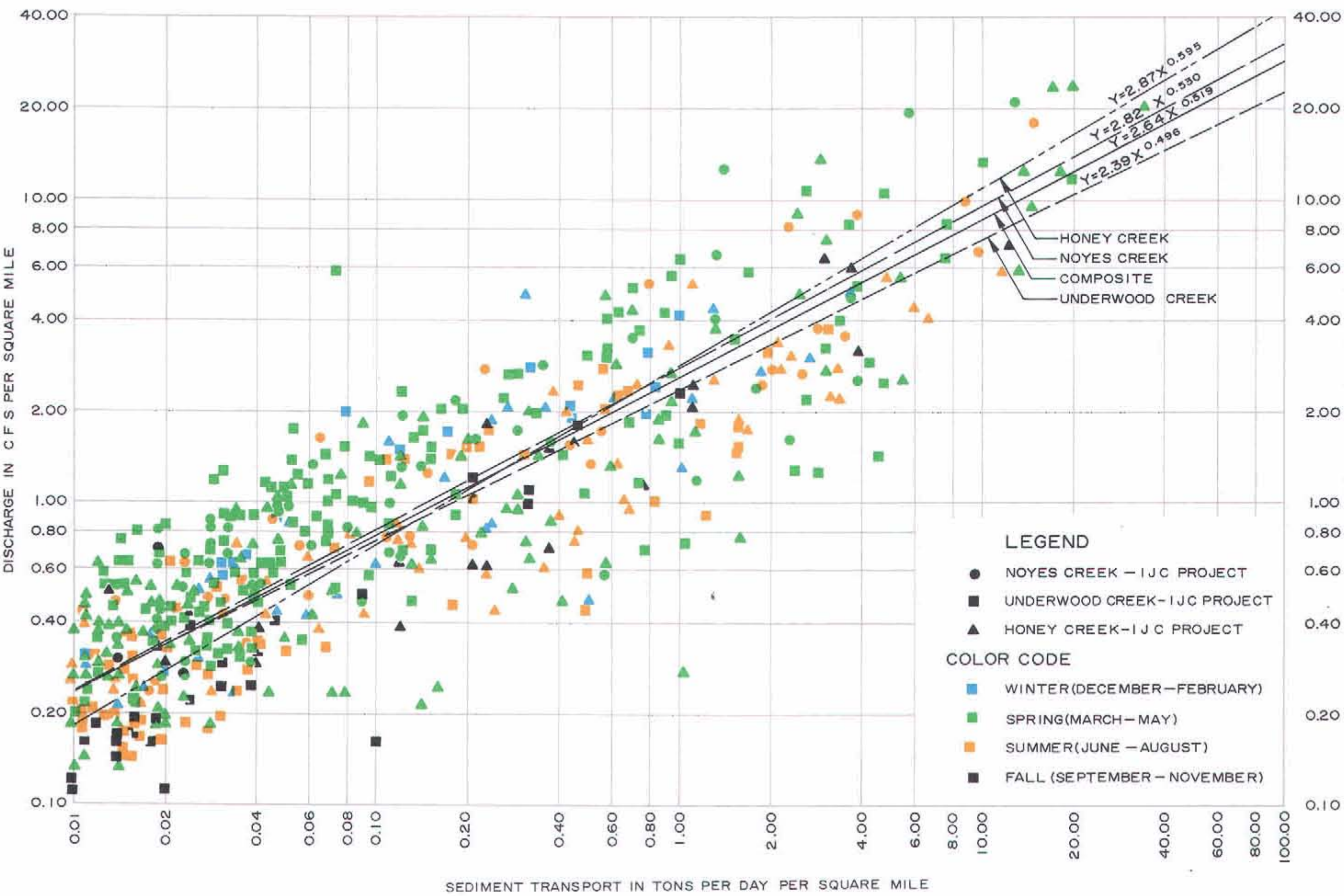
[c] *Source: SEWRPC (KKRWS, Inv. Memo 5, Exh. AU).*

[d] *Percent of watershed considered residential land under development.*

Source: SEWRPC.

Figure 43

RELATIONSHIP BETWEEN SEDIMENT TRANSPORT AND DISCHARGE FOR SELECTED URBAN BASINS IN THE MILWAUKEE METROPOLITAN AREA



Source: U. S. Geological Survey and SEWRPC.

no significant differences between sediment rating curves for the three urban catchments. Based on this conclusion, a fourth equation was developed based on all sediment transport-discharge data for the three urban catchments and that equation, which is also shown on Figure 43. This equation was used as the transport-discharge relationship for the Kinnickinnic River watershed.

The scatter of points about the lines corresponding to the best mathematical fit of the sediment-discharge data clearly indicates that the sediment rating curve is an approximation of a complex physical phenomenon. That is, the scatter indicates that sediment transport, although primarily a function of discharge, is also dependent on other factors not explicitly accounted for in the relationship. Other potentially important factors are moisture conditions and sediment accumulation prior to runoff events; the nature of the causative event, that is, rainfall or snowmelt or a combination of rainfall-snowmelt; the areal distribution of rainfall or snowmelt in the basin; basin size and slope; storm water drainage system characteristics; and the extent and nature of construction activities. Because the aggregate mathematically fitted relationship shown in Figure 43 is used only to estimate mean annual sediment yield, errors inherent in the relationship, as indicated by the scatter of data points, tend to compensate and should thus provide a reasonably accurate estimate of average annual yield suspended sediment.[16]

Development of Flow Duration Curve: A flow duration curve is a cumulative frequency curve indicating the percentage of time that a specified discharge may be expected to be equaled or exceeded. The calibrated hydrologic-hydraulic model described in Chapter VIII of this report was used to generate existing condition average daily discharges for the Kinnickinnic River at S. 7th Street. These discharges were statistically analyzed to develop the flow duration curve shown in Figure 18 in Chapter V.

Combination of Sediment Rating and Flow Duration Relationships: As noted above, the average annual yield of suspended sediment at a point on a watershed stream system may be estimated by combining the relationship between sediment transport and discharge, as embodied in the suspended sediment rating curve, with the relationships between discharge and frequency, as embodied in the flow duration curve. The aggregate sediment rating curve shown in Figure 43 was combined with the flow duration curve shown in Figure 18 in Chapter V using the tabular procedure set forth in Table 45.

Daily discharge rates were divided into 18 classes, and the number of days per year in which the flow is likely to be in each class was determined. Average annual suspended sediment load was calculated by summing the products of days per year that each flow class occurred and the corresponding sediment transport rate as determined from Figure 43.

As shown in Table 45, the suspended sediment load per square mile of the separately sewered area of the Kinnickinnic River watershed is estimated at 410 tons per year. Increasing this value 10 percent to account for the bed load, which consists of the coarser sediments transported in contact with the stream bottom as opposed to the finer sediments transported in suspension in the stream flow, the total average sediment yield per unit area of the separately sewered portion of the watershed is estimated at about 450 tons per square mile per year. Applying this unit sediment yield to the 20.24-square-mile separately sewered portion of the watershed produces a total average annual sediment yield from that portion of the basin to the estuary and harbor area of about 9,100 tons as set forth in Table 46.

The unit sediment load from the combined sewer service area may be expected to be somewhat larger than that of the separately sewered area. While both types of areas contribute particulate matter washed from the land surface during precipitation or snowmelt events, an additional source of particulate matter is available in the combined sewer service area; namely, solids that are carried into the combined sewers with sanitary sewage, settle out in the combined sewers, and are subsequently flushed out into the surface water system during combined sewer overflow events. The unit sediment load associated with this additional particulate matter was estimated at 5 percent of the unit sediment load attributable to particulate matter washed from the land surface.[17] Therefore, while a combined sewer service area has an additional source of particulate matter, that additional source is not significant enough for inclusion in the watershed sediment yield analysis.

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[16] *R. K. Linsley, M. A. Kohler, and J.L.H. Paulhus, "Sedimentation," Hydrology for Engineers, Second Edition, McGraw-Hill, New York, 1975.*

[17] *The annual quantity of solids carried into the combined sewers with sanitary sewage was calculated as 1,080 tons, which was obtained as the product of the population of the combined sewer service area (estimated at 30,000 persons) and the per capita contribution of suspended solids (0.20 pound per person per day times 365 days per year). Ten percent of the solids was assumed to be deposited in the combined sewers and subsequently flushed into the surface waters during overflow events, based on information in the Areawide Assessment Procedures Manual, Volume Three, U. S. Environmental Protection Agency, EPA Report No. 600/9-76-014, July 1976, p. 36. The resulting annual load of suspended solids discharged through combined sewer outfalls and attributed to sanitary sewage is about 100 tons, or 22 tons per year per square mile of the 4.54-square-mile combined sewer service area. This unit load is 4.9 percent of the 450 tons per square mile per year unit load of particulate matter washed from the land surface.*

Table 45

ESTIMATED AVERAGE ANNUAL SUSPENDED SEDIMENT YIELD
FOR THE KINNICKINNIC RIVER WATERSHED STUDY AT S. 7TH STREET

Average Daily Discharge[a]			Days within Flow Range[a]		Sediment Transport	
	Representative Discharge					
Range (cubic feet per second)	(cubic feet per second)	(cubic feet per second per square mile)	Percent of Year	Number of Days per Year	Tons per Day per Square Mile[b]	Tons per Square Mile per Year
0-16	12.0	0.66	10	36.50	0.069	2.51
16-18	17.0	0.94	20	73.00	0.14	10.22
18-20	19.0	1.05	20	73.00	0.17	12.41
20-21	20.5	1.14	20	73.00	0.20	14.60
21-27	24.0	1.33	10	36.50	0.27	9.86
27-35	31.0	1.72	5	18.25	0.44	8.03
35-51	43.0	2.38	5	18.25	0.82	14.96
51-63	57.0	3.16	2	7.30	1.41	10.29
63-77	70.0	3.88	2	7.30	2.10	15.33
77-87	82.0	4.54	1	3.65	2.85	10.40
87-101	94.0	5.21	1	3.65	3.71	13.54
101-119	110.0	6.09	1	3.65	5.02	18.32
119-151	135.0	7.48	1	3.65	7.46	27.23
151-211	181.0	10.0	1	3.65	13.2	48.18
211-273	242.0	13.4	0.5	1.82	23.0	41.86
273-523	398.0	22.0	0.4	1.46	59.9	87.45
523-669	596.0	33.0	0.05	0.18	131	23.58
669-1,093	881.0	48.8	0.04	0.15	280	42.00
Annual Total	--	--	99.99[c]	394.96	--	410.78

[a] *From flow-duration relationship.*

[b] *From sediment rating relationship as a function of discharge.*

[c] *For remaining 0.01 percent of year average daily flows exceed 1,093 cubic feet per second.*

Source: U. S. Geological Survey and SEWRPC.

Applying the unit sediment yield of 450 tons per square mile per year to the 4.5-square-mile combined sewer service area of the Kinnickinnic River watershed produces a total average annual yield from that portion of the basin to the estuary and harbor area of about 2,050 tons as set forth in Table 46. Therefore, the total average annual sediment yield from the watershed to the estuary and harbor area, as obtained with the sediment rating curve-flow duration curve method, is about 11,150 tons.

U. S. Environmental Protection Agency Preliminary Screening Procedure: Loading rates from urban land uses may be estimated by using a preliminary screening procedure developed under a study sponsored by the U. S. Environmental Protection Agency and based on review of available storm water pollutant loading data.[18]

This procedure permits a preliminary estimate of gross diffuse source loads of suspended sediment—as well as biochemical oxygen demand, nitrogen, and phosphate—as a function of land use, population density, average annual precipitation, and street sweeping frequency.

Average annual transports of suspended sediment—as well as of other pollutants—from the Kinnickinnic River watershed as obtained by application of a modification of this preliminary assessment procedure are set forth in Table 46 for both the separate and combined sewer service areas of the watershed. With modified procedure, estimates are made of the average annual transport of diffuse source pollutants from the land to the surface waters, but not necessarily of the transport of substances in the watershed stream system and from the watershed. However, pollutant loads set forth in Table 46 for the watershed are considered estimated average annual transports from the entire basin to the estuary because of the highly developed storm water and floodwater conveyance system in this basin. That is, diffuse source pollutants carried from the land into the stream system are assumed, on an annual basis, to be transported from the watershed to the estuary.

[18] *J. P. Heaney, W. C. Huber, and S. J. Nix, Storm Water Management Model: Level I-Preliminary Screening Procedures, U. S. Environmental Protection Agency, EPA Report No. 600/2-76-275, October 1976, pp. 16-21.*

Table 46

ESTIMATED POLLUTANT YIELDS FROM THE KINNICKINNIC RIVER WATERSHED BY VARIOUS METHODS

	Average Yield in Tons Per Year (pounds per acre per year in parentheses)																	
	Separately Sewered Area (20.24 square miles)						Combined Sewered Area (4.54 square miles)						Total Watershed (24.78 square miles)					
	Sediment Rating Curve-Flow Duration Curve Method	EPA Preliminary Screening Procedure	Historic Quality-Simulated Flow Method			Water Quality Modeling	Sediment Rating Curve-Flow Duration Curve Method	EPA Preliminary Screening Procedure	Historic Quality-Simulated Flow Method			Water Quality Modeling	Sediment Rating Curve-Flow Duration Curve Method	EPA Preliminary Screening Procedure	Historic Quality-Simulated Flow Method			Water Quality Modeling
Pollutant			Dry Weather	Wet Weather	Total				Dry Weather	Wet Weather	Total				Dry Weather	Wet Weather	Total	
Suspended Sediment	9,100 (1,400)	4,300 (660)	–	–	–	–	2,050 (1,410)	950 (650)	–	–	–	–	11,150 (1,450)	5,250 (685)	–	–	–	–
Five-day Biochemical Oxygen Demand	–	250 (39)	60 (9.0)	225 (35)	285 (44)	140 (21)	–	160 (110)	13 (9.0)	175 (120)	188 (129)		–	410 (53)	73 (9.0)	400 (52)	473 (61)	–
Phosphate-Phosphorus	–	–	0.6 (0.1)	2.3 (0.4)	2.9 (0.5)	3.6 (0.6)	–	–	0.1 (0.1)	4.8 (3.3)	4.9 (3.4)	–	–	–	0.7 (0.1)	7.1 (0.9)	7.8 (1.0)	–
Total Phosphorus	–	10 (1.5)	1.2 (0.2)	4.5 (0.7)	5.7 (0.9)	–	–	6 (4.0)	0.3 (0.2)	9.7 (6.7)	10.0 (6.9)	–	–	16 (2.1)	1.5 (0.2)	14.2 (1.8)	15.7 (2.0)	–
Total Nitrogen	–	40 (6.1)	1.2 (1.8)	22 (3.4)	34 (5.2)	78 (12)	–	34 (23)	3.0 (2.0)	2.8 (19)	31 (2.1)	–	–	74 (9.6)	1.5 (2.0)	50 (6.5)	65 (8.5)	–
Dissolved Solids	–	–	6,000 (920)	3,700 (570)	9,700 (1,490)	24,440 (3,770)	–	–	1,300 (900)	1,000 (690)	2,300 (1,590)	–	–	–	7,300 (950)	4,700 (610)	12,000 (1,560)	–
Chloride	–	–	–	–	–	8,370 (1,290)	–	–	–	–	–	–	–	–	–	–	–	–
Fecal Coliform	–	–	–	–	–	1.7×10^{14} counts/year 1.3×10^{16} counts/per acre per year	–	–	–	–	–	–	–	–	–	–	–	–

Source: SEWRPC

The preliminary screening procedure used to estimate sediment yield was modified to the extent that identical unit loads were assumed for both separately sewered and combined sewered areas. This assumption followed from the above-mentioned analysis, which concluded that the unit sediment yield from the combined sewered area would exceed that of the separately sewered area by less than 5 percent. In contrast, the preliminary assessment procedure indicates a four-fold increase in unit sediment yields for combined sewer service areas compared to separately sewered areas.

Comparison of Sediment Yield Estimates for the Kinnickinnic River Watershed: Application of the sediment rating curve-flow duration curve method resulted in a total sediment yield—suspended sediment plus sand bed load—of about 11,150 tons per year for the Kinnickinnic River watershed. Application of the U. S. Environmental Protection Agency preliminary screening procedure resulted in a total sediment yield of only 5,250 tons per year. Therefore, the sediment yield obtained from the sediment rating curve-flow duration curve method approximated twice that obtained with the EPA preliminary assessment procedure. If the EPA preliminary assessment procedure were applied with the indicated four-fold increase in unit sediment yields for the combined sewer service area—from 450 tons per square mile per year to 1,800 tons per square mile per year—the sediment yield for the watershed obtained following the EPA procedure would increase from 5,250 tons per year to 17,300 tons.

The estimated average annual total sediment yield of 11,150 tons per year[19] for the Kinnickinnic River watershed as obtained with the sediment rating curve-flow duration curve method is likely to be more accurate since it incorporates the hydrologic-hydraulic land use and cover conditions of the Milwaukee metropolitan area in general, and of the Kinnickinnic River watershed in particular. In contrast, the EPA preliminary assessment procedure is likely to be less accurate since it is based on a generalized national data set.

Comparison of Sediment Yield Estimates to Results Obtained from Other Studies: A study by the U. S. Geological Survey determined average annual suspended sediment yield for streams throughout Wisconsin.[20] The reported average yields, which exclude bed load, varied

[19] *If the 11,500 tons of sediment transported from the watershed in an average year were deposited on the land surface and permitted to dry, it would have a unit weight of about 100 pounds per cubic foot and would occupy a volume of 5.1 acre-feet, or a volume equivalent to about five feet of material spread over the area of a regulation football field.*

[20] *S. M. Hindall and R. F. Flint, "Sediment Yields of Wisconsin Streams," Hydrologic Investigations Atlas Ha-376, U. S. Geological Survey, Washington, D.C., 1970.*

widely, ranging from 5 to 700 tons per square mile per year. Northern, forested areas of the State exhibited the lowest yields while the highest yields of suspended sediment were observed in the "driftless area" of southwestern Wisconsin. The report indicates that high sediment yields are to be expected in urban and urbanizing areas because of such factors as the increased amount of surface runoff, channel modifications, and construction activities. The reported average suspended sediment yield for the seven-county Southeastern Wisconsin Region was about 50 tons per square mile per year. Considering the urban nature of the Kinnickinnic River watershed and its small size and highly developed drainage system, both of which tend to increase the sediment delivery ratio, and noting that the above regional sediment yield excludes bed load, the value of 450 tons per square mile per year obtained for the Kinnickinnic River watershed is consistent with the U. S. Geological Survey results.

Sediment analyses conducted under the Commission's Milwaukee River watershed planning program concluded that sediment yield, including allowance for bed load, approximated about 60 tons per square mile per year for this 694-square-mile primarily rural basin. Similar analyses conducted under the Commission's Menomonee River watershed planning program concluded that sediment yield, including an allowance for bed load, approximated about 98 tons per square mile per year for the rural and separately sewered urban portions of this 137-square-mile basin, 55 percent of which was in urban land use at the time of the study. Considering again the urban nature of the Kinnickinnic River watershed in comparison to both the Menomonee and Milwaukee River watersheds, as well as its small size and highly developed drainage system, the 450 tons per square mile per year total sediment yield obtained for the watershed is consistent with the 60 and 98 tons per square mile per year yield determined earlier for, respectively, the Milwaukee and Menomonee River watersheds.

Water Quality and Other Implications: The transport of sediment in the watershed stream system and from the watershed into receiving waters can result in serious water quality problems. In addition, the potential exists for localized sediment deposits in the stream channels and in storm water channels and sewers and resulting localized flooding and storm water inundation and accelerated channel meandering.

Recent Maintenance Dredging: A pragmatic implication of watershed sediment yield is its effect on navigation in the estuary portion of a river. The Kinnickinnic River estuary extends 2.40 miles upstream from the Milwaukee River to S. Chase Avenue. The river is navigable by large commercial vessels from its junction with the Milwaukee River to Kinnickinnic Avenue in the City of Milwaukee—a total of 1.28 miles. The U. S. Army Corps of Engineers periodically dredges the portion of the Kinnickinnic River estuary downstream of Kinnickinnic Avenue. As indicated in Table 47, such dredging has been done in 1960, 1962, 1964, 1965, 1968, 1975, and 1976 and is planned for 1978.

The Corps maintains the channel to a width varying from a maximum of about 600 feet at the confluence of the Kinnickinnic River with the Milwaukee River to a minimum of about 180 feet at S. Kinnickinnic Avenue. The downstream two-thirds of the estuary—the portion downstream of the Chicago & North Western Railway bridge at River Mile 0.84—is maintained so as to have a channel bottom at 551.10 feet above the National Geodetic Vertical Datum (Mean Sea Level Datum), or 29.50 feet below the City of Milwaukee Datum. The upper third of the estuary is maintained so as to have a channel bottom at 557.1 feet above the National Geodetic Vertical Datum, or 23.50 feet below the City of Milwaukee Datum.

The frequency, the lineal extent, and the depth of maintenance dredging is primarily a function of the amount of sediment transported by the Kinnickinnic River and its tributaries to the estuary area, the fraction of that sediment that is trapped in the estuary, and the spatial distribution of the trapped sediment. The Corps of Engineers usually conducts annual soundings of the estuary area. The resulting cross sections are examined to determine if shoaling—the gradual, localized accumulation of sediments which tend to begin at the upstream of the estuary and develop in the downstream direction—has proceeded to the point where sedimentation has reduced the water depth to less than that required for navigation, in which case dredging operations are conducted.

Table 47

DREDGING IN THE KINNICKINNIC RIVER ESTUARY BY THE U. S. ARMY CORPS OF ENGINEERS: 1960-1978[a]

Year	Cubic Yards	Total (dollars)	Unit (dollars per cubic yard)	Method of Spoils Disposal
1978[b]	160,000	960,000	6.00	Diked storage[c]
1976	100,520	369,666	3.68	Diked storage[c]
1975	68,370	89,763	1.31	Diked storage[c]
1968	13,775	17,327	1.26	Open lake dumping
1965	182,875	215,300	1.18	Open lake dumping
1964	5,270	9,579	1.82	Open lake dumping
1962	38,650	31,708	0.82	Open lake dumping
1960	38,780	29,608	0.76	Open lake dumping

[a] *From confluence of Kinnickinnic and Milwaukee Rivers to Kinnickinnic Avenue, the upstream limit of federal project.*

[b] *Anticipated dredging and associated cost scheduled for 1978.*

[c] *Spoils deposited in a permanent dike constructed at the foot of Lincoln Avenue.*

Source: U. S. Army Corps of Engineers (Chicago District) and SEWRPC.

This procedure was interrupted after the 1968 estuary dredging pending completion of outer harbor containment areas for disposal of the dredged material. Beginning with the 1975 dredging, spoils were pumped into a permanent diked disposal area within the outer harbor at E. Lincoln Avenue extended.

The seven 1960 through 1976 dredging operations in the Kinnickinnic River estuary resulted in the removal of 448,000 cubic yards of material from the bottom of the navigation channel, or an average of 26,500 cubic yards per year. These are "in-place" volumes since they represent the sediment reduction as determined by comparing soundings taken before and after the dredging operation.

Comparison of Volume of Sediment Yield to Volume of Dredging: Based on the sediment yield analysis described above, approximately 11,150 tons of sediment may be expected to be delivered annually to the harbor area from the Kinnickinnic River watershed. Assuming that the transported sediment consists of 80 percent clay and 20 percent silt,[21] that essentially all of the sediment settles out in the Kinnickinnic River estuary, and that the sediment has a submerged dry weight of 40 pounds per cubic foot,[22] the settled sediment would occupy a total volume of about 20,700 cubic yards. If this were spread uniformly over the bottom of the 107-acre portion of the estuary downstream of S. Kinnickinnic Avenue, including the municipal mooring basin, the sediment would accumulate uniformly at a rate of about 1.5 inches per year.

The estimated long-term average annual sediment delivery to the Kinnickinnic River estuary of 20,700 cubic yards is consistent with the estimated average annual dredging of 26,400 cubic yards. The difference between the estimated average annual sediment transport volume and the average annual dredging volume may be attributable to factors such as the assumptions inherent in the procedures used to estimate the annual volume of sediment yield to the estuary, the accumulation in the estuary, and the degree to which the 1960-1976 dredging quantities are representative of long-term volumes.

The Cost of Sediment Pollution: It is possible to assign a cost or "damage" to sediment pollution in the Kinnickinnic River watershed using actual unit costs associated with removal, for navigation purposes, of sediment that is deposited in the estuary. The current unit cost of sediment dredging and disposal is about $6.00 per "in-place" cubic yard based on recent Corps of Engineers expenditures in the estuary as set forth in Table 47. Assuming an average annual sediment yield to the estuary of 20,700 cubic yards, the associated annual cost or "damage" at $6.00 per cubic yard is about $124,000. This figure represents a conservative estimate since it does not include tangible and intangible, but nevertheless real, costs or "damages" associated with or resulting from maintenance of storm water and floodwater control facilities such as catch-basins, storm sewers, culverts and bridges, and improved channels; storm water inundation and flooding damage and disruption attributable to hydraulic constrictions caused by sediment accumulation; aesthetic degradation of the watershed surface waters; and loss of aquatic flora and fauna.

Biochemical Oxygen Demand Yield of the Watershed: The biochemical oxygen demand (BOD) yield of the Kinnickinnic River watershed, which is defined as the average annual quantity of biochemical oxygen demand transported from the watershed by rainfall and snowmelt runoff and by dry weather flow to and perhaps through the estuary, was estimated using three techniques. These techniques are: 1) the U. S. Environmental Protection Agency preliminary screening procedure which was described above; 2) the historic quality-simulated flow method which is described below; and 3) the water quality modeling method. The water quality modeling method and its calibration are described in Chapter VIII of this report, and the application of the model is described in Chapter XIII.

U. S. Environmental Protection Agency Preliminary Screening Procedure: The average annual transport of biochemical oxygen demand as obtained from the EPA preliminary screening procedure is set forth in Table 46 for both the separate and combined sewer service areas of the Kinnickinnic River watershed. The biochemical oxygen demand carried into the stream system is assumed, on an annual basis, to be transported by the watershed stream system to at least the estuary.

The preliminary screening procedure, as applied to estimate biochemical oxygen demand yield from the combined sewer service area, was a modification of the EPA procedure. The EPA preliminary screening procedure indicates a four-fold increase in unit biochemical oxygen demand yield for combined sewer service areas in comparison to separately sewered areas. The unit biochemical oxygen demand load from the combined sewer service area may be expected to be significantly larger than that of the separately sewered area and, therefore, such an adjustment is needed. While both types of sewer service areas will contribute oxygen-demanding matter washed from the land surface during precipitation or snowmelt events or carried in groundwater flow or in industrial discharges, an additional source of biochemical oxygen demand is available in the combined sewer service area; namely, the substances that are carried into the combined sewers with sanitary sewage, settle out in the combined sewers, and are subsequently flushed out into the surface water system during combined sewer overflow events. For the combined sewer service area of the Kinnickinnic River watershed, the unit biochemical oxygen demand

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[21] *Wisconsin Department of Natural Resources, University of Wisconsin System—Water Resources Center, and Southeastern Wisconsin Regional Planning Commission, International Joint Commission Menomonee River Pilot Watershed Study—Summary Pilot Watershed Report.*

[22] *Ibid., footnote 16.*

load associated with this additional particulate matter was estimated to be approximately twice the unit load of oxygen-demanding material contributed by the separately sewered area. Therefore, the additional source of biochemical oxygen demand in the combined sewer service area was accounted for by using a unit loading rate of three times that used in the separately sewered area.[23]

Historic Quality-Simulated Flow Method: In this approach, the average annual yield of biochemical oxygen demand is estimated by combining representative biochemical oxygen demand concentration information from recent water quality monitoring with average annual watershed runoff volumes as generated by the hydrologic simulation model described in Chapter VIII of this report. More specifically, biochemical oxygen demand concentration data for dry and wet weather conditions were determined from recent monitoring studies in that portion of the watershed stream system receiving runoff from separately sewered areas and as set forth in the various tables and figures in this chapter. These data were used in selecting the representative dry and wet weather biochemical oxygen demand concentrations set forth in Table 48. The selection of these representative values constitutes a highly simplified quantification of complicated phenomena but, nevertheless, characterizes surface water quality in a manner consistent with the significant differences in biochemical oxygen demand concentrations observed in the Kinnickinnic River watershed surface waters under wet and dry weather conditions.

Results from the application of the hydrologic simulation model to the 13-year period from January 1, 1965 through December 31, 1977 were used to estimate average annual volumes of various components of runoff from the separately sewered area of the watershed. These volumes are expressed in inches over the watershed land surface as shown in Figure 41. Average annual dry weather condition runoff was approximated as the sum of groundwater discharge—3.9 inches—and point source discharge—4.2 inches—for a total of 8.1 inches.

[23] *The annual quantity of biochemical oxygen demand (BOD) carried into the combined sewers with sanitary sewage was calculated as 1,080 tons which was obtained as the product of the population of the combined sewer service area (estimated at 30,000 persons) and the per capita contribution of BOD (0.20 pound per person per day times 365 days). Ten percent of the BOD was assumed to be deposited in the combined sewers and subsequently flushed into the surface waters during overflow events based on the earlier assumption that 10 percent of the suspended solids are deposited in the combined sewers and subsequently flushed into the surface waters. The resulting annual load of BOD discharged through the combined sewer outfalls and attributed to sanitary sewage is about 100 tons, or 22 tons per year per square mile of the 4.54-square-mile combined sewer service area. This unit load is about twice the 12 tons per year per square mile unit load of BOD washed from the land surface.*

Table 48

REPRESENTATIVE DRY AND WET WEATHER CONDITION CONCENTRATIONS OF BIOCHEMICAL OXYGEN DEMAND, PHOSPHORUS, NITROGEN, AND DISSOLVED SOLIDS IN THE KINNICKINNIC RIVER WATERSHED

Parameters	Concentration in mg/l[a]	
	Dry Weather Conditions	Wet Weather Conditions
Biochemical Oxygen Demand	5	15
Phosphate-Phosphorus	0.05	0.15
Total Phosphorus	0.10	0.30
Total Nitrogen	1.0	1.5
Dissolved Solids	500	250

[a] *Based primarily on historic monitoring in the Kinnickinnic River watershed and representative of wet and dry weather streamflow from separately sewered areas.*

Source: SEWRPC.

Average annual wet weather condition runoff was approximated by direct runoff—surface flow from pervious and impervious surfaces plus interflow—and was determined to be 10.6 inches. Therefore, the total runoff as used in the historic quality-simulated flow method is consistent with the hydrologic modeling and monitoring data used to calibrate the model, and was estimated at 18.7 inches—8.1 inches of dry weather condition flow from the watershed and 10.6 inches of wet weather condition flow from the watershed.

The average annual yield of biochemical oxygen demand from the separately sewered area was computed as the product of representative dry weather condition concentration of biochemical oxygen demand and dry weather runoff plus the product of representative wet weather condition concentration and wet weather runoff. A similar formula was used for the combined sewer service area except that an additional biochemical oxygen demand load was applied to account for the solids contributed by sanitary sewage. Approximately two-thirds of the biochemical oxygen demand contributed from the combined sewer service area in the Kinnickinnic River watershed is estimated to be attributable to overflow from combined sewers. The average annual transport of biochemical oxygen demand as obtained with the historic quality-simulated flow method is set forth in Table 46 for both the separate and combined sewer service areas of the watershed.

Water Quality Modeling Method: The average annual transport of biochemical oxygen demand from the Kinnickinnic River watershed as obtained with the water quality model is set forth in Table 46. The data are limited to the separately sewered area of the watershed because the pollution contribution from the combined sewer service area was not included in the modeling for reasons set forth in Chapter XIII of this report.

Discussion of Biochemical Oxygen Demand Yield Estimates: As indicated in Table 46, the average annual yield of biochemical oxygen demand from the separately sewered area of the Kinnickinnic River watershed as estimated using the EPA preliminary screening procedure is 250 tons per year, whereas the estimated yields obtained using the historic quality-simulated flow method and the water quality modeling method are 285 and 140 tons per year, respectively. Therefore, the biochemical oxygen demand yields from the separately sewered areas as estimated using three different methodologies are of the same magnitude. As also indicated in Table 46, the average annual yields of biochemical oxygen demand from the combined sewer area of the basin as estimated using the EPA preliminary screening procedure and the historic quality-simulated flow method are 160 and 188 tons per year, respectively. Therefore, the biochemical oxygen demand contribution from the combined sewer service areas as obtained by the different methodologies are also seen to be in relatively close agreement.

The values obtained using the water quality modeling method were selected as the best estimates of loadings of biochemical oxygen demand from the separately sewered service areas of the watershed for three reasons. First, of the various methodologies, the water quality modeling method most fully incorporates the point and nonpoint sources of pollution in the watershed and the natural phenomena and man-made features of the watershed that influence the quantity of pollutants discharged to the surface water and transported from the watershed. Second, the water quality modeling method is calibrated to historic water quality information. Third, the water quality model is the most versatile of the various procedures in that it can be used to test the impact of future land use changes and management measures. Therefore, the results obtained from that method for existing conditions should form the benchmark for such analyses.

Table 46 indicates that a disproportionately large mass of biochemical oxygen demand is contributed by the combined sewer service area. Although the combined sewer service area comprises only about 18 percent of the watershed area, it is estimated to contribute about 40 percent of the biochemical oxygen demand transported from the basin.

The results of the historic quality-simulated flow method as set forth in Table 46 suggest that a disproportionately large mass of biochemical oxygen demand is contributed during wet weather conditions. Although only about 18 percent of the days in a year are wet weather days, it is estimated that wet weather conditions account for about 85 percent of the biochemical oxygen demand transported from the basin. Furthermore, wet weather conditions account for 79 and 93 percent of the biochemical oxygen demand contribution from the separately and combined sewered areas in the Kinnickinnic River watershed, respectively.

Phosphorus Yield of the Watershed: The phosphorus yield of the Kinnickinnic River watershed, which is defined as the average annual quantity of phosphate-phosphorus and total phosphorus transported from the watershed by rainfall and snowmelt runoff and by dry weather flow to and perhaps through the estuary, was estimated using three techniques. These techniques are: 1) the U. S. Environmental Protection Agency preliminary screening procedure; 2) the historic quality-simulated flow method; and 3) the water quality modeling method. More particularly, all three methods were used to estimate the yield of phosphate-phosphorus the watershed, whereas only the historic quality-simulated flow method was applied to total phosphorus.

U. S. Environmental Protection Agency Preliminary Screening Procedure: The average annual transport of total phosphorus as obtained from the U. S. Environmental Protection Agency preliminary screening procedure is set forth in Table 46 for both the separate and combined sewer service areas of the Kinnickinnic River watershed. The phosphorus transport set forth in Table 46 is the estimated average annual transport from the entire basin to or through the estuary; that is, the total phosphorus carried from the land into the stream system is assumed, on an annual basis, to be transported by the watershed stream system to at least the estuary.

The preliminary screening procedure, as applied to estimate total phosphorus yield from the combined sewer service area, was modified. The procedure indicates a four-fold increase in unit phosphorus yield for combined sewer service areas relative to separately sewered areas. For the combined sewer service area of the watershed, the unit phosphorus load was estimated to be approximately eight times the unit load of phosphorus contributed by the separately sewered area. Therefore, the additional source of phosphorus in the combined sewer service area was accounted for by using a unit loading rate of eight times that used in the separately sewered area.[24]

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[24] *The annual quantity of total phosphorus carried into the combined sewers with sanitary sewage was calculated as 54 tons, which was obtained as the product of the population of the combined sewer service area (estimated at 30,000 persons) and the per capita contribution of total phosphorus (0.01 pound per person per day times 365 days). Ten percent of the total phosphorus was assumed to be deposited in the combined sewers and subsequently flushed into the surface waters during overflow events based on the earlier assumption that 10 percent of the suspended solids are deposited in the combined sewers and subsequently flushed into the surface waters. The resulting annual load of total phosphorus discharged through the combined sewer outfalls and attributed to sanitary sewage is about 5.4 tons, or 1.2 tons per year per square mile of the 4.54-square-mile combined sewer service area. This unit load is eight times the 0.15 ton per year per square mile unit load of total phosphorus washed from the land surface. The total unit load of phosphorus in the combined sewer service area was estimated to be eight times the unit load in a separately sewered area.*

Historic Quality-Simulated Flow Method: Phosphate-phosphorus and total phosphorus data for dry and wet weather conditions as determined from recent monitoring studies and as set forth in the various tables and figures in this chapter were used in selecting the representative dry and wet weather concentrations set forth in Table 48. Output from the hydrologic simulation model was used to estimate the volume of average annual dry and wet weather condition runoff from the separately sewered area of the watershed. This volume is expressed in inches over the land surface.

The average annual yields of phosphate-phosphorus and total phosphorus from the separately sewered area were computed as the product of the representative dry weather condition concentrations of phosphate-phosphorus and total phosphorus and the dry weather runoff plus the product of the representative wet weather condition concentrations of phosphate-phosphorus and wet weather runoff. A similar procedure was used for the combined sewer service area except that an additional phosphate-phosphorus and total phosphorus load was applied to account for the amount of nutrients contributed by sanitary sewage; namely, the phosphate-phosphorus and total phosphorus that are carried into the combined sewers with sanitary sewage, settled out in the combined sewers, and are subsequently flushed out into the surface water system during combined sewer overflow events. About 90 percent of the phosphate-phosphorus and total phosphorus contributed from the combined sewer service area in the Kinnickinnic River watershed is estimated to be attributable to overflow from combined sewers. The average annual transport of phosphate-phosphorus and total phosphorus as obtained using the historic quality-simulated method is set forth in Table 46 for the separate and combined sewer service areas of the watershed.

Water Quality Modeling Method: The average annual transport of phosphate-phosphorus from the Kinnickinnic River watershed as obtained using the water quality simulation model is set forth in Table 46. The data are limited to the separately sewered portion of the watershed because the pollution contribution from the combined sewer service area was not included in the modeling for reasons set forth in Chapter XIII of this report.

Discussion of Phosphorus Yield Estimates: As indicated in Table 46, the average annual yield of total phosphorus from the separately sewered area of the Kinnickinnic River watershed as estimated using the EPA preliminary screening procedure is 10 tons, and the estimated annual yield obtained using the historic quality-simulated flow method is 5.7 tons. The estimated yields of phosphate-phosphorus from the separately sewered area as obtained using the historic quality-simulated flow method and the water quality simulation method are 2.9 tons and 3.6 tons per year, respectively. As also indicated in Table 46, the average yields of total phosphorus from the combined sewered area of the basin as estimated using the EPA preliminary screening procedure and the historic quality-simulated flow method are 6 and 10 tons, respectively.

While the phosphorus yields from the separately and combined sewer areas as estimated using the various methodologies differ significantly, the actual yields probably lie with the range spanned by the various estimates. The values obtained using the water quality modeling method were selected as the best estimates of loadings of phosphate-phosphorus and total phosphorus from the separately sewered service area of the watershed for reasons presented in the discussion on biochemical oxygen demand yield.

Table 46 indicates that a disproportionately large mass of phosphorus is contributed by the combined sewer service area. Although the combined sewer service area comprises only about 18 percent of the watershed area, it is estimated to contribute about two-thirds of the phosphate-phosphorus and total phosphorus transported from the basin.

The results of the historic quality-simulated flow method as set forth in Table 46 suggest that a disproportionately large mass of phosphorus is contributed during wet weather conditions. Although only about 18 percent of the days in a year are wet weather days, it is estimated that wet weather conditions account for about 90 percent of the phosphate-phosphorus and total phosphorus transported from the basin. Furthermore, wet weather conditions account for about 80 percent of the phosphate-phosphorus and total phosphorus contribution from the separately sewered areas in the Kinnickinnic River watershed and for approximately 95 percent from the combined sewer service area.

Nitrogen Yield of the Watershed: The total nitrogen yield of the Kinnickinnic River watershed, which is defined as the average annual quantity of total nitrogen transported from the watershed by rainfall and snowmelt runoff and by dry weather flow to and perhaps through the estuary, was estimated using three techniques. These techniques are: 1) the U. S. Environmental Protection Agency preliminary screening procedure; 2) the historic quality-simulated flow method; and 3) the water quality modeling method.

U. S. Environmental Protection Agency Preliminary Screening Procedure: The average annual transport of total nitrogen as obtained from the EPA preliminary screening procedure is set forth in Table 46 for both the separate and combined sewer service areas of the Kinnickinnic River watershed. The total nitrogen quantity set forth in Table 46 is the estimated average annual transport from the entire basin to or through the estuary; that is, the total nitrogen carried from the land into the stream system is assumed, on an annual basis, to be transported by the watershed stream system to at least the estuary.

The preliminary screening procedure, as applied to the estimate total nitrogen yield from the combined sewer service area, followed the recommended steps. The indicated four-fold increase in unit total nitrogen yields for the combined sewer service area in comparison to separately sewered area was found to be reasonable for the Kinnickinnic River watershed.[25] This increase accounts for the additional source of nitrogen available in the combined sewer service area; namely, the substances that are carried into the combined sewers with sanitary sewage, settle out in the combined sewers, and are subsequently flushed out into the surface water system during combined sewer overflow events.

Historic Quality-Simulated Flow Method: Total nitrogen concentration data for dry and wet weather conditions as determined from recent monitoring studies and as set forth in the various tables and figures in this chapter were used in selecting the representative dry and wet weather total nitrogen concentrations set forth in Table 48. Output from the hydrologic submodel was used to estimate the volume of average annual dry and wet weather condition runoff from the separately sewered area of the watershed. This volume is expressed in inches over the land surface.

The average annual yield of total nitrogen from the separately sewered area was computed as the product of the representative dry weather condition concentration of total nitrogen and the dry weather runoff plus the product of the representative wet weather condition concentration and wet weather runoff. A similar formula was used for the combined sewer service area except that an additional total nitrogen load was applied to account for solids contributed by sanitary sewage. Approximately three-fourths of the total nitrogen contributed from the combined sewer service area in the Kinnickinnic River watershed is estimated to be attributable to overflow from combined sewers. The average annual transport of total nitrogen as obtained using the historic quality-simulated flow method is set forth in Table 46 for both the separate and combined sewer service areas of the watershed.

Water Quality Simulation Modeling: The average annual transport of total nitrogen from the Kinnickinnic River watershed as obtained using the water quality model is set forth in Table 46. The data are limited to the separately sewered area of the watershed because the pollution contribution from the combined sewer service area was not included in the modeling for reasons set forth in Chapter XIII of this report.

Discussion of Total Nitrogen Yield Estimates: As indicated in Table 46, the average annual yield of total nitrogen from the separately sewered area of the Kinnickinnic River watershed as estimated using the EPA preliminary screening procedure is 40 tons per year. The estimated yields obtained using the historic quality-simulated flow method and the water quality modeling method were 34 and 78 tons per year, respectively. Therefore, the total nitrogen yields from the separately sewered areas as obtained by three different methodologies are in relatively close agreement. As also indicated in Table 46, the average annual yields of total nitrogen from the combined sewer portion of the basin as estimated using the EPA preliminary screening procedure and the historic quality-simulated flow method are 34 and 31 tons per year, respectively. Therefore, the total nitrogen contribution from the combined sewer service areas as obtained by the different methodologies are also in relatively close agreement.

The values obtained from the water quality modeling method were selected as the best estimates of loadings of total nitrogen from the separately sewered areas of the watershed for reasons presented in the discussion on biochemical oxygen demand yield.

Table 46 indicates that a disproportionately large mass of nitrogen is contributed by the combined sewer service area. Although the combined sewer service area comprises only about 18 percent of the watershed area, it is estimated to contribute almost half of the total nitrogen transported from the basin.

The results of the historic quality-simulated flow method as set forth in Table 46 suggest that a disproportionately large mass of nitrogen is contributed during wet weather conditions. Although only about 18 percent of the days in a year are wet weather days, it is estimated that wet weather conditions account for about three-fourths of the total nitrogen transported from the basin. Furthermore, wet weather conditions account for about 65 and 90 percent of the total nitrogen contribution from, respectively, the separately and combined sewered areas in the Kinnickinnic River watershed.

Dissolved Solids Yield of the Watershed: The dissolved solid yield of the Kinnickinnic River watershed, which is defined as the average annual quantity of dissolved solids

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[25] *The annual quantity of total nitrogen carried into the combined sewers with sanitary sewage was calculated as 300 tons, which was obtained as the product of the population of the combined sewer service area (estimated at 30,000 persons) and the per capita contribution of total nitrogen (0.055 pound per person per day times 365 days). Ten percent of the total nitrogen was assumed to be deposited in the combined sewers and subsequently flushed into the surface waters during overflow events based on the earlier assumption that 10 percent of the suspended solids are deposited in the combined sewers and subsequently flushed into the surface waters. The resulting annual load of total nitrogen discharged through the combined sewer outfalls and attributed to sanitary sewage is about 30 tons, or 6.6 tons per year per square mile of the 4.54-square-mile combined sewer service area. This unit load is about 3.5 times the 1.9 tons per year per square mile unit load of total nitrogen washed from the land surface, or the total unit load of nitrogen in the combined sewer service area is 3.9 times the unit load in a separately sewered area.*

transported from the watershed by rainfall and snowmelt runoff and by dry weather flow to and perhaps through the estuary, was estimated using two techniques. These techniques are: 1) the historic quality-simulated flow method; and 2) the water quality simulation modeling method.

Historic Quality-Simulated Flow Method: Dissolved solids concentration data for dry and wet weather conditions as determined from recent monitoring studies and as set forth in the various tables and figures in this chapter were used in selecting the representative dry and wet weather dissolved solids concentrations set forth in Table 48. Output from the hydrologic simulation model was used to estimate the volume of average annual dry and wet weather condition runoff from the separately sewered area of the watershed. This volume is expressed in inches over the land surface.

The average annual yield of dissolved solids from the separately sewered area was computed as the product of the representative dry weather condition concentration of dissolved solids and the dry weather runoff plus the product of the representative wet weather condition concentration of dissolved solids and the wet weather runoff. A similar formula was used for the combined sewer service area except that an additional dissolved solids load was applied to account for solids contributed by sanitary sewage; namely, the dissolved solids carried into the combined sewers with sanitary sewage, settled out in the combined sewers, and then subsequently flushed out into the surface water system during combined sewer overflow events. Approximately 10 percent of the dissolved solids contributed from the combined sewer service area in the Kinnickinnic River watershed is estimated to be attributable to overflow from combined sewers. The average annual transport of dissolved solids as obtained using the historic quality-simulated flow method is set forth in Table 46 for both the separate and combined sewer service areas of the watershed.

Water Quality Modeling: The average annual transport of dissolved solids in the Kinnickinnic River watershed as obtained using the water quality model is set forth in Table 46. The data are limited to the separately sewered area of the watershed because the pollution contribution from the combined sewer service area was not included in the modeling for reasons set forth in Chapter XIII of this report.

Discussion of Dissolved Solids Yield Estimates: As indicated in Table 46, the average annual yield of dissolved solids from the separately sewered area of the Kinnickinnic River watershed as estimated using the historic quality-simulated flow method is 9,700 tons, and the estimated annual yield obtained from water quality modeling is 24,440 tons. Therefore, the dissolved solids yields from the separately sewered area as obtained by two different methodologies are quite different. As also indicated in Table 46, the average annual yield of dissolved solids from the combined sewer area of the basin as estimated using the historic quality-simulated flow method is 2,300 tons. The values obtained from the water quality modeling method were selected as the best estimates of loadings of dissolved solids from the separately sewered service area of the watershed for reasons presented in the discussion on biochemical oxygen demand yield.

Table 46 indicates that the mass of dissolved solids contributed by the combined sewer service area is in proportion to the relative sewer areas. That is, dissolved solids contributed by the combined sewer service area are not disproportionately high as are the contributions of biochemical oxygen demand, phosphate and total phosphorus, and total nitrogen.

The results of the historic quality-simulated flow method as set forth in Table 46 suggest that a disproportionately large mass of dissolved solids is contributed during wet weather conditions. Although only about 18 percent of the days in a year are wet weather days, it is estimated that wet weather conditions account for about 40 percent of the dissolved solids transported from the basin as well as from the separately and combined sewered areas in the Kinnickinnic River watershed.

Miscellaneous Sources of Selected Diffuse Pollutants: Estimates of diffuse source pollutants contributed to the watershed land surface or surface waters as a result of atmospheric fallout and washout, construction activities, street deicing practices, domestic animals, and hazardous spills are discussed below.

Atmospheric Fallout and Washout: Atmospheric fallout and washout may be significant direct or indirect sources of pollution to surface waters. Such atmospheric contributions may be deposited directly onto the surface waters, or they may be transported, transformed, and stored on the land surface prior to entry into the surface waters.

Man's activities and the physical environment influence air pollution concentration, dispersal, and fallout rates. Air pollutants that may ultimately enter surface waters are produced by point, area, and line sources from residential, industrial, agricultural, transportation-related, construction, and utility-related land uses and activities. Air pollutants, in the form of smoke, dust, soot, fly ash, fumes, mist, odors, seeds, pollens, spores, and contaminanted precipitation are sources of nutrients, particulate matter, oxygen-demanding substances, heavy metals, and chemicals. Some air pollutants present no threat to water quality, but others are significant contributors. Oxides of nitrogen may react with sodium, potassium, and other heavy metals to form soluble nitrates which, when washed out of the atmosphere by rain, may contribute to the fertility of surface waters. Phosphorus absorbed on fine clay and silt-sized particles will be transported by wind erosion and deposited in surface waters.[26]

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[26] *For a detailed discussion of the types and sources of atmospheric pollution see Chapter V of SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin.*

Particulate Matter: Estimates of average annual loadings of particulate matter, phosphorus, nitrogen, and lead from atmospheric sources to the Kinnickinnic River watershed were made to determine the relative magnitude of such sources compared to other diffuse sources of pollution. The unit loading rate for dry fallout of particulate matter on the watershed was estimated at 600 pounds per acre per year based on a 1971 study by the Milwaukee County Department of Air Pollution Control.[27] The average concentration of particulate matter in precipitation was estimated at 10 mg/l based on reported limited values.[28] Assuming an average annual precipitation of 30 inches on the watershed, a concentration of 10 mg/l of particulate matter is equivalent to about 70 pounds per acre per year. This figure suggests that the bulk of particulate matter contributed by the atmosphere—about 90 percent—occurs as dry fallout. The total atmospheric contribution of particulate matter on the watershed—that is, dry fallout plus washout—is estimated at 670 pounds per acre per year, or about 210 tons per square mile per year.

Applying the total unit load to the 24.78-square-mile area of the Kinnickinnic River watershed yields an average annual estimated atmospheric contribution of particulate matter of 5,400 tons per year. Approximately 0.21 percent, or 10 tons, of the 5,400 tons per year of particulate matter contributed by the atmosphere may be expected to fall directly on the surface waters. Essentially all of the particulate matter falls on the pervious and impervious surfaces of the watershed, and an indeterminate portion of this will be ultimately transported to the surface waters.

The estimated annual total sediment yield of the Kinnickinnic River watershed is 11,150 tons. Because the estimated average annual atmospheric contribution of particulate matter is 5,400 tons per year, or slightly less than half the average annual sediment yield, the atmosphere may be a significant source of the particulate matter that is ultimately carried by the surface waters from the watershed.

Total Phosphorus: The unit loading of total phosphorus to the Kinnickinnic River watershed by both dry fallout and precipitation is estimated at approximately 0.7 pound per acre per year based on reported limited values[29,30] and on preliminary results from the International Joint Commission Menomonee River watershed study. Of this total, roughly three-fourths of the total phosphorus is thought to be contributed by dry fallout, with the remainder occurring as precipitation washout. Applying the total phosphorus unit load of 0.7 pound per acre per year to the 24.78-square-mile Kinnickinnic River watershed yields an average annual loading of phosphorus from atmospheric sources to the watershed land surface of 5.7 tons per year. Because surface waters comprise approximately 0.21 percent of the watershed land surface, approximately 0.21 percent, or about 24 pounds, of the 5.7 tons per year of phosphorus contributed by atmospheric sources may be expected to fall directly on the surface waters. Essentially all of the phosphorus falls on the pervious and impervious surfaces of the watershed and an indeterminate portion of this will be ultimately transported to the surface waters.

As noted above, the estimated average annual yield of total phosphorus from the Kinnickinnic River watershed is estimated at 15.7 tons per year. Therefore, atmospheric contributions of total phosphorus could comprise a significant portion of the total phosphorus ultimately carried from the watershed by the surface water system.

Total Nitrogen: The average annual unit load of total nitrogen on the Kinnickinnic River watershed land surface is estimated at 10 pounds per acre per year based on values reported for urban areas.[31,32] As is the case with total phosphorus, roughly three-fourths of the nitrogen contributed by atmospheric sources is thought to occur as dry fallout, with the remainder being associated with precipitation.

Applying the total nitrogen unit load of 10 pounds per acre per year to the entire 24.78-square-mile area of the Kinnickinnic River watershed results in a total atmospheric load to the watershed of 82 tons per year. Because surface waters comprise only 0.21 percent of the watershed area, approximately 0.21 percent, or 350 pounds, of the 82 tons per year of nitrogen contributed by atmospheric sources may be expected to fall directly on the surface waters. Essentially all of the nitrogen falls on the pervious and impervious surfaces of the watershed and an indeterminate portion of this will be ultimately transported to the surface waters.

As discussed above, the average annual yield of total nitrogen from the watershed via the surface water system is estimated at 65 tons per year. Because the total atmospheric load exceeds this figure, the atmosphere could be a major source of nitrogen in the nitrogen budget of the watershed.

[27] *Milwaukee County Department of Air Pollution Control, 1971 Report on Solids Deposition in Milwaukee County, May 1972.*

[28] *See Chapter III of SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume Three, Urban Storm Water Runoff, July 1977.*

[29] *Ibid.*

[30] *P. D. Uttormark, J. D. Chapin, and K. M. Green, "Atmospheric Contributions of Nitrogen and Phosphorus," Estimating Nutrient Loadings of Lakes from Nonpoint Sources, U. S. Environmental Protection Agency, EPA Report No. 660/3-74-020, August 1974.*

[31] *Ibid., footnote 28.*

[32] *Ibid., footnote 30.*

Total Lead: The dry fallout of lead on the Kinnickinnic River watershed is estimated at 0.27 pound per acre per year. In addition, the washout of lead on the watershed land surface is estimated at about 0.27 pound per acre per year based on an average annual precipitation of 30 inches and an average concentration of lead in precipitation of 40 micrograms per liter. Therefore, about half of the lead contributed by atmospheric sources occurs as dry fallout and the remaining half as washout. These estimates are based on preliminary results of the International Joint Commission Menomonee River pilot watershed study. Applying the total unit load of lead of 0.54 pound per acre per year to the entire 24.78-square-mile Kinnickinnic River watershed results in a total atmospheric contribution to the watershed of 8,865 pounds per year, or about 4.4 tons per year.

Because surface waters comprise approximately 0.21 percent of the area of the watershed, about 0.21 percent, or 20 pounds, of the 8,865 pounds per year of lead contributed by atmospheric sources may be expected to fall directly on the surface waters. Most of the lead falls on the pervious and impervious surfaces of the watershed and an indeterminate portion of this will be ultimately transported to the surface waters.

Construction Activities: The development and redevelopment of residential, commercial, industrial, transportation, and recreational areas within the watershed can cause significant quantities of pollutants to be contributed to the surface waters of the basin. Construction practices which may be significant contributors to the degradation of surface waters are clearing and grubbing, rough grading, facility construction, and finish grading and site restoration. Clearing and grubbing of vegetation, removal of top soil, and unwanted buildings on facility sites and rights-of-way are of particular importance—especially where large areas of land are involved as in the conversion of land from rural to urban uses. Insecticides, rodenticides, and herbicides are sometimes used on construction sites to control unwanted insects, rodents, and weeds. Rough grading for site and right-of-way preparation creates several potential pollution problems. The heavy construction equipment that is used releases diesel fuel, oil, and lubricants to the environment and causes compaction of subsoils, thereby lowering the water infiltration and soil aeration rates. Facility construction primarily involves subsurface excavation and drilling and foundation installation, but may also include dust control operations using oil, spent sulfide liquors, calcium chloride, or water to stabilize access roads and sites; diversion of streams to construct bridges, culverts, dams, and other water control facilities; and construction of storage areas and asphalt operations. Concrete placement operations may release pollutants from spillage and disposal of excess materials. Even the restoration of a construction site through finish grading, loosening and tillage of compacted soils, establishment of permanent vegetation, removal of temporary sediment control structures, removal of temporary construction facilities and equipment, and vegetation of borrow pits and stockpile areas may contribute pollutants. Construction activities also involve dirt, gravel, cement, and materials-hauling trucks, which may contribute sediment loadings to streets in and near the construction area.

The amount and duration of construction spillage or soil disturbance and the specific modifications of the land surface and subsurface are the principal factors which determine the magnitude and importance of construction activities as a source of water pollution. Potential pollutants from construction activities include soil particles, pesticides, petroleum products, solid waste materials, sanitary and other waste waters, and fertilizers. Pollutants from construction sites may be transported to surface waters by runoff of rainfall and snowmelt waters as overland flow, within storm water channels, or through the storm sewer system. Other means whereby pollutants are transported from construction sites to surface waters include infiltration to the groundwater reservoir and subsequent release to the surface waters, wind, soil slippage or landslide, and mechanical transfer on vehicles.

Sediment is the most important pollutant emanating from construction sites. Sediment and associated pollution loads from construction activities are extremely variable and difficult to quantify because they depend upon the period and areal extent of the construction operation; the configuration, location, and topography of the site; the soils at the site; and the construction methods utilized and the ameliorative measures used to control the release of pollutants from the construction area. Because of the temporary, detailed, and localized character of these variables, it is not possible to obtain specific loading data by monitoring or by analytic procedures for construction sites within the Kinnickinnic River watershed. Nevertheless, a gross estimate can be made of sediment yield from construction and development activities in the watershed to demonstrate the relative importance of the level of this diffuse source of pollution to surface waters.[33]

The U. S. Environmental Protection Agency estimates that 150,000 pounds per acre per year of sediments are eroded from land under construction.[34] As of 1970, 178 acres, or 1.1 percent of the Kinnickinnic River watershed, were classified as "residential under development." Assuming that 1 percent of the watershed is an

[33] *For a detailed discussion of types of construction activities likely to produce surface water pollution problems, factors affecting the type and degree of pollutant loads, and specific pollutants generated, refer to Chapter V of SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin.*

[34] *U. S. Environmental Protection Agency, "Construction Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants, EPA Report No. 430/9-73-014, October 1973.*

approximate measure of the area "under construction" in the watershed, and applying the construction site erosion rate of 150,000 pounds per acre per year, total construction site erosion in the Kinnickinnic River watershed is estimated at 24,000,000 pounds, or 12,000 tons, of sediment per year.[35] Not all of this eroded material will reach the major stream channels and be transported from the watershed since some will be retained on or near the construction site either because of the natural topographic conditions at the site or because of erosion control measures established or used at the site.

As discussed above, the average annual total sediment yield from the Kinnickinnic River watershed from all sources was estimated at 11,150 tons. Because these total sediment yields for the watershed are of the same order of magnitude as the estimated erosion of 12,000 tons for construction sites, erosion at the construction sites and other areas under development in the Kinnickinnic River watershed may account for a very large portion of the annual sediment yield from the basin even though construction sites and other land under development encompass only a small part of the basin. This is an occurrence that has also been observed in field studies conducted elsewhere. For example, a study of a 4.7-square-mile Virginia basin undergoing urban development found that 94 percent of the sediment yield transported from the basin during a three- to four-year period originated on only 6 percent of the basin that was undergoing construction. A similar study on a 4.5-square-mile basin near Washington, D.C., found that 85 percent of the sediment transported from the basin came from highway construction encompassing only 11 percent of the basin area.

In addition to being sources of sediment, construction activities are important sources of biochemical oxygen demand, total phosphorus, and total nitrogen. For example, of the 10 land use-cover combinations set forth in Table 43, only two have a biochemical oxygen demand unit load greater than construction and none has a greater unit load of total phosphorus or nitrogen.

Street Deicing Salts: The application of deicing salts on streets and highways during the winter significantly affects the quality of runoff water. Salt applied to streets and highways enters the surface waters as overland flow, flow in storm water channels, or flow through storm sewers, or as interflow or groundwater flow. As indicated earlier in this chapter, chloride concentrations as high as 2,100 mg/l have been recorded in the Kinnickinnic River. Improper or excessive salt application may lead to groundwater or surface water contamination, soil contamination, damage to plants and wildlife, increased corrosion, and possible human toxicity in extreme circumstances.

Deicing Practices: Salts are usually applied early in a snowstorm to prevent the bonding of the snow to the street surface, and then reapplied after snowplowing. Sodium chloride is the most commonly used deicing salt, but it loses its effectiveness when the temperature drops to about 20°F. Mixtures of sodium chloride and calcium chloride, effective to about 0°F, are used at lower temperatures. Deicing salts dissolve to form solutions of lower freezing points than water. Calcium chloride has a lower freezing point than sodium chloride, has an affinity for water, and emits heat as it goes into solution. However, it has higher storage costs, creates handling problems, and leaves the pavement wet since it has a slow evaporation rate.[36]

Survey of Deicing Practices and Application to Kinnickinnic River Watershed: A street and highway practices survey conducted by the Commission under the areawide water quality planning and management program indicates that a total of about 42,000 tons of sodium chloride was applied by the City of Milwaukee to the city streets and alleys during the 1975-1976 winter season, or about 440 tons per square mile of City. In addition, relatively small amounts of dry and liquid calcium chloride were applied to city streets and alleys. The above survey also indicates that a total of about 31,500 tons of sodium chloride was applied by Milwaukee County to county and state highways during the 1975-1976 winter season, or about 130 tons per square mile of County. A gross estimate of average annual sodium chloride application to the Kinnickinnic River watershed can be determined by assuming that the 1975-1976 winter salt use is representative of long-term average salt usage and by applying the total city and county salt application of 570 tons per square mile per year to the entire 24.78-square-mile watershed. The resulting estimate is 14,000 tons per year, or approximately 8,570 tons per year of chloride.

The potential impact of deicing salt on surface water quality may be illustrated by estimating the flow-weighted concentration of deicing salt in watershed runoff. Assuming that 90 percent of the applied chloride reaches the surface water system of this urban watershed under long-term conditions[37] and that the average annual

[35] *Assuming that all the sediment settles out on the land surface or in intermittent channels, it would have a dry specific weight of about 100 pounds per cubic foot and would occupy a volume of 5.5 acre-feet or a volume equivalent to about 5.5 feet of material spread over the area of a regulation football field.*

[36] *For more information on street deicing practices and problems associated with such practices see SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin, (to be published in 1978), and R. Field, et al., Water Pollution and Associated Effects from Street Salting, U. S. Environmental Protection Agency, EPA Report No. R2-73-257, May 1973.*

[37] *A. B. McElroy, et al., Loading Functions for Assessment of Water Pollution from Nonpoint Sources, U. S. Environmental Protection Agency, EPA Report No. 600/2-76-151, May 1976, pp. 202-204.*

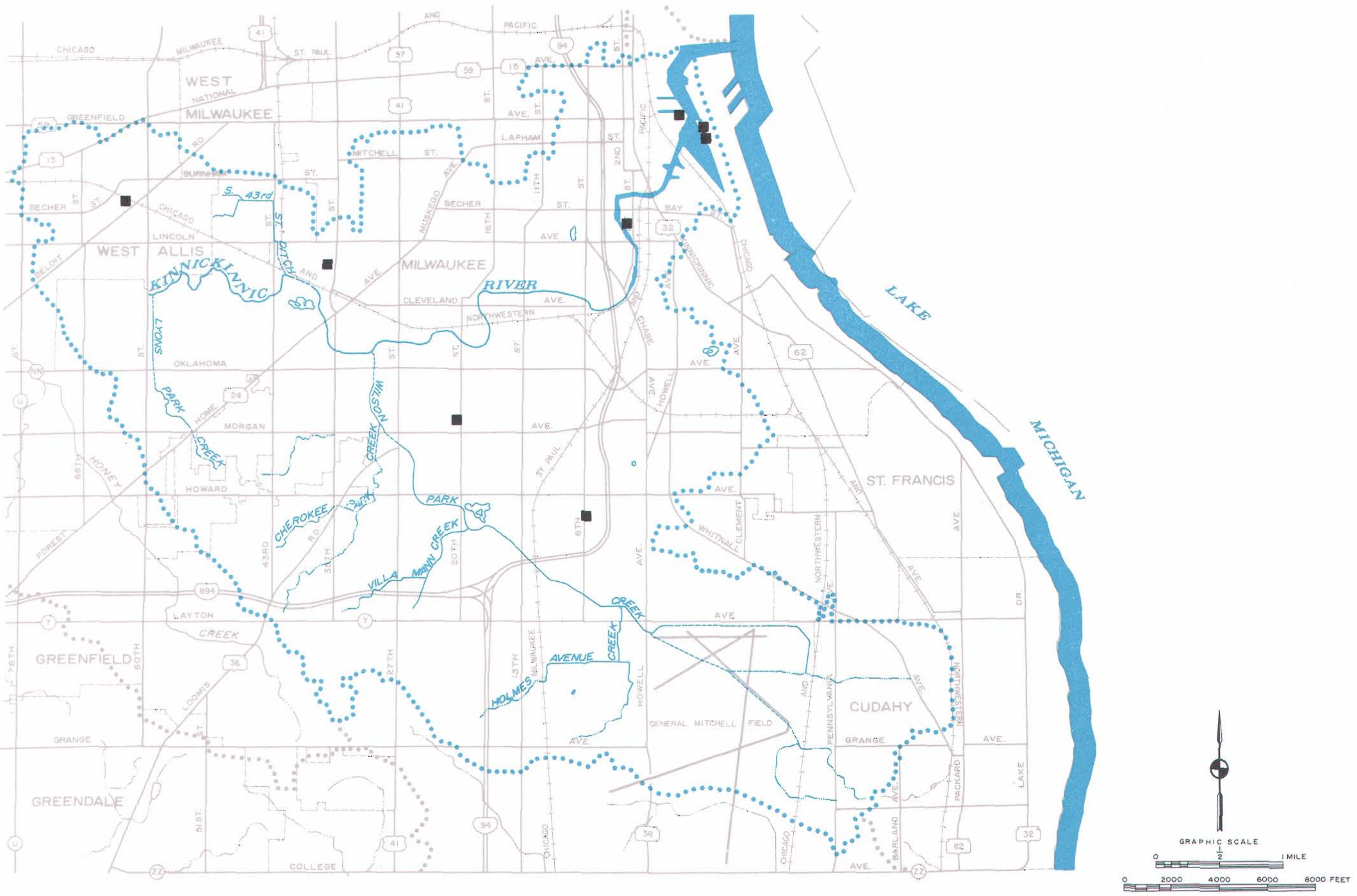
runoff from the watershed is 22.6 inches of water, the flow-weighted concentration of chloride in streamflow from the watershed is estimated at about 200 mg/l, or 10 times the 20 mg/l background level typical of rural areas in southeastern Wisconsin that are not influenced by activities of man. The actual concentration of chloride in the watershed streamflow varies widely ranging from highs known to be in excess of 2,000 mg/l during snowmelt conditions to a low of about 30 mg/l in the fall prior to the resumption of street deicing.

Salt Storage Facilities: An inventory conducted by the Commission under the areawide water quality management planning program revealed that as of the 1975-1976 winter season, eight salt storage facilities were located within the Kinnickinnic River watershed as shown on Map 39. Five of the salt storage facilities use shed-type enclosing structures, and it is estimated that only 13 percent of the salt was stored in piles exposed to the environment with the remainder being stored in protective sheds, thereby minimizing loss of stored salt as a result of precipitation and wind. Also, as of the 1975-1976 winter season, there were no locations in the watershed used for disposal of snow removed from streets and highways.

Domestic Animals: Fecal waste from dogs and cats may be an important source of organic matter, nutrients, solids, and bacteriological contamination of the surface waters of the Kinnickinnic River watershed. Depending on the manner in which it is controlled and disposed of, fecal waste from dogs and cats can also detract from the overall quality of the urban development. As the result of public health concerns, the City of Milwaukee has a dog litter ordinance intended to control the manner in which dog litter is disposed of.

Map 39

DEICING SALT STORAGE FACILITIES IN THE KINNICKINNIC RIVER WATERSHED: 1975-1976 WINTER SEASON



As of the 1975-1976 winter season, eight salt storage facilities were located within the Kinnickinnic River watershed. It is estimated that only 13 percent of the salt was stored in piles exposed to the environment with the remainder being stored in protective sheds, thereby minimizing loss of stored salt as the result of precipitation and wind.

Source: SEWRPC.

The Wisconsin Humane Society estimates the cat and dog population of southeastern Wisconsin is one dog for every six residents and one cat for every three residents. Based on these ratios and the estimated 1975 watershed population of 165,000 persons, it is estimated that the Kinnickinnic River watershed contains 27,500 dogs and 55,000 cats. It is also estimated that the daily fecal deposition—solid plus liquid matter—from larger dogs such as German shepherds, Saint Bernards, Doberman pinschers, Great Danes, Siberian huskies, and malamutes averages 0.75 pound.[38] It is estimated that such deposition from smaller dogs averages about 0.25 pound daily. Assuming an equal population of small and large dogs, the average daily fecal deposition may be estimated at 0.50 pound per dog. Assuming that cats produce about 0.1 pound fecal waste daily and assuming that the fecal matter of 75 percent of the dogs and 10 percent of the cats is deposited outdoors and not collected for proper disposal as solid waste, then 4,000,000 pounds, or 2,000 tons per year of dog and cat fecal matter, are deposited on the watershed land surface and are available for washoff by rainfall and snowmelt to the surface waters.

Separate sanitary sewers are normally considered the ideal means of safely and quickly conveying fecal matter from the point of origin to a sewage treatment plant for proper treatment and disposal. However, because some of the fecal matter from dogs and cats is deposited directly on the land surface, the surface water quality impact of fecal waste from these animals is likely to be greater in areas served by separate storm and sanitary sewers than in areas served by combined sewers. In the case of combined sewers, some of the fecal matter and associated organic material, nutrients, solids, and bacteria that is not trapped in catch basins at storm water inlets will, during runoff events, be carried via the combined sewers and the interceptors to a sewage treatment plant. However, in the case of the separate sewer systems, all of the fecal matter from dogs and cats that is flushed from the urban land surfaces and not trapped in catch basins at storm water inlets will be carried, via the surface or subsurface storm water system, directly to the surface waters.

[38] *A. M. Beck, "The Public Health Implications of Urban Dogs," American Journal of Public Health, Volume 65, No. 12, December 1975, pp. 1315-1318.*

Hazardous Spills: Industrial spills are an additional source of pollution to surface waters. Common to nearly all industrial activities is the storage of petroleum and chemical substances. Heavy loadings of nutrients, oxygen-demanding substances, suspended and dissolved solids, toxic substances, and fecal coliform bacteria may be contributed to surface waters by leaking oil drums; overflowing hoppers and bins of scrap metal saturated with cutting oils; punctured industrial waste hoppers; and spilled greases, fuels, batteries, tannery wastes, animal wastes, food wastes, chemical wastes, toxic wastes, polychlorinated biphenyls (PCB's), heavy metals, and other unique organic materials.

Table 49 indicates that nine reported accidental spills occurred within the Kinnickinnic River watershed in 1977, as reported to the Wisconsin Department of Natural Resources. These data are presented here to suggest the type and source of hazardous spills that may occur. Additional unreported accidental spills and deliberate illegal discharges probably occurred within the watershed in 1977 without the knowledge of regulatory agencies. The resulting pollution of the surface water resources by careless or improper handling of industrial substances can be catastrophic depending on the nature of those substances and the quantity and location of the spill.

Table 49

KNOWN HAZARDOUS SPILLS OCCURRING IN THE KINNICKINNIC RIVER WATERSHED: 1977

Reported Location	Date	Source of Spill	Type of Spill	Quantity	Receiving Water
S. Chase Avenue at Kinnickinnic River	March 15, 1975	Unknown	Oil	--	Kinnickinnic River
Mitchell Field	June 6, 1977	Air National Guard	Degreasing Solvent	--	Wilson Park Creek
Mitchell Field	June 16, 1977	Air National Guard	Solvents	--	Wilson Park Creek
Mitchell Field	August 18, 1977	Air National Guard	Fuel Oil	--	Wilson Park Creek
Kinnickinnic River Mooring Basin	September 24, 1977	Unknown	Bilge Waste	30 Gallons	Kinnickinnic River
S. Chase Avenue at Kinnickinnic River	October 20, 1977	Unknown	Fuel Oil	100-200 Gallons	Kinnickinnic River
S. Chase Avenue at Kinnickinnic River	October 28, 1977	Unknown	Pickle Liquor	--	Kinnickinnic River
S. 6th Street at Kinnickinnic River	November 9, 1977	Air National Guard	Oil	--	Wilson Park Creek
Mitchell Field	November 14, 1977	Air National Guard	Fuel Oil	--	Wilson Park Creek

Source: Wisconsin Department of Natural Resources.

It is important to note that Milwaukee County has, since 1976, issued and enforced a spill prevention control and countermeasure plan for General Mitchell Field in compliance with the oil pollution prevention regulations promulgated as Volume 40, Code of Federal Regulations, Part 112 under the authority of the Federal Water Pollution Control Act Amendments of 1972. The operating, inspection, maintenance, and countermeasure procedures established by the plan and implemented by the County and its airport tenants are designed to reduce the number of spills to a humanly achievable minimum and to prevent such spills as do occur from reaching Wilson Park Creek or the tributary to Oak Creek.

Some "spills" of hazardous substances of industrial origin may occur intermittently or continuously for a long period of time and be undetected, thereby compounding the potential seriousness of the pollutant discharge. An example of a long-term, intermittent discharge of a pollutant in the Milwaukee metropolitan area is the gradual accumulation of hazardous creosote in the bottom muds of the Little Menomonee River in Milwaukee County as a result of an industrial creosoting operation.[39]

Pollution Sources: Overview

Figure 44 provides a graphic summary of average annual yields of selected pollutants from the Kinnickinnic River watershed according to dry and wet weather conditions, type of sewer service area, point and nonpoint sources, and season. Information presented in Figure 44 was obtained in this chapter with the exception of the seasonal distribution of pollutant yields, which is obtained in the water quality submodel described in Chapter XIII of this report.

The following observations may be made and conclusions may be drawn based on the identification, characterization, and quantification of pollution sources:

- Sanitary sewage enters the surface water system of the watershed through five types of flow relief devices: combined sewer outfalls, crossovers, bypasses, relief pumping stations, and portable pumping stations.

- About 8 percent of the flow that leaves the Kinnickinnic River watershed on an annual basis enters the stream system via combined outfalls, whereas the remaining four types of flow relief devices account for about 0.5 percent of the average annual flow from the watershed.

- The average annual contribution of suspended solids by flow relief devices other than combined sewer outfalls is only about 0.1 percent of the annual transport of this material from the watershed. The average annual contribution of biochemical oxygen demand, total phosphorus, total nitrogen, dissolved solids, and chloride through such relief devices is 2 percent or less of the average annual transport of these materials from the watershed.

- Although flow relief devices do not have a severe impact on instream water quality conditions relative to other pollution sources, they should be identified and eliminated because they constitute health hazards in the immediate vicinity of the discharge point, they may be expected to cause objectionable aesthetic conditions, and they are symptomatic of excessive clear water entering the sanitary sewer system and therefore of basement flooding and hydraulic overloads of sewage treatment facilities.

- The 84 industrial discharges known to exist in the watershed constitute an important component of the hydrologic budget of the basin in that they account for one-third of the total average annual flow from the basin and about two-thirds of the dry weather flow.

- The average annual contribution of biochemical oxygen demand, phosphate-phosphorus, total phosphorus, total nitrogen, chloride, and total dissolved solids by industrial point sources is small, ranging from 2 to 14 percent of the total annual transport of such materials from the basin.

- Industrial point sources are relatively continuous and uniform, and their relative impact on the total loads to the surface waters increases during dry weather flow conditions, which occur on about 82 percent of the days of the year. During that time, industrial point sources account for essentially all of the phosphorus being carried in the stream and about 10 percent of the biochemical oxygen demand and total nitrogen.

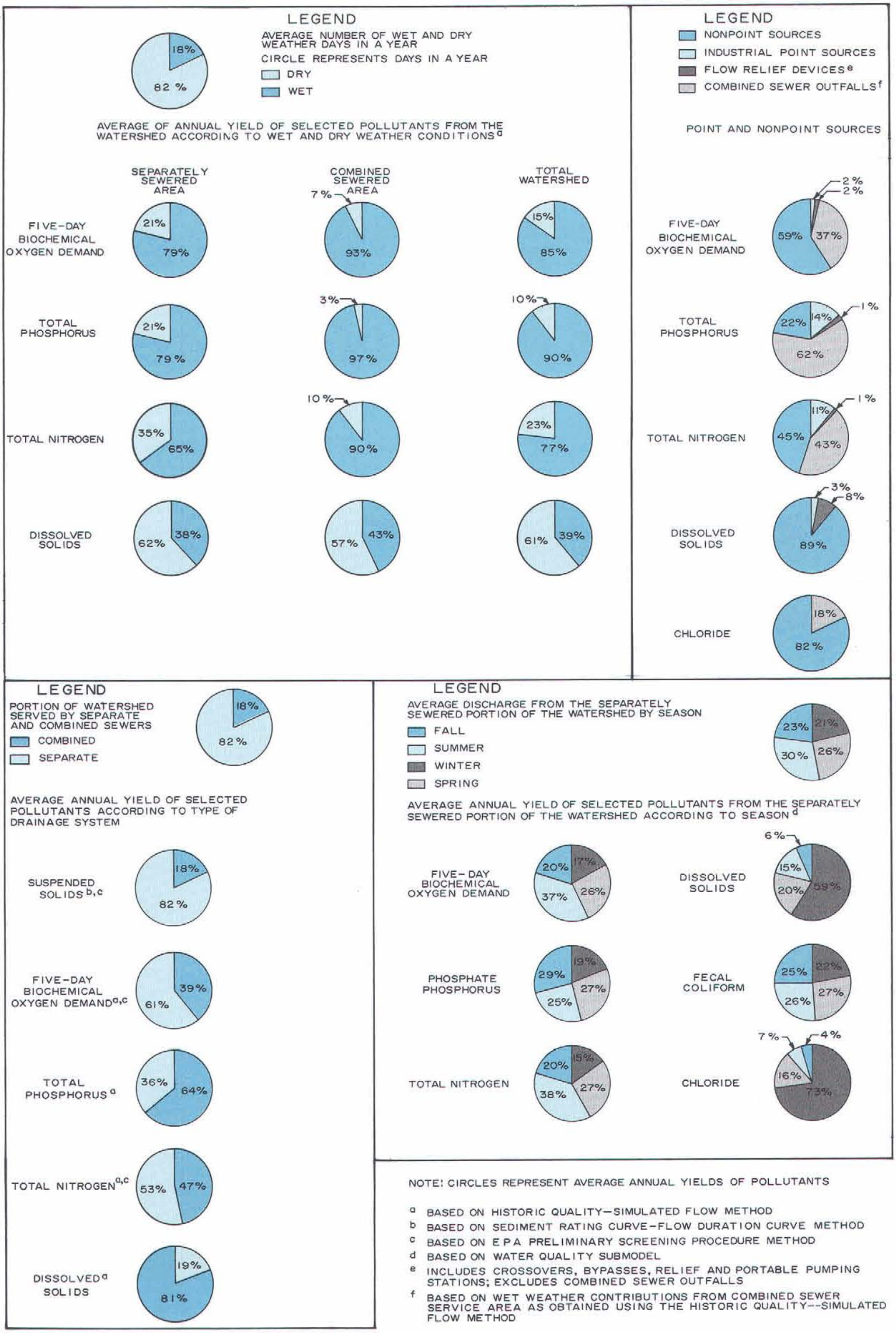
- Diffuse source pollution includes substances washed from the land surface or subsurface by rainfall and snowmelt runoff and then conveyed to the surface waters by that runoff, although such substances may enter the surface waters via a discrete location such as a storm or combined sewer outfall. The accumulation of potential pollutants on or near the land surface may be traced to a variety of man's activities, or to the effects of man's activities.

- A significant difference between diffuse and point source pollution from the perspective of management and control is that the rate at which the diffuse source pollution is transported to the surface waters is highly irregular in that large portions of the overall transport occur during rainfall or snowmelt events.

[39] *See SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume One, Inventory Findings and Forecasts, October 1977.*

Figure 44

SUMMARY OF AVERAGE ANNUAL POLLUTANT YIELDS ACCORDING TO DRY AND WET WEATHER CONDITIONS, TYPE OF SEWER SERVICE AREA, POINT AND NONPOINT SOURCES, AND SEASON IN THE KINNICKINNIC RIVER WATERSHED: 1977



Source: SEWRPC.

- Diffuse sources account for a major proportion of the pollution load imposed on the surface waters of the Kinnickinnic River watershed—22 percent of the total phosphorus, 45 percent of the total nitrogen, 59 percent of the biochemical oxygen demand, and 90 percent of the dissolved solids. The remaining load is attributed to industrial point sources and flow relief devices including combined sewer outfalls.

- About two-thirds of the Kinnickinnic River watershed is served by conveyance-oriented separate storm sewers. Although they may serve an important local drainage function, such hydraulically efficient systems provide an effective means for transport of diffuse source pollution to surface waters. This finding, coupled with the dominance of diffuse source pollution in the watershed, suggests that planning for future storm water facilities should consider control of the quality and quantity of the runoff.

- Unit loads of diffuse source pollutants may be expected to vary markedly according to land use and cover, and, therefore, certain land use-cover combinations will generate a disproportionate amount of the total quantity of a given pollutant produced in the Kinnickinnic River watershed. This finding, coupled with the dominance of diffuse source pollution in the watershed, suggests that optimum pollution control in the watershed will not be achieved by uniform application of management and control measures but will require focusing such measures on critical land use-cover combinations.

- The average annual sediment yield of the Kinnickinnic River watershed is estimated at 11,150 tons. The transport of sediment within and from a watershed can result in serious water quality problems as well as other problems, including the need to conduct maintenance dredging in the navigable downstream portion of the watershed. The average annual cost of approximately $83,000 for maintenance dredging in the watershed estuary provides a conservative estimate of the total annual monetary damage attributed to erosion and sedimentation in the watershed.

- A disproportionately large quantity of biochemical oxygen demand, phosphate-phosphorus, total phosphorus, total nitrogen, and dissolved solids is contributed during wet weather conditions. Although wet weather conditions occur on only about 18 percent of the days in a year, they account for 85 percent of the biochemical oxygen demand, 90 percent of the total phosphorus, 77 percent of the nitrogen, and 39 percent of the dissolved solids transported from the basin. This suggests that some management and control measures will only need to be operative during and perhaps immediately before or after wet weather conditions and that some measures should vary in intensity and mode of operation by season.

- A disproportionately large mass of biochemical oxygen demand, total phosphorus, and total nitrogen is contributed by the combined sewer service area. Although the combined sewer service area comprises only 18 percent of the watershed area, it contributes about 39 percent of the biochemical oxygen demand, 64 percent of the total phosphorus, and 47 percent of the nitrogen transported from the basin. This confirms earlier water quality studies in the Milwaukee metropolitan area which determined that combined sewer outfalls are major pollution sources.

- The yields of chloride and dissolved solids exhibit a marked seasonal variation in that 73 percent of the average annual yield of chloride and 59 percent of the average annual yield of dissolved solids occur in winter.

- An estimate of the average annual atmospheric contribution of particulate matter, total phosphorus, and nitrogen to the Kinnickinnic River watershed indicates that the atmosphere may be a significant source of the load of these substances ultimately carried by the surface waters from the basin.

- The estimated construction site erosion in the watershed is of the same order of magnitude as the estimated sediment yield from the basin, suggesting that erosion in areas under development could account for a large portion of the annual sediment yield from the basin even though such sites encompass only a small part of the basin.

- An examination of the quantity of deicing salt applied to streets and highways in the watershed indicates that deicing salt probably accounts for the very high chloride levels noted in the surface waters at all times of the year.

- It is estimated that 2,000 tons of dog and cat fecal matter are deposited on the watershed land surface each year, thereby becoming available for washoff by rainfall and snowmelt to the surface waters. The efficiency of that transport may be expected to be highest in areas served by separate sanitary sewers.

- Accidental spills of hazardous materials in the watershed present a serious problem because of their unexpected nature and because of the wide variety of potential pollutants involved.

SUMMARY

The activities of man affect and are affected by water quality, particularly in an urban setting such as the Kinnickinnic River watershed where the effects of human activities on water quality tend to overshadow natural influences. A comprehensive watershed planning program must assess water quality conditions and, if pollution problems exist or are likely to develop, must address the abatement of such problems in the plan preparation phase of the work. This chapter determines the extent to which surface waters in the Kinnickinnic River watershed have been and are polluted, and identifies the probable causes or sources of that pollution.

"Water quality" encompasses the physical, chemical, and biological characteristics of the water. Water is deemed to be polluted when foreign substances caused by or related to human activity are in such form and concentration so as to render the water unsuitable for desired beneficial uses. Water pollution may be classified as one or more of the following eight types, depending on the nature of the substance causing the pollution: toxic pollution, organic pollution, nutrient pollution, pathogenic or disease-carrying pollution, thermal pollution, sediment pollution, radiological pollution, and aesthetic pollution. Water pollution is relative in the sense that determination of whether or not a particular water resource is polluted is a function of the intended use of that water resource; that is, water may be polluted with respect to some uses and not polluted with respect to others.

Many parameters, or indicators, are available for measuring and describing water quality. Some of the more important parameters used in analyzing of water quality conditions in the Kinnickinnic River are temperature, dissolved solids, suspended solids, specific conductance, turbidity, hydrogen ion concentration, chloride, dissolved oxygen, biochemical oxygen demand, total and fecal coliform bacteria, phosphorus and nitrogen forms, aquatic flora and fauna, heavy metals, pesticides, and polychlorinated biphenyls (PCB's).

Water quality standards supporting water use objectives for the watershed's surface water system provides a scale against which historic and existing water quality can be judged. For purposes of the comparative water quality analyses set forth in this chapter, the water quality standards corresponding to the "warmwater fishery and aquatic life, recreational use, and minimum standards" objectives established under the areawide water quality planning program in conformance with the national water quality objectives cited in Public Law 92-500 have been used.

A distinction must be drawn between instream water quality during dry weather conditions and during wet weather conditions. Dry weather instream quality reflects the quality of groundwater discharged to the stream plus the continuous or intermittent discharge of various point sources such as industrial cooling or process waters or leakage or other continuous discharge from sanitary or combined sewers. While instream water quality during wet weather conditions includes the above discharges, the dominating influence, particularly during major rainfall or snowmelt events, is the soluble and insoluble substances washed into the streams by direct storm water runoff. This runoff moves from the land surface to the storm waters by overland routes, such as drainage ditches and street and highway ditches and gutters, or by the underground storm sewer system and combined sewer system. Wet weather conditions—defined as being days on which 0.10 inch or more of precipitation occurs—may be expected to occur on an average of 18 percent of the days in a given year.

A variety of data sources, based primarily on field studies and dating back to 1908, were used to assess the historic and existing water quality in the surface waters in the Kinnickinnic River watershed. Most of the historic water quality and monitoring information available for the watershed represents dry weather conditions and relatively little information is available on either dry or wet weather condition concentrations of potential pollutants such as heavy metals, pesticides, and PCB's.

Substandard water quality conditions, along with high concentrations of potential pollutants, are more likely to occur during wet weather conditions in the Kinnickinnic River watershed than during dry weather conditions. The ratio of wet weather to dry weather transport is significantly greater than the ratio of wet weather to dry weather concentrations because of the dilution effect of rainfall and snowmelt runoff. That is, wet weather conditions generally have an even greater impact on pollutant transport from the watershed than on pollution concentration.

During dry weather conditions, the established temperature, pH, dissolved oxygen, ammonia-nitrogen, and total phosphorus standards appear to be satisfied most of the time, whereas the fecal coliform standard is violated about half of the time during dry weather conditions.

During wet weather conditions, the established temperature, pH, dissolved oxygen, and ammonia-nitrogen standards appear to be satisfied most of the time. However, the established fecal coliform and total phosphorus standards are violated most of the time during wet weather conditions. Chloride concentrations in the surface waters of the watershed are well in excess of those found in the rural basins of southeastern Wisconsin. Concentrations of heavy metals, mercury and cadmium, and PCB's are known to have exceeded the established standards. Concentrations of other heavy metals and of pesticides may exceed established standards, but a definitive determination cannot be made from available data since most of the laboratory tests were of insufficient sensitivity.

Heavy metals and PCB's tend to accumulate in bottom sediments of streams, with the average concentration of these substances in the sediment ranging from 1,000 to

20,000 times the concentrations in the flowing stream. The benthic community of the watershed is composed of large populations of pollutant-tolerant species of fauna that are indicative of polluted conditions.

When the flushing tunnel is operating, estuary water quality approximates that of the water being pumped from Lake Michigan and is superior to that of the Kinnickinnic River upstream of the estuary. When the Kinnickinnic River estuary flushing tunnel is not in operation, the most significant water quality effects are low to substandard dissolved oxygen levels and an increase in chloride levels.

Of the eight potential types of surface water pollution identified above, all but thermal and radiologic pollution are known to exist in the Kinnickinnic River watershed. The surface waters of the Kinnickinnic River watershed do not support the warm water fishery and aquatic life objective nor do they support the recreational use objective.

The existing and proposed major channelization and the close proximity of commercial and industrial and other urban development are likely to detract from the aesthetic value of surface waters in the watershed, thus violating the recreational use objective. Notable exceptions are those portions of the watershed stream system contained within Milwaukee County parklands.

The quantity of the pollutant loads to the surface water of the Kinnickinnic River watershed under dry and wet weather conditions, from separate and combined sewer service areas, from point and nonpoint sources, and according to the seasons were estimated using several methods, including the sediment rating curve-flow duration curve method, the historic quality-simulated flow method, the U. S. Environmental Protection Agency preliminary screening procedure, and the water quality simulation model. The average annual contribution of suspended sediment, biochemical oxygen demand, total phosphorus, total nitrogen, dissolved solids, and chloride through sanitary sewage flow relief devices such as crossovers, bypasses, and relief and portable pumping stations is 2 percent or less of the average annual transport of these materials from the watershed. Although flow relief devices may not have a severe impact on instream water quality conditions relative to other pollution sources, they should be identified and eliminated because they constitute health hazards in the immediate vicinity of the discharge point, they may be expected to cause objectionable aesthetic conditions, and they are symptomatic of excessive clear water entering the sanitary sewage system.

The 30 industries discharging through the 84 outfalls known to exist in the watershed are an important component of the hydrologic budget but contribute a relatively small portion of the annual transport of biochemical oxygen demand, phosphate-phosphorus, total phosphorus, total nitrogen, chloride, and total dissolved solids carried from the watershed. The relative impact of industrial point sources increases during dry weather conditions.

Diffuse or nonpoint sources of pollution account for 20 to 90 percent of the pollution load imposed on the surface waters of the Kinnickinnic River watershed. A disproportionately large quantity of biochemical oxygen demand, phosphate-phosphorus, total phosphorus, total nitrogen, and dissolved solids is contributed during wet weather conditions. Although wet weather conditions occur on only about 18 percent of the days of the year, they account for 85 percent of the biochemical oxygen demand, 90 percent of the total phosphorus, 77 percent of the nitrogen, and 39 percent of the dissolved solids transported from the basin.

A disproportionately large amount of pollutants are contributed by the combined sewer service area. Although the combined sewer service area comprises only 18 percent of the watershed area, it contributes about 39 percent of the biochemical oxygen demand, 64 percent of the total phosphorus, and 47 percent of the nitrogen transported from the basin.

Atmospheric fallout and washout may be significant sources of the loads of particulate matter, total phosphorus, and nitrogen ultimately carried by the surface water from the Kinnickinnic River watershed. High chloride levels noted in the surface waters of the watershed at all times of the year are most likely attributable to deicing salt applied to the streets and highways in the basin.

The quality of the surface waters in the Kinnickinnic River watershed does not satisfy the adopted water use objectives and supporting water quality standards. Improvement of surface water quality in the Kinnickinnic River watershed so as to achieve the water use objectives will require a watershedwide water quality management effort aimed primarily at controlling diffuse sources of pollution.

Chapter VIII

WATER RESOURCE SIMULATION MODEL

INTRODUCTION

A quantitative analysis of watershed hydrology, hydraulics, and water quality under existing and alternative future conditions is a fundamental requirement of any comprehensive watershed planning effort. Of particular interest to the watershed planning process are: 1) those aspects of the hydrology and hydraulics of the watershed which effect peak flood discharges and stages and, therefore, floodland management planning; and 2) those aspects which affect water quality conditions, such as periods of critically low stream flows or of washoff from the land surface, and therefore water quality management planning.

Discharge, stage, and water quality at any point and time within the surface water system[1] of a watershed are a function of three factors. The first is the meteorological events which determine the amount of runoff and, therefore, not only the amount of water that the stream system must carry in times of high flow, but also base flow levels and the amounts of water available for various instream uses including the maintenance of a fishery, recreation, and waste assimilation. The second factor is the nature and use of the land, with emphasis on those features that affect the quantity and temporal distribution of runoff and the quality of that runoff. The third factor is those stream characteristics that determine the manner in which runoff from the land moves through the stream system. These characteristics significantly influence flood discharges and stages, the rate at which pollutants are either assimilated within or transported from the watershed.

Recently developed water resources engineering techniques make it possible to calculate existing and future hydrologic, hydraulic, and water quality conditions in a watershed as influenced by the above three factors. These techniques involve the formulation and application of mathematical models that simulate[2] the behavior of the surface water system. These models, which are usually programmed for digital computer application, permit the necessary quantitative analysis of hydrology, hydraulics, and water quality under existing and alternative future conditions as required in the comprehensive watershed planning effort.

The purpose of this chapter is to describe the Water Resource Simulation Model--actually a combined hydrologic, hydraulic, water quality, and flood economics model--used in the Kinnickinnic River watershed planning program. More specifically, this chapter discusses model selection, the submodels contained within the model, input data requirements and data base development, and model calibration.[3] Not all of the voluminous quantity of input and output data resulting from the modeling effort is included in this report. However, data not included are available in Commission files.

It is important to emphasize that the model used in the Kinnickinnic River watershed planning program, or more specifically the mathematical computations and logic decisions executed during the operation of that model, are no more and no less sophisticated or valid than the operations which could, with virtually unlimited personnel and time, be accomplished manually by technical staff. The only advantage of digital computer simulation over manual computations is the rapidity of the computer computations and logic operations relative to the manual computations. The application of mathematical simulation models to water resources planning and engineering was dependent on the development of a computational device--the digital computer--capable of rapidly making, without error, voluminous repetitive calculations and logic operations and was not dependent on an increased understanding of hydrologic, hydraulic, and water quality processes. In fact, most of the hydrologic, hydraulic, and water quality phenomena included in the most sophisticated water resource simulation models were known and formulated many years prior to the advent of simulation, some as early as the eighteenth century. Because of the staff and time requirements and associated monetary costs, it would have been impractical to manually execute the computations necessitated in even a single application of the model used in the Kinnickinnic River watershed study.

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[1]*A system is defined as a set of interdependent physical units and processes organized or arranged so as to interact in a predictable, regular manner, the understanding or manipulation of which can be used to advance some objective or function.*

[2]*Simulation is defined as reproduction of the important behavioral aspects of the system. It should be emphasized that simulation, as used in comprehensive watershed planning, does not normally achieve, or need to achieve, exact duplication of all aspects of system behavior.*

[3]*For background information on water resources modeling including discussions of the need for and nature of modeling, discrete event versus continuous process models, and the use of algorithms, see Chapter VIII of SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume One, Inventory Findings and Forecasts, October 1976.*

MODEL USED IN THE KINNICKINNIC RIVER WATERSHED PLANNING PROGRAM

Model Selection Criteria

Prior to the selection by the Commission in 1974 of a hydrologic-hydraulic-water quality-flood economics model for use in the Menomonee River watershed planning program, that proposed planning program as well as the water resource problems of that watershed were examined in order to determine the applicability of simulation modeling. Based on that examination, it was determined that the "ideal" model should:

1. Be able to simulate the hydrology, hydraulics, and water quality conditions of streams and watercourses in both rural and urban areas.

2. Be able to compute 100-year recurrence interval flood discharges and stages with sufficient accuracy for use in delineating floodland regulatory districts and areas.

3. Be able to calculate a wide range of flood discharges and stages for federal flood insurance study purposes.

4. Be able to accurately incorporate the effects of hydraulic structures such as bridges, culverts, and dams and of localized floodland encroachments on upstream and downstream flood discharges and stages.

5. Be able to compute average annual flood damages and costs and benefits of alternative floodland management measures.

6. Be able to accurately incorporate the hydrologic and hydraulic effects of land use changes--particularly the effects of the conversion of land from rural to urban uses--not only within the floodlands but within the entire tributary watershed.

7. Be able to accurately incorporate the hydrologic and hydraulic effects of alternative structural flood control works such as channelization, dikes and floodwalls, and storage impoundments.

8. Permit assessment of the impact on surface water quality of discharges from point sources of pollution such as municipal and industrial discharges.

9. Permit assessment of the impact on surface water quality of diffuse sources of pollution, such as organic materials and plant nutrients washed from the land surface or leached out of soil profiles.

In addition to the application of these nine criteria which pertain directly to the needs of the Menomonee River watershed planning program--and which are also applicable to the Kinnickinnic River Watershed planning program--the model selection process involved two determinations related to the overall work program of the Commission. First, because the installation of a new model, or a portion of a new model, requires considerable staff time and expense, maximum use should be made of existing in-house models. Second, the model selected for use in the Commission watershed planning programs should have the potential to substantially fill the water resource simulation modeling needs of other ongoing or scheduled Commission water resources planning programs. During the time period in which the model was being selected and implemented on the Commission's computer system for the Menomonee River watershed study--approximately June 1974 to April 1975--the Commission was either participating in or planning to undertake the following major water resource-related studies: the International Joint Commission Menomonee River pilot watershed study,[4] the Kinnickinnic River watershed planning program,[5] and the areawide water quality planning and management program.[6] Since it was anticipated that the model or portions of it would be extensively used in these and other Commission water resources planning programs over a period of several years, it was deemed desirable to select a flexible model and one for which some formal model maintenance, refinement, and extension services were available.

Model Selection

No single digital computer model existed that had the capability of meeting all of the selection criteria. Therefore, the modeling requirements were satisfied by using a combination of several different existing digital computer programs--a model "package"--that could be used in sequence to satisfy the modeling needs of the Commission water resource-related planning programs. Figure 45, which graphically illustrates the overall structure of the selected model, identifies five submodels, or computer programs, within the model that perform the calculations; shows the relationships between these submodels; indicates the input and output of each submodel; and indicates the uses of the simulation model results. The set of submodels contains both continuous process and discrete event submodels selected so as to maximize the favorable features of each of the two basic model types.

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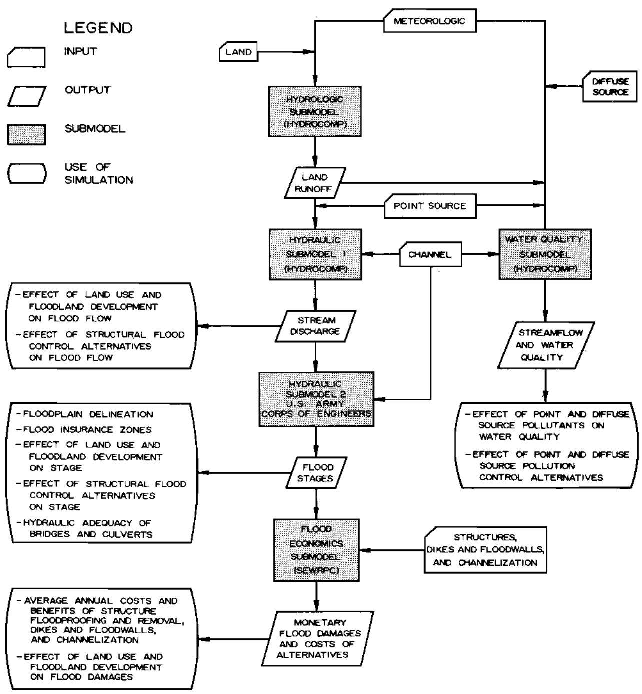
[4]*Wisconsin Department of Natural Resources, University of Wisconsin System-Water Resources Center, and Southeastern Wisconsin Regional Planning Commission, Menomonee River Pilot Watershed Study Work Plan, September 1974.*

[5]*Southeastern Wisconsin Regional Planning Commission, Kinnickinnic River Watershed Planning Program Prospectus, November 1974.*

[6]*Southeastern Wisconsin Regional Planning Commission, Study Design for the Areawide Water Quality Planning and Management Program for Southeastern Wisconsin, 1975-1977, Revised August 1975.*

Figure 45

HYDROLOGIC-HYDRAULIC-WATER QUALITY-FLOOD ECONOMICS MODEL USED IN THE KINNICKINNIC RIVER WATERSHED PLANNING PROGRAM



Source: SEWRPC.

The Hydrologic Submodel, Hydraulic Submodel 1, and the Water Quality Submodel are three computer programs contained within a program package called "Hydrocomp Simulation Programming."[7] This computer program, which is available on a proprietary basis through the consulting firm Hydrocomp, Inc., has been under development since the early 1960's, when pioneer work in hydrologic-hydraulic modeling was initiated at Stanford University.[8] In 1972, the Hydrocomp firm added water quality simulation capability to the model. The Hydrocomp programming--that is, the Hydrologic Submodel, Hydraulic Submodel 1, and the Water Quality Submodel--are continuous process submodels that were installed on the SEWRPC computer system in late 1974 and early 1975.

The submodel identified as Hydraulic Submodel 2 is the U. S. Army Corps of Engineers program called "Water Surface Profiles".[9] This discrete event, steady state model was provided to the Commission without cost by the Hydrologic Engineering Center of the Corps of Engineers and is continuously maintained by the Center at no cost to the Commission. This large computer program has been used extensively by the Commission in its floodland management planning and plan implementation activities since mid-1972,[10] and has been operable on the Commission computer system since February 1974. The Flood Economics Submodel is an extension of a computer program originally prepared by the Commission staff in November 1973 for the purpose of conducting an economic analysis of floodland management alternatives along the North Branch of the Root River in the City of West Allis.

Each of the five submodels is described briefly below. These separate discussions emphasize the function of each submodel within the overall modeling scheme, the types of algorithms that are contained within each submodel, data needs, and the kinds of output that are provided.

Hydrologic Submodel: The principal function of the Hydrologic Submodel is to determine the volume and temporal distribution of flow from the land to the stream system. As used here, the concept of runoff from the land is broadly interpreted to include surface runoff, interflow, and groundwater flow to the streams. The amount and rate of runoff from the land to the watershed stream system are largely a function of two factors. The first is the meteorological events which determine the quantity of water available on or beneath the land surface and the second key factor is the nature and use of the land.

The basic physical unit on which the Hydrologic Submodel operates is the hydrologic land segment. A hydrologic land segment is defined as a surface drainage unit that exhibits a unique combination of meteorological parameters, such as precipitation and temperature, and land characteristics, such as proportion covered by impervious surfaces, soil type, and slope. A strict interpretation of this definition would lead to the conclusion that there is virtually an infinite number of hydrologic land segments within even a small watershed because of the large number of meteorological parameters

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[7] *Hydrocomp, Inc., Hydrocomp Simulation Programming Operations Manual, Fourth Edition, January 1976; and Hydrocomp, Inc., Hydrocomp Water Quality Operations Manual, April 1977.*

[8] *N. H. Crawford and R. K. Linsley, Digital Simulation in Hydrology: Stanford Watershed Model IV, Technical Report No. 39, Department of Civil Engineering, Stanford University, July 1966.*

[9] *U. S. Army Corps of Engineers, Hydrologic Engineering Center, Computer Program 723-X6-L202A, HEC-2, Water Surface Profiles Users Manual, Davis, Calif. November 1976.*

[10] *From late 1970 to mid-1972, the Commission used the U. S. Army Corps of Engineers program "Backwater-Any Cross-Section," the predecessor of the current program.*

and land characteristics and because each such parameter exhibits a continuous, as opposed to discrete, spatial variation throughout the watershed.

A practical, operational definition of a hydrologic land segment is a surface drainage unit consisting of a subbasin or a combination of subbasins within the geographic area that is represented by a particular meteorological station and which is relatively uniform with respect to three land characteristics: soil type, slope, and land use or cover. As described later in this chapter, seven hydrologic land segment types and 29 hydrologic land segments were identified within the Kinnickinnic River watershed for the modeling of existing conditions.

The hydrologic processes explicitly simulated within the Hydrologic Submodel are shown on Figure 46. The submodel, operating on a time interval of one hour or less, continuously and sequentially maintains a water balance within and between various hydrologic processes. The water balance accounting procedure is based on the interdependence between the various hydrologic processes shown schematically in Figure 47. The Hydrologic Submodel maintains a running account of the quantity of water that enters, leaves, and remains within each phase of the hydrologic cycle during each successive time interval.

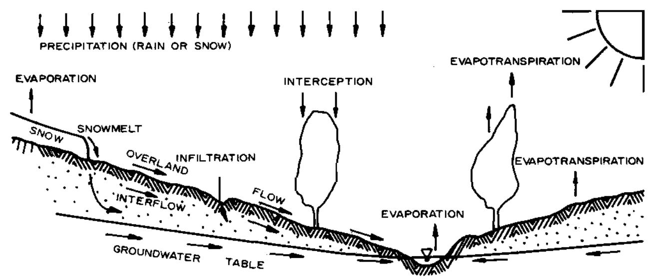
As already noted, the volume and rate of runoff from the land is determined by meteorological phenomena and the nature and use of the land. Therefore, meteorological data and land data constitute the two principal types of input data for each land segment type in the Hydrologic Submodel. Table 50 identifies eight categories of historic meteorological data sets, seven of which are input directly or indirectly to the Hydrologic Submodel for each land segment type, and notes the use of each data set. The procedures used to acquire or develop the eight different types of meteorological data sets used in simulating the hydrologic response of the Kinnickinnic River watershed land surface are described later in this chapter.

Table 51 identifies the 28 land-related parameters that are input to the Hydrologic Submodel for each hydrologic land segment type and indicates the primary source of numerical values for each parameter. The numerical values assigned to each of these land parameters for a given land segment have the effect of adapting the Hydrologic Submodel to the land segment type. The procedures used to assign values to the land parameters for each hydrologic land segment type are described later in this chapter.

Hydraulic Submodel 1: The primary function of Hydraulic Submodel 1 is to accept as input the runoff from the land surface in combination with point and groundwater discharges as produced by the Hydrologic Submodel, to aggregate it, and to route[11] it through the stream system, thereby producing a continuous series of discharge values at predetermined locations along the rivers and streams of the watershed. Computations proceed at a time interval of an hour or fraction thereof.

Figure 46

PROCESSES SIMULATED IN THE HYDROLOGIC SUBMODEL



Source: Hydrocomp, Inc. and SEWRPC.

Statistical analyses performed on the resulting continuous series of discharges yield the discharge-frequency information that is then input to Hydraulic Submodel 2 for calculation of stage. Stages are also computed by Hydraulic Submodel 1 but, because of the highly simplified manner in which channel-floodplain geometry is represented in the model, these stages are not, in the opinion of the Commission staff, accurate enough for certain watershed planning purposes, including mapping of floodland regulatory zones, testing of the hydraulic adequacy of bridges and culverts, and determination of flood damages. The discharges produced by Hydraulic Submodel 1 are, however, judged adequate for all watershed planning applications.

In addition to maintaining a continuous accounting of inflow to the stream system, Hydraulic Submodel 1 performs two types of routing calculations--one for channel reaches and another for impoundments, that is, lakes and reservoirs. These two routing procedures are similar in concept in that both employ the conservation of mass principle and basic hydraulic laws. The procedures differ significantly, however, with respect to input data needs and the detailed manner in which the computations are executed. For the purpose of applying these two routing techniques, the channel system is divided into reaches and impoundment sites.

Reach routing is accomplished on a continuous basis using the kinematic wave technique. Application of this technique requires that the following information be provided for each reach: length; upstream and downstream channel invert elevation; a channel-floodplain cross section consistent with a prismatic representation of the reach; Manning roughness coefficients for the channel and the floodplains; and size and other characteristics of the tributary drainage area.

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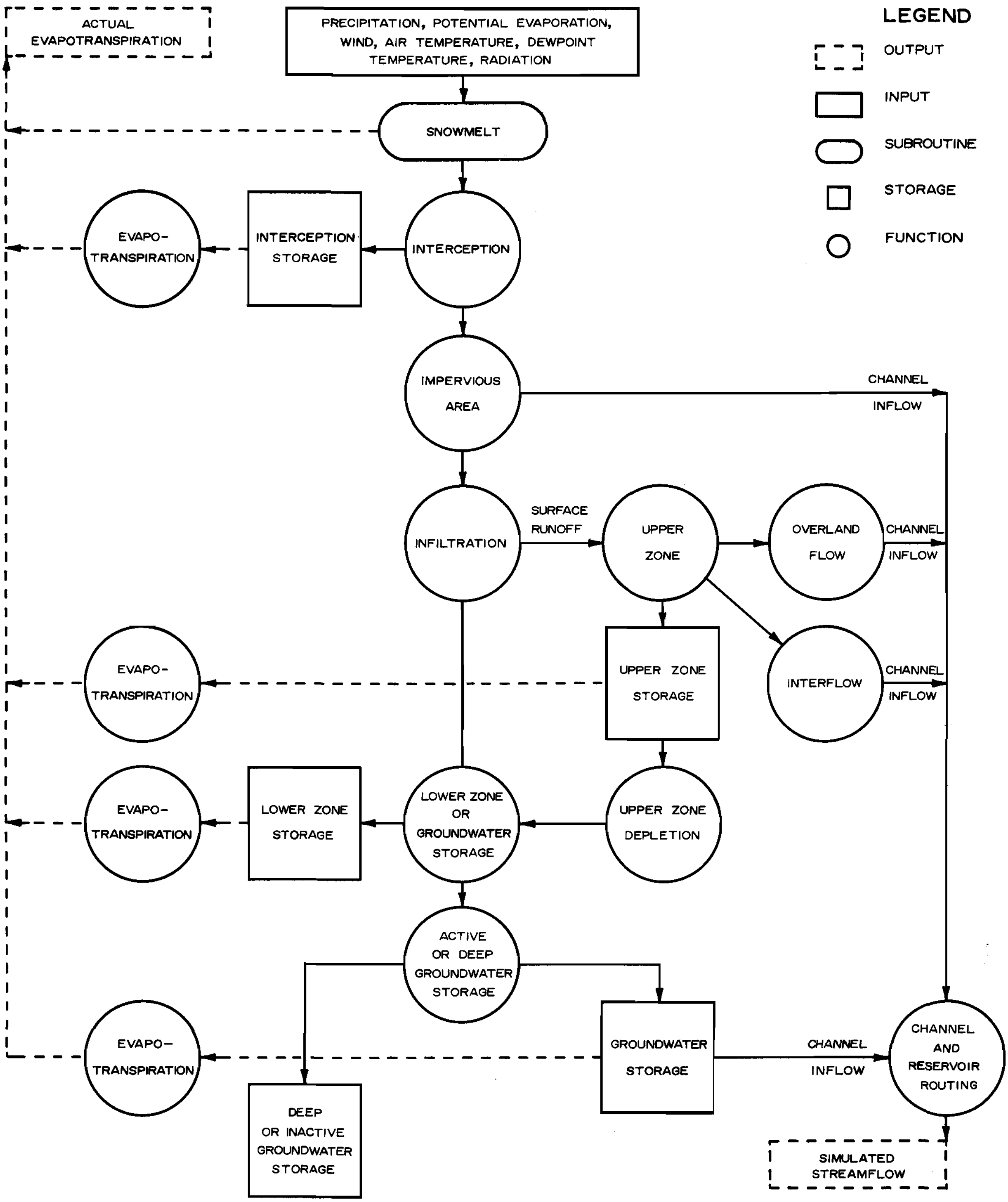
[11] *Routing refers to the process in which a streamflow hydrograph for a point at the entrance to a river reach or an impoundment such as a lake or reservoir is significantly attenuated--that is, the peak flow is reduced and the base lengthened--through the reach or impoundment as a result of either temporary channel-floodplain storage or temporary impoundment storage.*

Figure 47

INTERDEPENDENCE BETWEEN PROCESSES IN THE HYDROLOGIC SUBMODEL



Source: Hydrocomp, Inc. and SEWRPC.

Table 50

METEOROLOGICAL DATA SETS AND THEIR USE IN THE HYDROLOGIC AND WATER QUALITY SUBMODELS

Data Set	Units	Frequency		Origin of Data		Use in Hydrologic Submodel	Use in Water Quality Submodel	Use in Synthesizing Other Meteorological Input Data for the Submodels
		Desirable	Allowable	Historic	Computed			
Precipitation	10^{-2} inches	Hourly or more frequent	Daily	X	—	Rain or snowfall applied to the land Data from hourly stations used to disaggregate data from daily stations	—	—
Radiation	Langleys/ Day[a]	Daily	Semimonthly	—	X	Snowmelt	Water temperature-heat flux to water by short wave solar radiation	Compute potential evaporation
Potential Evaporation	10^{-3} inches	Daily	Semimonthly	—	X	Evaporation from lakes, reservoirs, wetlands, depression storage, and interception storage Evapotranspiration from upper zone storage, lower zone storage, and groundwater storage Evaporation from snow	—	—
Temperature	^{o}F	Daily (maximum and minimum)	—	X	—	Snowmelt Density of new snow Occurrence of precipitation as snow	Water temperature-heat flux to water surface by long wave solar radiation Water temperature-heat flux from water by conduction-convection	Average daily temperature used to compute evaporation
Wind Movement	Miles/Day	Daily	—	X	—	Snowmelt by condensation-convection Evaporation from snow	Water temperature-heat loss from water surface by evaporation Lake reaeration	Compute evaporation
Dewpoint-Temperature[b]	^{o}F	Daily	Semimonthly	X	—	Snowmelt by condensation-convection Evaporation from snow	Water temperature-heat loss from water surface by evaporation	Compute evaporation
Cloud Cover	Decimal fraction	Daily	Semimonthly	X	—	—	Water temperature-heat flux to water surface by long wave solar radiation	—
Sunshine	Percent possible	Daily	—	X	—	Used indirectly	Used indirectly	Compute solar radiation which was in turn used to compute evaporation

[a] *Solar energy flux, that is, the rate at which solar energy is delivered to a surface—such as the earth's surface—is expressed in terms of energy per unit area per unit time. The langley expresses energy per unit area and is equivalent to 1.0 calories/cm^2 or 3.97 x 10^{-3} BTU/cm^2. Therefore, a langley/day, which expresses solar energy flux in terms of energy per unit area per unit time, is equivalent to 1.0 calories/cm^2/day or 3.97 x 10^{-3} BTU/cm^2/day. The solar energy flux above the earth's atmosphere and normal to the radiation path is about 2,880 langleys/day.*

[b] *Dewpoint temperature is the temperature at which air becomes saturated when cooled under conditions of constant pressure and constant water vapor content.*

Source: Hydrocomp, Inc., and SEWRPC.

Table 51

PARAMETERS REQUIRED FOR EACH HYDROLOGIC LAND SEGMENT TYPE SIMULATED WITH THE HYDROLOGIC SUBMODEL

Parameter				
Number	Symbol	Definition or Meaning	Unit	Primary Source of Numerical Values[a]
1	K1	Ratio of average annual segment precipitation to average annual precipitation at measuring station	None	Isohyetal map of annual precipitation
2	A	Impervious area factor related to directly connected impervious area in segment as a percent of total area	None	Aerial photographs
3	EPXM	Maximum interception storage	Inches	Extent and type of vegetation as determined from aerial photographs and field examination
4	UZSN	Nominal transient groundwater storage in the upper soil zones	Inches	A function of LZSN and therefore determined primarily by calibration
5	LZSN	Nominal transient groundwater storage in the lower soil zones	Inches	Related to annual precipitation but determined primarily by calibration
6	K3	Evaporation loss index: percent of segment area covered by deep-rooted vegetation	None	Extent and type of vegetation as determined from aerial photographs and field examination
7	K24L	Decimal fraction of the groundwater recharge that percolates to deep or inactive groundwater storage	None	- -[b]
8	K24EL	Decimal fraction of land segment with shallow groundwater subject to direct evapotranspiration	None	Soils and topographic data
9	INFILTRATION	Nominal infiltration rate	None	Calibration
10	INTERFLOW	Index of interflow	None	Calibration
11	L	Average length of overland flow	Feet	Topographic maps
12	SS	Average slope of overland flow	None	Topographic maps
13	NN	Manning roughness coefficient for overland flow	None	Field reconnaissance
14	IRC	Interflow recession rate	None	Hydrograph analysis
15	KK24	Groundwater recession rate	None	Hydrograph analysis
16	KV	Variable to permit the KK24 to vary with the groundwater slope	None	- -[b]
17	RADCON	Adjust theoretical snowmelt equations to field conditions	None	- -[b]
18	CONDS-CONV	Adjust theoretical snowmelt equations to field conditions	None	- -[b]
19	SCF	Adjust snowfall measurements to account for typical catch deficiency	None	- -[c]
20	ELDIF	Elevation of segment above mean elevation of temperature station	10^3 feet	Topographic maps
21	IDNS	Density of new snow at $0^{\circ}F$	None	- -[b]
22	F	Decimal fraction of land segment with forest cover	None	Aerial photographs
23	DGM	Groundmelt rate attributable to conduction of heat from underlying soil to snow	Inches/day	- -[b]
24	WC	Maximum water content of the snowpack, expressed as a fraction of the water equivalent of the pack; that is, the maximum amount of liquid water that can be accumulated in the snowpack	None	- -[c]
25	MPACK	Water equivalent of snowpack when segment is completely covered by snow	Inches	- -[b]
26	EVAPSNOW	Adjust theoretical snow evaporation equations to field conditions	None	- -[b]
27	MELEV	Mean elevation of segment	Feet Sea Level Datum	Topographic map
28	TSNOW	Air temperature below which precipitation occurs as snow	$^{\circ}F$	- -[b]

[a] *Regardless of the primary source of parameter values, all land parameters were subject to adjustment during the calibration process.*

[b] *Initial values were assigned based on experience with the Hydrologic Submodel on watersheds having similar geographic or climatological characteristics. See Chapter VIII of SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volumn 1, Inventory Findings and Forecasts, October 1976.*

[c] *Initial values were assigned based on information and data reported in hydrology textbooks. See R. K. Linsley, M. A. Kohler, and J. L. H. Paulhus, Hydrology for Engineers, Second Edition, McGraw-Hill, N.Y. 1975.*

Source: Hydrocomp, Inc., and SEWRPC.

Table 52 identifies the 15 channel parameters that are input to Hydraulic Submodel 1 for each reach and indicates the primary source of numerical values for each. Numerical values assigned to each of these channel parameters for a given reach have the effect of adapting Hydraulic Submodel 1 to the reach. The principal means of establishing the channel parameters is direct observation or measurement of the watershed stream system. Additional information on the procedures used to assign values to the channel parameters for each channel reach is presented later in this chapter.

As simulated by the kinematic wave routing algorithm, a volume of flow enters the reach during a given time increment with the flow entering from the reach immediately upstream or coming directly from the land contiguous to the reach. The incremental volume of flow is added to that already in the reach at the beginning of the time interval, and the Manning equation is then used to estimate the discharge rate within the reach during the time increment and, thereby, the volume of flow that would discharge from the reach during the time increment. The volume of water in the reach at the end of the time increment is then calculated as the initial volume plus the inflow volume minus the outflow volume. The above computational process is then repeated for the next time increment and, as in the case for the first time increment, the average flow rate from the reach is obtained. The channel routing computations proceed in a similar manner for subsequent time increments in the reach in question and for all other reaches, thus effectively simulating the passage of flood waves through the channel system.

Impoundment routing through lakes or reservoirs is accomplished on a continuous basis using the technique known as reservoir routing. Use of this analytic procedure requires that a stage-discharge-cumulative storage table be prepared for each reservoir with the values selected so as to encompass the entire range of physically possible reservoir water surface elevations. As simulated by the reservoir routing algorithm, a volume of flow enters the impoundment during a particular time increment with the origin of the flow being discharge from a reach or impoundment immediately upstream and from land contiguous to the impoundment. The incremental volume of flow is added to that already in the impoundment at the beginning of the time interval, and the stage-discharge-cumulative volume relationship is then used to estimate the rate of discharge from the impoundment during the time increment. The volume of water stored in the impoundment at the end of the time increment is calculated as the initial volume plus the inflow volume minus the outflow volume. This computational process is then repeated for subsequent time increments with the result of each such computation being the stage of, and the discharge rate from, the impoundment at the end of each time increment. Any number of stage-discharge-storage relationships may be utilized for a given existing or potential lake or reservoir site, thus facilitating the simulation of a variety of potential outlet works and operating procedures.

Hydraulic Submodel 2: The primary function of Hydraulic Submodel 2 is to determine the flood stages attendant to the flood flows of specified recurrence interval produced by Hydraulic Submodel 1. Given a starting discharge and stage, this "backwater" computer program employs the conservation principles of mass and energy to calculate river stages at successive, preselected upstream locations.

A computational procedure known as the "standard step method" is used in floodland reaches between hydraulic structures such as bridges, culverts, and dams. Given a discharge and stage at a starting floodland cross section, a trial stage is selected for the next upstream cross section. The Manning equation for open channel flow is used to calculate the mechanical energy loss between the two cross sections, and then a check is made to determine if the conservation of energy principle is satisfied. If not, another upstream stage is selected and tested, and the process repeated until the unique upstream stage is found at which the conservation of energy is satisfied. The above iterative computational process is then repeated for successive upstream floodland reaches. The end result is a calculated flood stage at each of the cross-section locations.

Hydraulic Submodel 2 also determines the hydraulic effect of a bridge or culvert and the associated approach roadways by computing the upstream stage as a function of the downstream stage, flood discharge, and the physical characteristics of the hydraulic structure. Starting downstream of the structure, the mechanical energy loss due to the expansion of the flow leaving the structure is computed, then the energy losses directly attributable to flow through or over the structure are calculated, and finally the energy loss due to contraction of the flow approaching and entering the structure is computed. Flow through or over a bridge or culvert may consist of various combinations of open channel flow, pressure flow, and weir flow depending on the position of the upstream stage relative to the low chord of the waterway opening and the profile of the roadway surface.

Input data for that portion of Hydraulic Submodel 2 that performs backwater computations through floodland reaches between hydraulic structures include flood discharges, channel-floodplain cross sections including distances between such sections, and Manning roughness coefficients for the channel and each floodplain. Data requirements for that portion of Hydraulic Submodel 2 that calculates the hydraulic effect of bridges, culverts, and other hydraulic structures include channel bottom elevations, waterway opening measurements, pier position and shape, profiles along the approach roads and across the structure from one side of the floodland to the other, and dam crest shape and elevation.

The backwater computations assume proper waterway opening design and maintenance so that the full waterway opening of each bridge or culvert, as it existed at the time of the hydraulic structure inventory, is available for the conveyance of flood flow. In recognition

Table 52

CHANNEL PARAMETERS REQUIRED FOR EACH REACH SIMULATED WITH HYDRAULIC SUBMODEL 1

DISCHARGE-RELATED PARAMETERS

Parameter		Definition or Meaning	Unit	Primary Source of Numerical Values
Number	Symbol			
1	REACH	Reach identification number	None	Assigned so as to increase in the downstream direction
2	LIKE	Permits repeating W1, W2, H, S-FP, N-CH, and N-FP of a preceding reach by entering the number of that reach	None	--
3	TYPE[a]	Indicates the type of channel or the presence of an impoundment. RECT indicates a rectangular channel, CIRC indicates a circular conduit, and DAM indicates the presence of a dam and an impoundment	None	Observed condition of existing stream system or hypothetical future condition of stream system
4	TRIB	Identification number of the reach that the reach in question is tributary to	None	Stream system configuration and assigned identification numbers
5	SEGMT	Index number of land segment type tributary to reach	None	Map of watershed subbasins and stream system
6	TRIB-AREA	Watershed area directly tributary to reach	Square Miles	

CROSS SECTION-RELATED PARAMETERS

Parameter		Definition or Meaning	Unit	Primary Source of Numerical Values
Number	Symbol			
7	LENGTH	Length of reach	Miles	Map of watershed subbasins and stream system
8	EL-UP	Channel bottom elevation at upstream end of reach	Feet	Channel bottom profile
9	EL-DOWN	Channel bottom elevation at downstream end of reach	Feet	
10	W1	Channel bottom width	Feet	Generalized, representative reach floodland cross section constructed from detailed cross sections prepared for Hydraulic Submodel 2
11	W2	Channel bank-to-bank width	Feet	
12	H	Channel depth	Feet	
13	S-FP	Lateral slope of the floodplains	None	

ROUGHNESS COEFFICIENTS

Parameter		Definition or Meaning	Unit	Primary Source of Numerical Values
Number	Symbol			
14	N-CH	Manning roughness coefficient for the channel	None	Coefficients established for Hydraulic Submodel 2 revised as needed during calibration
15	N-FP	Manning roughness coefficient for both floodplains	None	

[a] *If TYPE is CIRC, then W1 is replaced with DIA—circular conduit diameter in inches—and W2 is replaced by NN-CH—Manning roughness coefficient for the conduit—and the following channel parameters are not needed: H, S-FP, N-CH, N-FP.*
If TYPE is DAM, then the channel parameters are replaced with a set of parameters describing the dam and its impoundment.

Source: Hydrocomp, Inc. and SEWRPC.

of the fact that waterway openings can be temporarily blocked as a result of ice and buoyant debris being carried on floodwaters, floodplain regulations applicable to areas adjacent to or on the fringes of flood-prone areas normally require protection to an elevation equal to the 100-year recurrence interval flood stage plus a freeboard of two feet. A similar freeboard is normally used in the design of structural flood control works intended to convey 100-year flood flows such as dikes and floodwalls or major channel modifications.

Flood Economics Submodel: The Flood Economics Submodel fulfills two principal functions in the total simulation modeling. The first function is to calculate flood stage-damage relationships for urban riverine areas under a variety of developmental conditions which are then used in the submodel to estimate average annual monetary damages. The second key function of the Flood Economics Submodel is to calculate the cost of alternative flood control and floodland management measures, including the cost of floodproofing and of removal of flood-prone structures, the cost of alternative configurations of earthen dikes and concrete floodwalls, and the cost of major channel modifications. Capital costs as well as operation and maintenance costs are calculated by the submodel and the total costs are summarized on both a present worth and average annual basis.

With the exception of certain minor refinements designed to make the Flood Economics Submodel more suitable for use in this study, the submodel is fully described in SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume one, Inventory Findings and Forecasts.

Water Quality Submodel: The principal function of the Water Quality Submodel as used in the Kinnickinnic River watershed planning program is to simulate the time-varying concentration, or levels, of the following nine water quality indicators at selected points throughout the surface water system of the watershed: temperature, dissolved oxygen, fecal coliform, phosphate-phosphorus, total dissolved solids, carbonaceous biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrogen, and nitrite-nitrogen. These indicators were selected because they are directly related to the water quality standards that support the adopted water use objectives set forth in Chapter X of this report.

The concentration of a particular water quality constituent in the surface waters of the watershed at a particular point and time is a function of three factors. The first is the temporal and spatial distribution of runoff--surface or overland runoff, interflow and baseflow--which determines the amount of water available to transport a potential pollutant to and through the surface water system. The second factor is the nature and use of the land, with emphasis on those features that affect the quantity and quality of point and diffuse sources of pollutants. For example, a portion of a watershed that supports agricultural activity is a nutrient source for the surface waters. The third factor is the characteristics of the stream system which determine the rate and manner in which a potential pollutant is either assimilated or transported from the watershed.

Simulation of the above three factors that influence instream water quality requires a large and diverse data base. As shown on Figure 45, operation of the Water Quality Submodel requires the input of six data sets--meteorological, land, channel, riverine-area structure, diffuse source, and point source--as well as output from the Hydrologic Submodel. Table 50 identifies the six categories of historic meteorological sets that are input directly or indirectly to the Water Quality Submodel and notes the use of each data set. The channel data required for the hydraulic portion to the Water Quality Submodel are similar to the data required for Hydraulic Submodel 1, (See Table 52). In addition, a considerable amount of nonhydraulic channel data must be provided. These data consist primarily of water quality parameters and coefficients such as the maximum benthic algae concentration and the deoxygenation coefficient for each reach.

The basic physical unit on which the Hydrologic Submodel operates is called the "hydrologic-water quality land segment." A hydrologic-water quality land segment is defined as an area of land which exhibits a unique combination of meteorological parameters such as precipitation and temperature; land characteristics such as percent imperviousness, soil type, slope, and crop and other vegetative cover; and land management practices such as contour plowing on agricultural land or street sweeping in urban areas. Hydrologic-water quality land segments are identified by using hydrologic land segments as the base and incorporating additional factors likely to influence the washoff of pollutants from the land surface. Up to three different land segments may be used to describe the area tributary to each reach.

A set of diffuse pollution source data is required for each constitutent that is to be modeled on each hydrologic-water quality land segment type. Each set of data contains monthly land loading rates for the pervious and impervious portions, expressed as a weight per unit area, and a loading limit for the pervious and impervious areas, expressed in weight per unit area of land surface. The diffuse source data set for each land segment also contains the concentration of the constitutent in the groundwater flow from the segment to the stream system. Each point source of pollution similarly requires a data set consisting of identification of the river reach to which the source discharges, a series of monthly volumetric flow rates, and a series of corresponding concentrations for each of the constitutents to be modeled. The final category of input to the Water Quality Submodel is output from the Hydrologic Submodel which consists of hourly runoff volumes from the pervious and impervious portion of each hydrologic land segment as well as daily groundwater discharges to the stream system.

For the purpose of discribing the operation of the Water Quality Submodel, the simulation process may be viewed as being composed of a land phase and a channel phase, each of which is simulated on an hourly basis. In the land phase, the quantity of a given constituent that is available for washoff from the land at the beginning of a runoff event is equal to the amount of material remaining on the land surface after the last runoff event plus the net amount of material that has accumulated on the land surface since the last runoff event. The hourly quantity of washoff from the land to the stream system during a runoff event is proportional to the amount of material on the land surface at the beginning of the interval and is also dependent on the hourly runoff rate. The above process is not used to simulate the temperature and dissolved oxygen of land runoff. The model assumes that the temperature of the runoff is equal to atmospheric temperature and that the runoff is fully saturated with dissolved oxygen. Pervious surface runoff and impervious surface runoff during and immediately after rainfall or rainfall-snowmelt events are the two mechanisms for transporting accumulated diffuse source constitutents from the land surface to the stream system. Groundwater flow is the mechanism for continuously transporting potential pollutants to the stream system from the subsurface of the watershed.

Operating on a reach-by-reach basis, the channel phase of the Water Quality Submodel uses kinematic routing to determine the inflow to, outflow from, and net accumulation of flow within each reach on an hourly basis. This is followed by a summation over the hourly interval of all mass inflows and outflows of each water quality constitutent so as to determine an average concentration throughout the reach based on the assumption of complete, instantaneous mixing.

The biochemical processes are then simulated for a one-hour period so as to yield a reach concentration of each constitutent for the end of the period. The above channel phase computations are then repeated within the reach for subsequent time intervals and also are repeated for all other reaches. Water quality processes explicitly simulated within the Water Quality Submodel are shown on Figure 48.

DATA BASE DEVELOPMENT

The largest single work element in the preparation and application of the hydrologic-hydraulic-water quality-flood economics model is data base development. This consists of the acquisition, verification, and coding of data needed to operate, calibrate, test, and apply the model. The model data base for the Kinnickinnic River watershed is a file of information that quantitatively depicts the characteristics or condition of the surface water system of the watershed.

As shown schematically on Figure 45, application of the model requires the development of an input data base composed of the following six distinct categories of information: meteorological data, land data, channel data, riverine-area structure data, diffuse source data, and point source data. Each of the six data categories provides input to at least one of the five submodels. Of the six input data sets, the meteorological data set is the largest because it consists of 37 years of daily or hourly information for each of the eight historic meteorological data types. The meteorological data set is also the most critical in that experience with the model indicates that simulated discharges, stages, and water quality levels are very sensitive to how well the meteorological data set--particularly precipitation--represents historical meteorological conditions.

With respect to their origin, the data in the data base are largely historic in that they are based on existing records of past observations and measurements. For example, the bulk of the meteorological data in the data base are historic in that they are assembled from National Weather Service (NWS) records. Some of the data in the data base are original in that they were obtained by field measurements made during the watershed planning program. Most of the channel data, for example, were obtained from field surveys conducted during the course of the study. A small fraction of the data in the data base are synthetic in that they were calculated from other readily available historic data. Calculated data sets were used when historic data were not available and it would have been impossible or impractical to obtain original data. The solar radiation data used, for example, are synthetic in that they were computed from historic percent sunshine measurements because of the absence of long-term historic radiation observations in or near the watershed coupled with the impracticality of developing long-term original solar radiation data.

A distinction should be drawn between model input data and model calibration data. The six categories of data identified above constitute the input data for the model and constitute the data base needed to operate the various submodels in the model. Calibration data, which are discussed in a subsequent section of this chapter, are not required to operate the model, but are vital to the calibration of the model. The principal types of calibration data are streamflow, flood stage, and water quality.

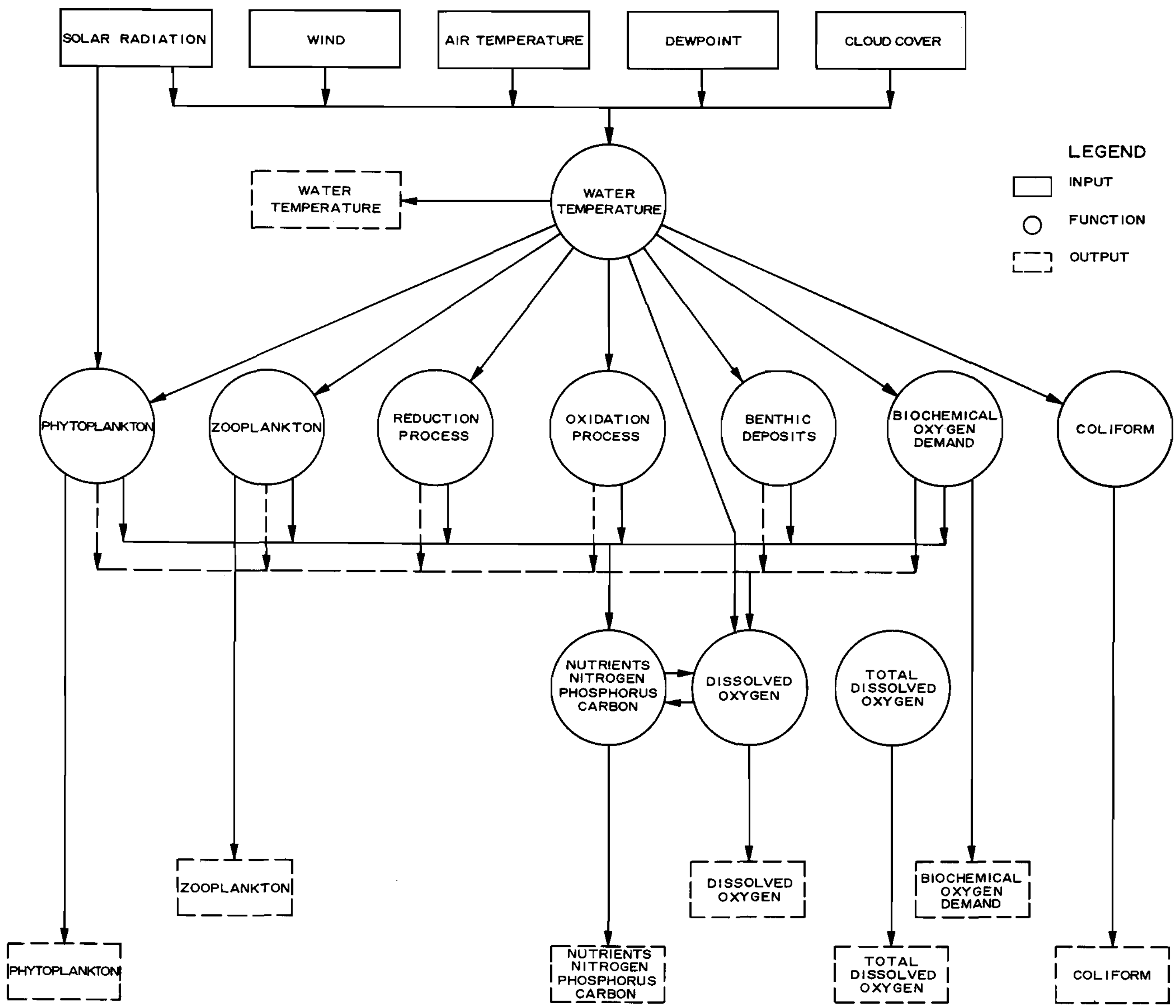
Each of the six types of input data, as well as the validation data, is described separately in the following sections. The origin of each data set is described as are the procedures used to verify and code the information. In the case of some of the data types, the means of acquisition have been described in earlier chapters of this report or in another report, and, with the exception of a brief reference, will not be repeated in this chapter.

Meteorologic Data

As shown in Table 50, the following seven of the eight types of meteorological data are required as direct input to the Hydrologic and/or Water Quality Submodels: hourly precipitation, daily maximum-minimum temperature, daily wind movement, daily solar radiation, daily dewpoint temperature, daily potential evaporation,

Figure 48

INTERDEPENDENCE OF PROCESSES IN THE WATER QUALITY SUBMODEL



Source: Hydrocomp, Inc. and SEWRPC.

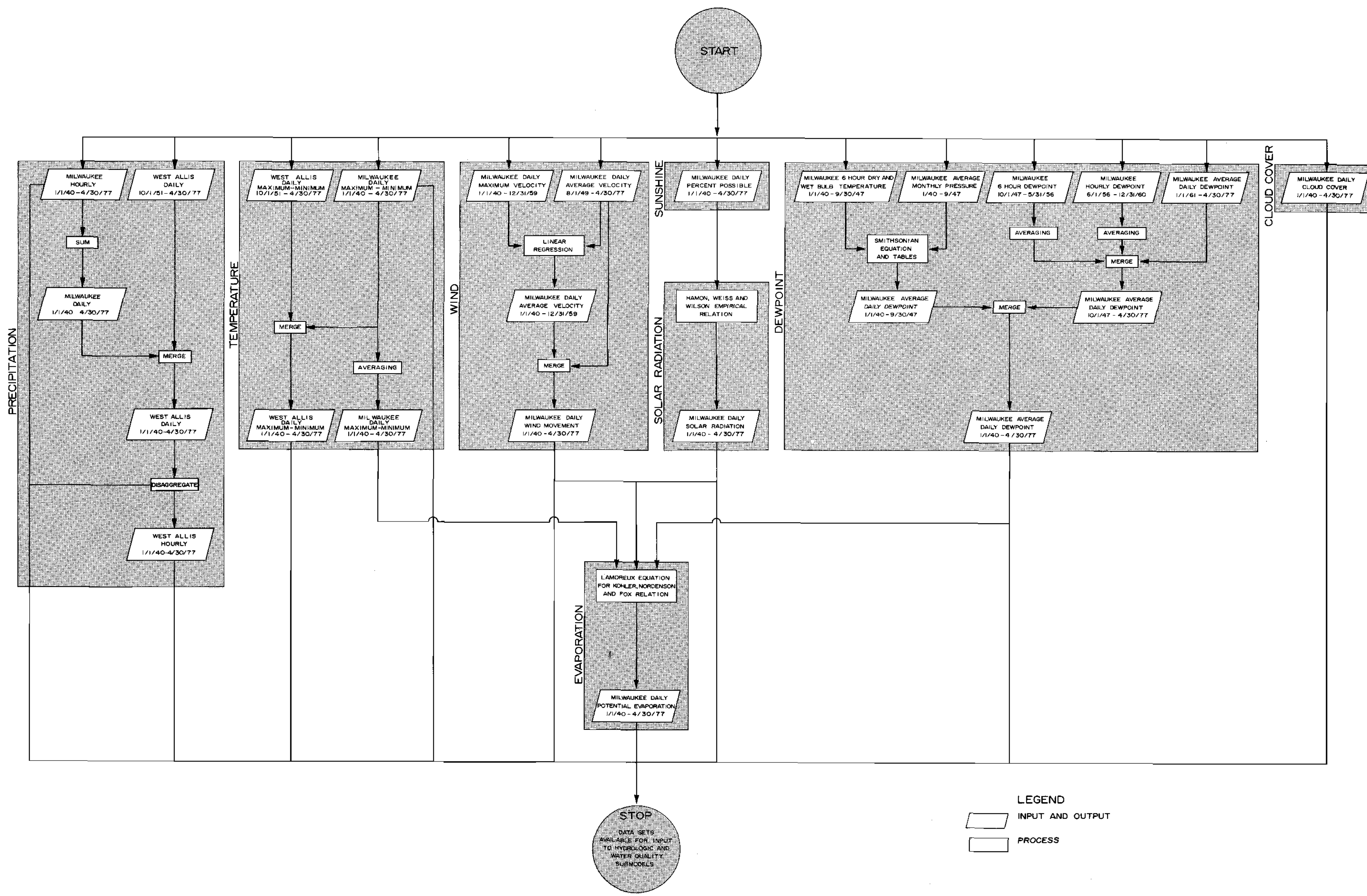
and daily cloud cover. Map 12 in Chapter III shows 11 National Weather Service meteorologic observation stations located in or near the watershed and the Thiessen polygon network which was constructed for the purpose of delineating the geographic area to be represented by each station. All of the watershed lies within the Milwaukee and West Allis polygons and, therefore, the daily precipitation and maximum temperature data for these two stations were selected as being the most representative of the watershed. Hourly precipitation data for the Milwaukee station was used to disaggregate daily precipitation totals for the West Allis station.

The other required meteorological data sets--daily wind movement, daily solar radiation, daily dewpoint temperature, daily potential evaporation, daily cloud cover--where available or could be developed only for the Milwaukee station but were applied to the entire watershed. Therefore, the meteorological data base for the watershed is drawn entirely from historic data from two stations--Milwaukee and West Allis.

The process used to develop the meteorological data sets for the model is schematically depicted on Figure 49. Most of the meteorologic data base development was

Figure 49

PROCESS USED TO DEVELOP METEOROLOGICAL DATA SETS FOR THE MODEL



Source: SEWRPC.

completed under the Commission's Menomonee River Watershed planning program.[12] The principal work element under the Kinnickinnic River watershed planning program was a 28-month extension of the termination date of the meteorologic data base from December 31, 1974 to April 30, 1977.

Selected information about the six meteorological data sets used for the Hydrologic Submodel and Hydraulic Submodel is presented in Table 53. Meteorological data sets were developed for the 37-year period from 1940 through the first third of 1977. January 1, 1940, was selected as the starting date for the data sets since it marks the beginning of hourly observations at the Milwaukee station.

Land Data

As shown on Figure 45, land data are important in that they are needed to operate the Hydrologic Submodel, the output of which influences the four other submodels. Table 51 identifies the 28 land-related parameters that are required for each land segment type that is to be simulated. As defined earlier in this chapter, a land segment is a surface drainage unit consisting of a subbasin or a combination of contiguous subbasins that is represented by a particular meteorological station and contains a unique combination of three key land characteristics--soil type, slope, and land use-cover. Four/and characteristics--meteorology, soil type, slope, and land use-cover--are the major determinants of the magnitude and timing of surface runoff, interflow, and groundwater flow from the land to the watershed stream

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[12] *For a discussion of acquisition of the meteorologic data, double mass curve analysis, conduct of contingency checks, merging and disaggregation procedures, and use of emperical equations see Chapter VIII of SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume 1, Inventory Findings and Forecasts, October 1976.*

Table 53

SELECTED INFORMATION ON DATA SETS USED FOR THE HYDROLOGIC SUBMODEL AND HYDRAULIC SUBMODEL 1

Data Category	Data Type	Interval	Index Number of Data Set	Geographic Reference of Data: Name	NWS I.D. Number	USGS I.D. Number	Period of Data Set: From Month	From Day	From Year	To Month	To Day	To Year	Duration of Data Set (years)
Meteorological	Precipitation	Hourly	1	Milwaukee	5479	–	1	1	1940	4	30	1977	37
			4	West Allis	9046	–	1	1	1940	4	30	1977	37
	Solar Radiation	Daily	41	Milwaukee	5479	–	1	1	1940	4	30	1977	37
	Potential Evaporation	Daily	43	Milwaukee	5479	–	1	1	1940	4	30	1977	37
	Wind Movement	Daily	47	Milwaukee	5479	–	1	1	1940	4	30	1977	37
	Dewpoint Temperature	Daily	49	Milwaukee	5479	–	1	1	1940	4	30	1977	37
	Maximum–Minimum	Daily	51	Milwaukee	5479	–	1	1	1940	4	30	1977	37
	Temperature		54	West Allis	9046	–	1	1	1940	4	30	1977	37
Land	Land Parameters	–	36	–	–	–	–	–	–	–	–	–	–
	Land Surface Runoff	30 Minutes	160	Segment 1	–	–	1	1	1940	4	30	1977	37
			161	Segment 2	–	–	1	1	1940	4	30	1977	37
			162	Segment 3	–	–	1	1	1940	4	30	1977	37
			163	Segment 4	–	–	1	1	1940	4	30	1977	37
			165	Segment 5	–	–	1	1	1940	4	30	1977	37
			167	Segment 6	–	–	1	1	1940	4	30	1977	37
			168	Segment 7	–	–	1	1	1940	4	30	1977	37
Channel	Channel Parameters	–	38	–	–	–	–	–	–	–	–	–	–
Point Source	Industrial Discharges	Daily	141	Reach 12	–	–	1	1	1940	12	31	1977	38
			142	Reach 14	–	–	1	1	1940	12	31	1977	38
			143	Reach 19	–	–	1	1	1940	12	31	1977	38
			144	Reach 44	–	–	1	1	1940	12	31	1977	38
			145	Reach 58	–	–	1	1	1940	12	31	1977	38
			146	Reach 62	–	–	1	1	1940	12	31	1977	38
Calibration and Testing	Streamflow	Daily	153	Kinnickinnic River	–	4 087 160	9	14	1976	5	4	1977	Less than 1
		Hourly	154	Kinnickinnic River	–	4 087 160	9	14	1976	4	4	1977	Less than 1

Source: SEWRPC.

system and therefore are the basis for hydrologic land segment identification and delineation. There are other land characteristics that may influence the hydrologic response of the land surface; for example, depth to bedrock, type of vegetation, and density of the storm water drainage system. However, the above four characteristics were selected for use as both the most basic and most representative.

Identification of Hydrologic Land Segment Types: The process used to identify hydrologic land segments in the watershed began with the subdivision of the watershed into subbasins using the procedure described in Chapter V. As shown on Map 28 in Chapter V, a total of 51 subbasins were delineated ranging in size from 0.05 to 1.70 square miles. These subbasins provided the basic "building blocks" for the identification of hydrologic land segments and subsequently, for hydrologic-water quality land segments in the watershed.

Influence of Meteorological Stations: As noted earlier in this chapter, and as shown on Map 12 in Chapter III of this report, a Thiessen polygon network was constructed for the watershed and surrounding areas in order to facilitate subdivision of the watershed into areas closest to the Milwaukee and West Allis meteorological stations. The polygon boundaries were approximated by subbasin boundaries and then each subbasin was assigned to either the Milwaukee or West Allis meteorological stations. Thus, each subbasin was associated with the closest meteorological station and therefore with the station most likely to be representative of the meteorological processes affecting the subbasin.

Hydrologic Soil Group: The soils of the Region have been classified into four hydrologic soil groups, designated A, B, C, and D, based upon those soil properties affecting runoff. In terms of runoff characteristics, these four soil groups range from Group A soils, which exhibit very little runoff because of high infiltration capacity, high permeability, and good drainage, to Group D soils, which generate large amounts of runoff because of low infiltration capacity, low permeability, and poor drainage. As discussed in Chapter III, because of the extent of urban development within the watershed and the attendant disturbed character of the soils, survey data are available for only six square miles, or about 24 percent of the total area of the watershed, being limited to that portion south of Layton Avenue. The Kinnickinnic River watershed was determined to be primarily covered with Hydrologic Group C soils based on the nature of the soils and the physiography of contiguous areas for which detailed soils data are available.

Slope: A watershed slope analysis was conducted by determining the ground slope at the center of each U. S. Public Land Survey quarter section. Topographic information required to estimate the ground slope was taken from 1" = 2000' scale, 10' contour interval, U. S. Geological Survey quadrangle maps since they provided the best available uniform coverage for the entire watershed. Although more accurate slope values could have been obtained from either large-scale topographic maps or from Commission soils maps, these sources of information were not used because the resulting accuracy would have exceeded that required by the model. Watershed slopes were found to vary from zero to 7 percent with a median value of about 2 percent. Based on the narrow range and the flatness of the slopes throughout the watershed and previous slope sensitivity studies,[13] it was not necessary to categorize subbasins as to slope other than to conclude that mild slopes are applicable to all subbasins in the watershed.

Land Use and Cover: The combination of land use and cover is the characteristic which most often reflects man's influence on the hydrologic processes in that land use-cover, particularly in the Kinnickinnic River watershed, is largely the result of man's activities. Land cover differs from land use in that it describes the types of surface--for example, paved, grassed, and wooded. Whereas land use describes the purpose served by the land--for example, residential, commercial, and recreational. Consider two four-acre areas with identical population densities that may be assumed to represent medium-density residential land use. One area consists of a high-rise apartment building on one-half acre with recreation and open space on the remaining 3.5 acres. The other four-acre tract has single-family residences distributed over the entire area. From a hydrologic viewpoint, these two areas with identical land use but different land cover have different amounts of directly connected impervious surface and different amount of area available for infiltration and, as a result, are likely to exhibit significantly different runoff volumes and peak flows. The combination of land use and cover is quantified and represented in the model for hydrologic modeling purposes through use of percent imperviousness.

Table 54 lists the four imperviousness categories defined for the purpose of identifying hydrologic land segments in the Kinnickinnic River watershed. These four imperviousness categories encompass the full spectrum of existing and probable future conditions in the watershed. The four imperviousness categories were selected by first determining the relative area of each of eight land use-cover classifications within each of the watershed subbasins using 1975 1" = 400' scale Commission aerial photographs and corresponding land use data. A weighted average percent impervious value was calculated for each subbasin based on the relative areas of each land use-cover type using a percent imperviousness assigned to each of the eight land use-cover classifications. A frequency distribution of the subbasin percent imperviousness values and information from previous watershed studies were then used to select the four representative percent imperviousness categories.

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[13]*See Chapter VIII SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume One, Inventory Findings and Forecasts, October 1976.*

Table 54

IMPERVIOUSNESS CATEGORIES IN THE KINNICKINNIC RIVER WATERSHED AS DEFINED FOR THE HYDROLOGIC SUBMODEL

Identification Number	Description	Nominal Percent Imperviousness	Range of Percent Imperviousness	Typical Corresponding Land Use-Cover Combinations
1	Low to Medium Impervious	28	21-33	Low to medium-density residential with supporting urban uses and associated land cover
2	Medium Impervious	40	34-45	Medium-density residential with supporting urban uses and associated land cover
3	High Impervious	56	46-65	High-density residential with supporting urban uses and associated land cover
4	Very High Impervious	77	66-100	Urban commercial and industrial with associated urban uses and paved areas

Source: SEWRPC

Resulting Hydrologic Land Segment Types and Hydrologic Land Segments: Application of the above process yielded a total of seven different hydrologic land segment types in the Kinnickinnic River watershed. The seven hydrologic land segment types used to represent the land surface of the Kinnickinnic River watershed for hydrologic-hydraulic simulation are defined in Table 55 in terms of their hydrologic soil grouping, slope, imperviousness, and proximity to a meteorological station.

It was determined that the hydrologic response of urban areas with combined sewers would be similar to that for areas with separate sewers. Therefore, the distinction between these two types of sewer systems was not used to identify hydrologic land segment types.

The size and spatial distribution of the seven hydrologic land segment types in the watershed under 1975 conditions are depicted on Map 40. The map also shows the actual 29 hydrologic land segments; that is, surficial drainage units as input to the model. Each hydrologic land segment consists of a subbasin or combination of contiguous subbasins that is within the influence of a given meteorological station and contains a unique combination of soil type, slope, and percent imperviousness.

Assignment of Parameters to Hydrologic Land Segment Types: Subsequent to identification of the hydrologic land segment types and delineation of the hydrologic land segments present in the watershed, numerical values were selected for each of the 28 land-related parameters required for each of the land segment types. Table 51 indicates that the numerical values were established in a number of ways including direct measurement of watershed characteristics, experience gained through previous application of the Hydrologic Submodel to watersheds having geographic and climatologic characteristics similar to the Kinnickinnic River watershed, information taken from hydrology references, and calibration--under the Kinnickinnic River Watershed planning program--of the Hydrologic Submodel and Hydraulic Submodel 1 against historic streamflow records. The calibration process, which is the principal means of assigning numerical values to four parameters,[14] is discussed later in this chapter.

Channel Data

Channel conditions including slope and cross section are important determininants of the hydraulic behavior of a stream system. As indicated in Figure 45, channel data are needed to operate Hydraulic Submodel 1, Hydraulic Submodel 2, and the Water Quality Submodel. The channel data required for Hydraulic Submodel 2 will be discussed first since the amount and detail of data required by Hydraulic Submodel 2 exceeds that needed for Hydraulic Submodel 1 and since the data needed for Hydraulic Submodel 1 is based on data assembled for Hydraulic Submodel 2.

Channel Data for Hydraulic Submodel 2: The following four types of channel data are required as input to Hydraulic Submodel 2: discharge; channel-floodplain cross sections, including the distance between cross

[14]*LZSN, UZSN, INFILTRATION, and INTERFLOW.*

Table 55

HYDROLOGIC LAND SEGMENT TYPES REPRESENTATIVE OF THE KINNICKINNIC RIVER WATERSHED[a]

Identification Number of Hydrologic Land Segment Type	Most Influential Meteorological Station		Imperviousness Category				Subbasins In Watershed Represented by Land Segment Type		Comment
	Milwaukee	West Allis	1 Low to Medium	2 Medium	3 High	4 Very High	Number	Percent of Total	
1	X	–	X	–	–	–	4	7.8	–
2	X	–	–	X	–	–	12	23.5	Soil, slope, and land cover are similar to Noyes Creek test basin
3	X	–	–	–	X	–	15	29.4	Soils, slope, and land cover are similar to Honey Creek test basin
4	X	–	–	–	–	X	2	3.9	–
5		X	X		–	–	3	5.9	–
6	–	X	–	–	X	–	14	27.5	Same as segment 3
7	–	X	–	–	–	X	1	2.0	–
Total	–	–	–	–	–	–	51	100.0	–

[a] The entire watershed may be represented by hydrologic soil group C and slope less than 4 percent.
Source: SEWRPC.

sections; Manning roughness coefficients for the channel and each floodplain; and hydraulic structure--bridge, culvert, and dam--data. Hydraulic structure data includes channel bottom elevations, waterway opening measurements, pier position and shape, profiles along the approach roads and across the structure from one side of the floodlands to the other, and dam crest shape and elevation.

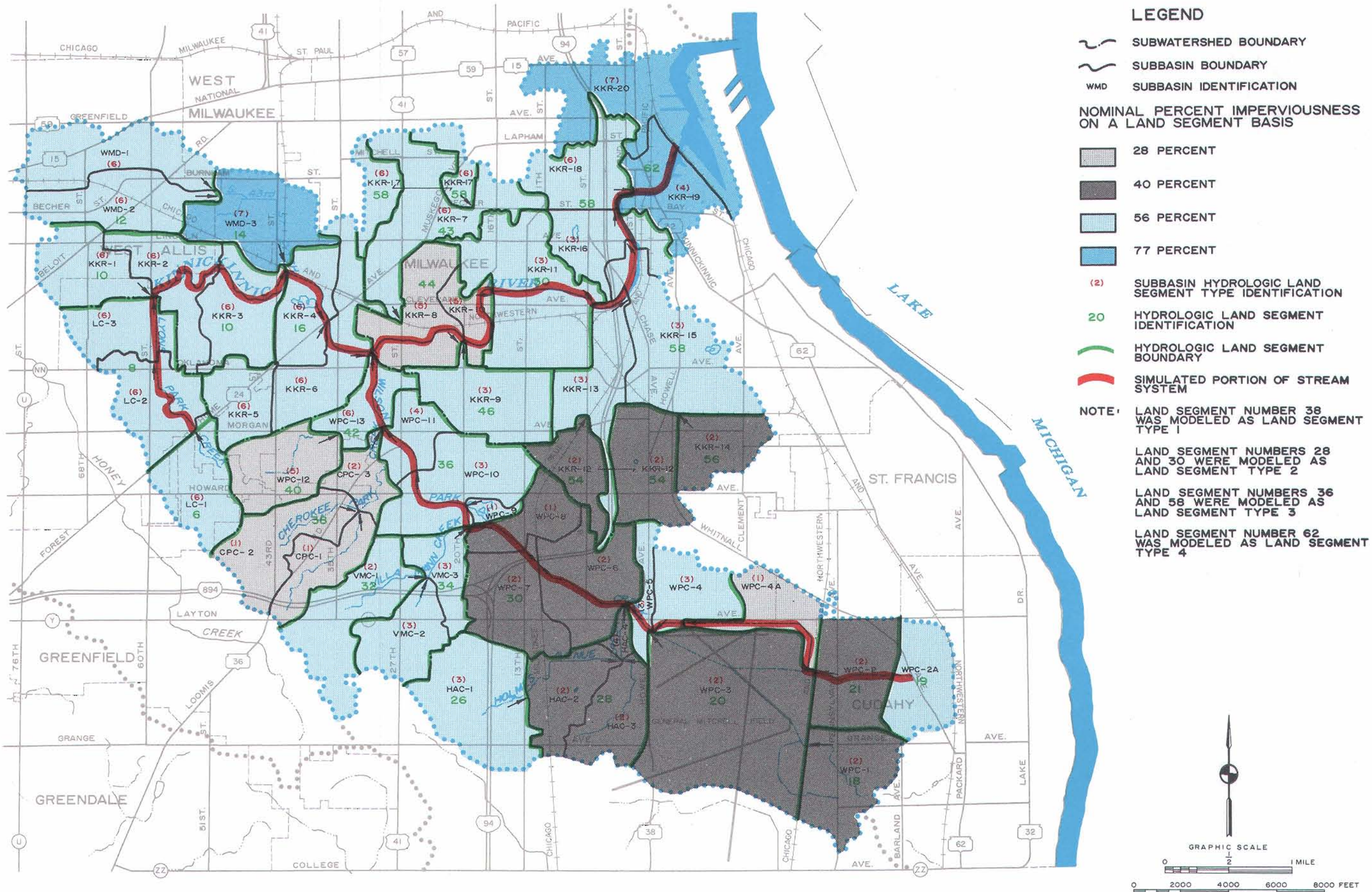
The required discharges are obtained as a result of operating Hydraulic Submodel 1 and performing discharge frequency analyses on those discharges using the log-Pearson Type III technique.[15] The frequency analyses yield flood discharges of a known recurrence interval at various points throughout the watershed stream system. This procedure was used to obtain 1-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, and 500-year recurrence interval discharges which were input to the Hydraulic Submodel 2, which in turn was used to compute the corresponding flood state profiles. The procedures used to obtain the other three types of data required by Hydraulic Submodel 2 are described in detail in Chapter V. As indicated there, the necessary information, including floodland cross sections with an average spacing of about 500 feet and physical descriptions of 84 hydraulically significant structures, was obtained for about 15 miles of watershed stream selected for simulation.

Channel Data for Hydraulic Submodel 1: The following three categories of channel data are required as input to Hydraulic Submodel 1 for each river reach that is to be simulated: discharge; channel-floodplain cross sections, including the length and upstream and downstream elevations of the reach represented by each cross section; and Manning roughness coefficients for the channel and the floodplains. Table 52 lists the 15 channel parameters that are input to the submodel for each reach and indicates the primary source of numerical values for each. If lakes or reservoirs are present in the system and are to be modeled, a stage-discharge-cumulative storage table must be provided along with the surface area of the impoundment and other impoundment characteristics.

[15] *"Guidelines for Determining Flood Flow Frequency," Bulletin No. 17, United States Water Resources Council, Washington, D. C., March 1976.*

Map 40

REPRESENTATION OF THE KINNICKINNIC RIVER WATERSHED FOR HYDROLOGIC-HYDRAULIC SIMULATION: 1975



For purposes of hydrologic-hydraulic modeling, the watershed land surface was partitioned into 29 hydrologic land segments and the watershed stream system was subdivided into 13 reaches. Each hydrologic land segment has a particular combination of soil, slope, percent imperviousness, and proximity to a meteorologic station and is used within the hydrologic-hydraulic model to simulate the conversion of rainfall and snowmelt to streamflow. Each stream reach has a unique set of parameters describing channel slope, cross-sectional shape, and flow resistance and is used to simulate the accumulation of runoff from land surface in the stream system and the transport of that flow through the watershed.

Source: SEWRPC.

The types of data required for Hydraulic Submodel 1 are generally quite similar to those required for Hydraulic Submodel 2 in that both require discharges, floodland cross sections, and Manning roughness coefficients. Submodel input data requirements differ, however, in several significant ways. First, Hydraulic Submodel 2 uses closely spaced floodland cross sections--an average spacing of 500 feet was used in the watershed modeling--consistent with its primary function of using given discharges to accurately compute flood stages. Hydraulic Submodel 1 uses generalized floodland cross sections, with each cross section representing an average reach length of about 1.2-mile to be consistent with its primary function of calculating discharges. Second, the floodland cross sections prepared for Hydraulic Submodel 1 are general representations of the channel-floodplain topography, whereas the cross sections developed for Hydraulic Submodel 2 are more precise representations. In Hydraulic Submodel 2, the cross-section shape is defined by up to 100 coordinates, in Hydraulic Submodel 1, the cross section is defined by only a channel bottom width, a bank-to-bank width, a channel depth, and a single lateral slope representative of the floodplains on both sides of the channel. Third, Hydraulic Submodel 2 accepts more than one Manning roughness coefficient for each floodplain. Under Hydraulic Submodel 1, however, only one coefficient is permitted to represent both floodplains. Fourth, Hydraulic Submodel 2 includes algorithms for calculating the hydraulic effect of a bridge or culvert and associated approach roadways under a variety of upstream and downstream conditions, whereas bridge and culvert computations are not included in Hydraulic Submodel 1 except where they are modeled as impounding structures.

The process used to establish numerical values for the channel parameters was initiated by subdividing the 15.5 miles of stream system selected for simulation into reaches and assigning tributary areas to the reaches. The first step in this process is to insure that there is exactly one channel reach associated with each land segment. This is a requirement of the model in that the channel reach provides the mechanism whereby runoff from the land surface is intercepted, aggregated with flows from upstream reaches, and then routed downstream through the stream system. The second step in reach identification is determination of the minimum allowable reach length based on the relationship between the computational time interval, as used in the Hydrologic Submodel and Hydraulic Submodel 1, and the reach flow through time. It is necessary for the computational interval to be approximately equal to or less than twice the reach flow through time in order for the model to properly perform hydrograph routing. Applying this criterion, it was determined that for the 30-minute computational time interval used in the modeling, the minimum reach length should be about one mile. The third and final criterion used to identify reaches is that each reach be relatively homogeneous with respect to floodland cross-sectional shape, channel slope, and channel-floodplain roughness coefficients. Reaches were thus terminated at points of confluence in the stream system, at locations where the tributary area exhibited abrupt changes in land use, and at locations where discharges were to be computed. The net effect of the above factors was the partitioning of the 15.47 miles of stream system into 13 reaches, as shown on Map 40, having an average length of about 1.2 miles.

After subdivision of the stream system into reaches, channel cross sections representative of each reach were quantified. Seven cross section-related parameters were assigned on a reach-by-reach basis. Cross sections were selected from the set of detailed cross sections prepared for Hydraulic Submodel 2, the selected cross sections were composited, and one generalized representative cross section was constructed for each reach. That cross section was then used to determine numerical values for channel parameters 10 through 13 in Table 52. A procedure similar to the above was used to assign a channel Manning roughness coefficient and a floodplain Manning roughness coefficient to each reach. Coefficients established for Hydraulic Submodel 2 were examined in order to select representative channel and floodplain coefficients for each of the reaches. This completed the assignment of the 15 channel parameters listed in Table 52 and required for operation of Hydraulic Submodel 1. A channel data set was prepared for each stream system configuration--for example, existing condition and proposed channel improvements--that was to be simulated.

Channel Data for Water Quality Submodel: Hydraulic channel data required for the Water Quality Submodel are similar to the data described above for Hydraulic Submodel 1, but with several differences. In addition, nonhydraulic channel data must be provided for each water quality channel reach.

The Water Quality Submodel hydraulic channel data requirements and procedures used to develop the input data differ from Hydraulic Submodel 1 requirements in several ways. First, Hydraulic Submodel 1 uses cross sections which represent the channel and floodplains to be consistent with its primary function of computing flood discharges. The Water Quality Submodel cross sections primarily represent the channel to be consistent with the submodel's function of determining low recurrence interval discharges which are contained within the channel banks. Second, the computational time interval used in the Water Quality Submodel is one hour, whereas 30 minutes are used in Hydraulic Submodel 1. Since the reach flow-through time should be greater than the computational interval in both submodels, the reaches selected for the Water Quality Submodel are necessarily longer. Third, Hydraulic Submodel 2 allows only one land segment to be associated with each channel reach whereas the Water Quality Submodel accepts up to three land segments per reach.

Nonhydraulic channel data consist of water quality parameters and coefficients such as the biochemical oxygen demand reaction rate coefficient, maximum benthic algae concentration, total coliform die-away coefficient, and benthal release rates for nutrients. The principal source of numerical values for these parameters and coefficients is the literature on previous successful experiences with the Water Quality Submodel.

Riverine Area Structure and Related Data

Physical and economic data for riverine area structures--residential and commercial buildings--are needed as input to the Flood Economics Submodel along with flood event information and dike-floodwall and channelization data. Numerical values for up to 68 structure, flood event, dike-floodwall, channelization, and related parameters are required for each flood-prone reach for which flood damage, floodproofing removal costs, dike-floodwall costs, and channelization are to be calculated. This section describes the process used to subdivide flood-prone areas into reaches and subreaches and to obtain or assign numerical values to the parameters.

Preparation of submodel input data was initiated with the assignment of basic cost and economic data applicable to all reaches. Flood damage reaches--reaches for which flood economics calculations were executed using the submodel--were then established based partly on historic flood information collected under the watershed study and described in Chapter VI of this volume, and partly on the results of the hydrologic-hydraulic simulation as described in this chapter. In addition to delineating flood damage reaches so as to encompass areas of existing or potential flood problems, reach boundaries were made coincident with civil division boundaries so as to facilitate the summarization of flood damages and the costs of structure floodproofing-removal, dikes and floodwalls, and channelization by civil division. This approach provides each community with a monetary quantification of both the seriousness of its flood problem and of alternative solutions to that flood problem. The reaches were also selected to encompass areas in which each structure category--for example, single-family residential--exhibited similar market values. Each reach was extended out from the river beyond the

100-year recurrence interval flood hazard line so as to encompass both the primary flooding zone--the floodland area adjacent to the channel and subject to overland flooding during a 100-year flood--and the secondary flooding zone--the area contiguous with the primary zone in which basement flooding may occur as a result of sanitary and storm sewer backup.

The next step in submodel data preparation consisted of partitioning the reaches into subreaches, the principal consideration being that the length of each subreach along the river be selected so that each would have approximately uniform flood stages from the upstream end to the downstream end. The implication of this criterion is that steeper streams will have shorter subreaches than streams with flatter slopes. Subreach boundaries were made coincident with hydraulic restrictions such as bridges and culverts as determined under Hydraulic Submodel 2, because these locations represented abrupt changes in the flood stage profile. Flood-prone riverine areas for which floodproofing-removal measures or dike-floodwall protection measures could be applied were included in separate subreaches so as to permit a direct comparison of the costs of structural measures to the benefits--reduced flood damages--that would result from those measures. The resulting subreaches were delineated on the best available topographic maps, and the necessary subreach identification parameters were assigned.

Output from Hydraulic Submodel 2, consisting of flood stage profiles for a range of recurrence intervals, provided the flood event input data required for each subreach. Structural, physical, and economic information was obtained from large-scale topographic maps, aerial photographs, field surveys, civil division assessors, and personal interviews. For those subreaches where dike-floodwall or channelization alternatives were considered, the plan of the potential dike-floodwall or channelization systems--as delineated on a topographic map or aerial photograph--was used in combination with additional information obtained from river bed profiles to establish the input parameters, thus completing the assignment of numerical values for all parameters.

Point Source Data

Figure 45 illustrates how point source data are input to Hydraulic Submodel 1 and to the Water Quality Submodel. Point source input data for Hydraulic Submodel 1 consisted of monthly discharge values for 19 potentially significant point industrial sources in the watershed as shown on Map 41. As indicated in Table 53 and as shown on Map 41, the 19 point sources were aggregated and represented as input to six reaches in the watershed for operation of Hydraulic Submodel 1.

Point source input data for the Water Quality Submodel consisted of the above monthly discharge values plus monthly water quality values for the 11 potentially significant point sources in the portion of the watershed represented by the submodel. Selected information about each of the 11 point sources is set forth in Table 56.

Diffuse Source Data

Figure 45 illustrates how diffuse source data are input to the water quality submodel, along with meteorologic, point source, and channel data and output from the hydrologic submodel. The choice of initial numerical values for some diffuse source pollution parameters, such as land surface loading rates, was based largely on values reported in the literature for urban and rural areas similar to the Kinnickinnic River watershed[16] and previous experience under the water quality submodel in the Menomonee River watershed and areawide water quality management planning programs. Some of these values were subsequently adjusted during the calibration process to improve the correlation between observed and simulated water quality. A set of diffuse source pollution parameters was established for each subbasin in the watershed and then aggregated to provide a set of diffuse source pollution parameters for each hydrologic-water quality land segment.

Selected information for the nine hydrologic-water quality land segment types in the watershed under 1975 conditions is provided in Table 57. Map 42 indicates how the 10.6 linear miles of channel system upstream of approximately S. 27th Street--the upstream limits of the combined sewer service area in the basin--were subdivided into three channel reaches for purposes of simulating instream water quality processes.

Calibration Data

The six categories of data discussed above--meterological, land, channel, riverine area structure, point pollution source, and diffuse pollution source--constitute the total input data for operation of the model that are required to operate the five submodels. Of equal importance are calibration data which, although not needed to operate the model, are necessary for the calibration of the model. These data, which are derived strictly from field measurements, include "real world" streamflow, river stage, and water quality data. Since calibration data represent the actual historic response of the watershed to a variety of hydro-meteorological events and conditions, such data may be compared to the simulated response of the watershed and the model thereby calibrated.

Streamflow Data: The principal source of historic streamflow information in the watershed are the streamflow measurements made by the U. S. Geological Survey (USGS) from September 13, 1976 to May 5, 1977 at the continuous recording gage maintained at the S. 7th Street crossing of the Kinnickinnic River by the

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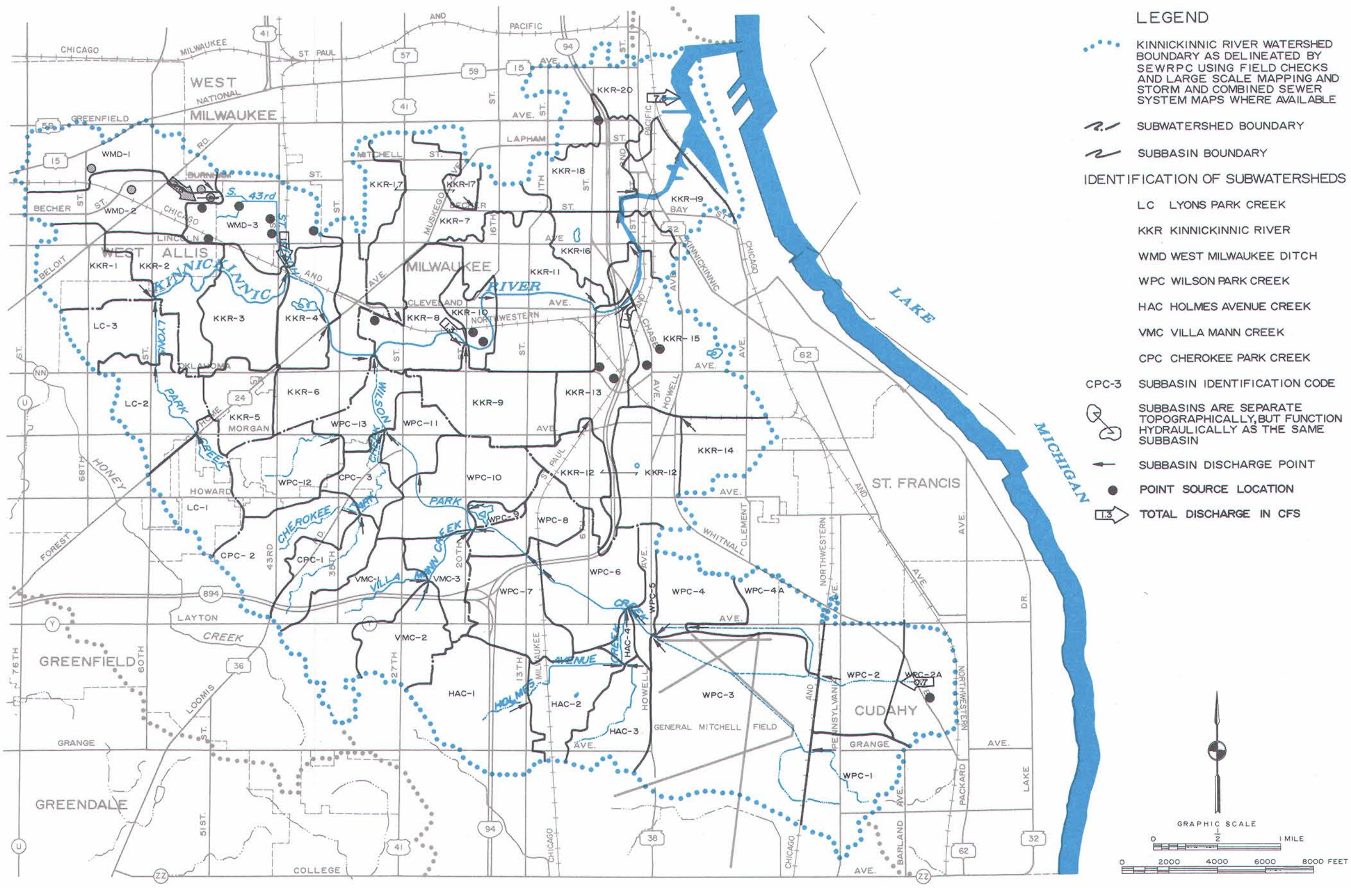
[16]*See Chapter IV of SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume three, Urban Storm Water Runoff, July 1977; Hydrocomp, Inc., Hydrocomp Water Quality Operations Manual, Fourth Edition, April 1977; and U. S. Army Corps of Engineers-Seattle District, Environmental Management for the Metropolitan Area Cedar-Green River Basins, Washington, Park II: "Urban Drainage," December 1974, p. 86.*

Map 41

SIGNIFICANT POINT SOURCES IN THE KINNICKINNIC RIVER WATERSHED: 1977



Point sources of discharge to the Kinnickinnic River and its tributaries are important to successful hydrologic-hydraulic-water quality modeling since point sources account for much of the streamflow and input of potential pollutants during low flow periods. A total of 19 significant point sources were identified in the watershed. These point sources were aggregated for modeling purposes and represented as input at six locations on Wilson Park Creek and the Kinnickinnic River.

Source: SEWRPC.

Table 56

SELECTED INFORMATION ON POINT SOURCES REPRESENTED IN THE WATER QUALITY SUBMODEL

				Average Annual Parameter Values											
Reach	Quantity	SubBasin	Name	Flow (cfs)	Temperature (°C)	Five-day Biochemical Oxygen Demand (mg/1)	Dissolved Oxygen (mg/1)	Ammonia-Nitrogen (mg/1)	Nitrate-Nitrogen (mg/1)	Nitrite-Nitrogen (mg/1)	Organic Nitrogen (mg/1)	Phosphate-Phosphorus (mg/1)	Chloride (mg/1)	Total Dissolved Solids (mg/1)	Fecal Coliform (MFFCC/ 100 ml)
1	1	WPC-2	Ladish Company	0.722	13.3	0.8	10.60	0.03	0.24	0.03	0.20	0.06	13.0	200	0.0
3	10	WMD-1	Briggs & Stratton Corporation	2.29	30.0	0.0	7.63	0.00	0.03	0.00	1.10	0.01	0.0	579	0.0
		WMD-1	Murphy Diesel Company	0.03	36.6	0.0	6.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0
		WMD-1	Teledyne Wisconsin Motor	0.048	16.0	11.7	4.48	0.40	0.22	0.00	1.24	0.04	23.3	300	0.0
		WMD-2	Eaton Corporation	0.19	25.78	16.5	4.12	0.00	0.00	0.00	0.00	0.05	22.5	300	0.0
		WMD-3	Allied Smelting Corporation	0.188	9.0	0.0	11.59	0.00	0.00	0.00	0.00	0.00	0.0	340	0.0
		WMD-3	Froedtert Malt Corporation	0.03	13.68	0.0	10.42	0.00	0.00	0.00	0.00	0.00	0.0	300	0.0
		WMD-3	General Electric Company—Products Department	0.164	16.3	1.2	9.95	0.00	0.00	0.00	0.00	0.00	0.0	300	0.0
		WMD-3	General Electric Company—Medical Systems Division	0.73	13.2	0.0	10.60	0.00	0.00	0.00	0.00	0.00	0.0	300	0.0
		WMD-3	Kurth Malting Corporation	0.232	11.3	0.0	11.08	0.00	0.00	0.00	0.00	0.00	0.0	300	0.0
		WMD-3	Wehr Steel Company	0.392	26.6	0.0	8.07	0.00	0.00	0.00	0.00	0.01	0.0	300	0.0

Source: SEWRPC and WPDES

Table 57

SELECTED INFORMATION ON LAND SEGMENTS REPRESENTED IN THE WATER QUALITY SUBMODEL

Land Segment Idnetification Number	Stream Reach Identification Number	Area (square mile)	Percent of Reach	Hydrologic Land Segment Type[a]		Average Annual Diffuse Surface Loading Rates (mg/1)[b]																	
						Impervious Surface									Pervious Surface								
				Meteorological Station	Impervious Category	Biochemical Oxygen Demand	Ammonia-Nitrogen	Nitrate-Nitrogen	Nitrite-Nitrogen	Organic Nitrogen	Phosphate-Phosphorus	Chloride	Total Dissolved Solids	Fecal Coliform	Five-day Biochemical Oxygen Demand	Ammonia-Nitrogen	Nitrate-Nitrogen	Nitrite-Nitrogen	Organic Nitrogen	Phosphate-Phosphorus	Chloride	Total Dissolved Solids	Fecal Coliform
1	1	4.219	67.2	Milwaukee	Medium	0.156	0.014	0.027	0.001	0.023	0.005	3.9	13.5	420	0.093	0.020	0.003	0.001	0.012	0.004	0.019	23.0	430
2	1	1.570	25.0	Milwaukee	High	0.233	0.029	0.067	0.001	0.068	0.005	3.9	13.5	720	0.634	0.051	0.010	0.002	0.077	0.011	0.048	39.0	430
3	1	0.491	7.8	Milwaukee	Low to Medium	0.248	0.023	0.046	0.001	0.058	0.004	3.9	13.5	720	0.093	0.032	0.009	0.001	0.012	0.019	0.048	39.0	430
4	2	1.718	35.0	Milwaukee	Low to Medium	0.154	0.015	0.040	0.001	0.027	0.005	3.9	13.5	420	0.095	0.020	0.003	0.001	0.013	0.008	0.025	21.0	110
5	2	1.718	35.0	Milwaukee	High	0.154	0.011	0.040	0.001	0.022	0.005	3.9	13.5	420	0.095	0.020	0.008	0.001	0.013	0.011	0.025	25.0	110
6	2	1.473	30.0	Milwaukee	Medium	0.153	0.022	0.025	0.001	0.028	0.005	3.9	13.5	500	0.106	0.040	0.005	0.001	0.013	0.017	0.042	36.0	110
7	3	3.716	66.2	West Allis	High	0.144	0.010	0.041	0.001	0.021	0.005	3.9	13.5	400	0.150	0.030	0.005	0.001	0.012	0.020	0.046	38.0	95
8	3	1.168	20.9	West Allis	High	0.144	0.010	0.041	0.001	0.022	0.005	3.9	13.5	400	0.144	0.034	0.002	0.001	0.012	0.014	0.007	31.0	95
9	3	0.724	12.9	West Allis	Extra High	0.128	0.013	0.015	0.001	0.020	0.005	3.9	13.5	400	0.144	0.069	0.011	0.001	0.012	0.005	0.036	14.0	95

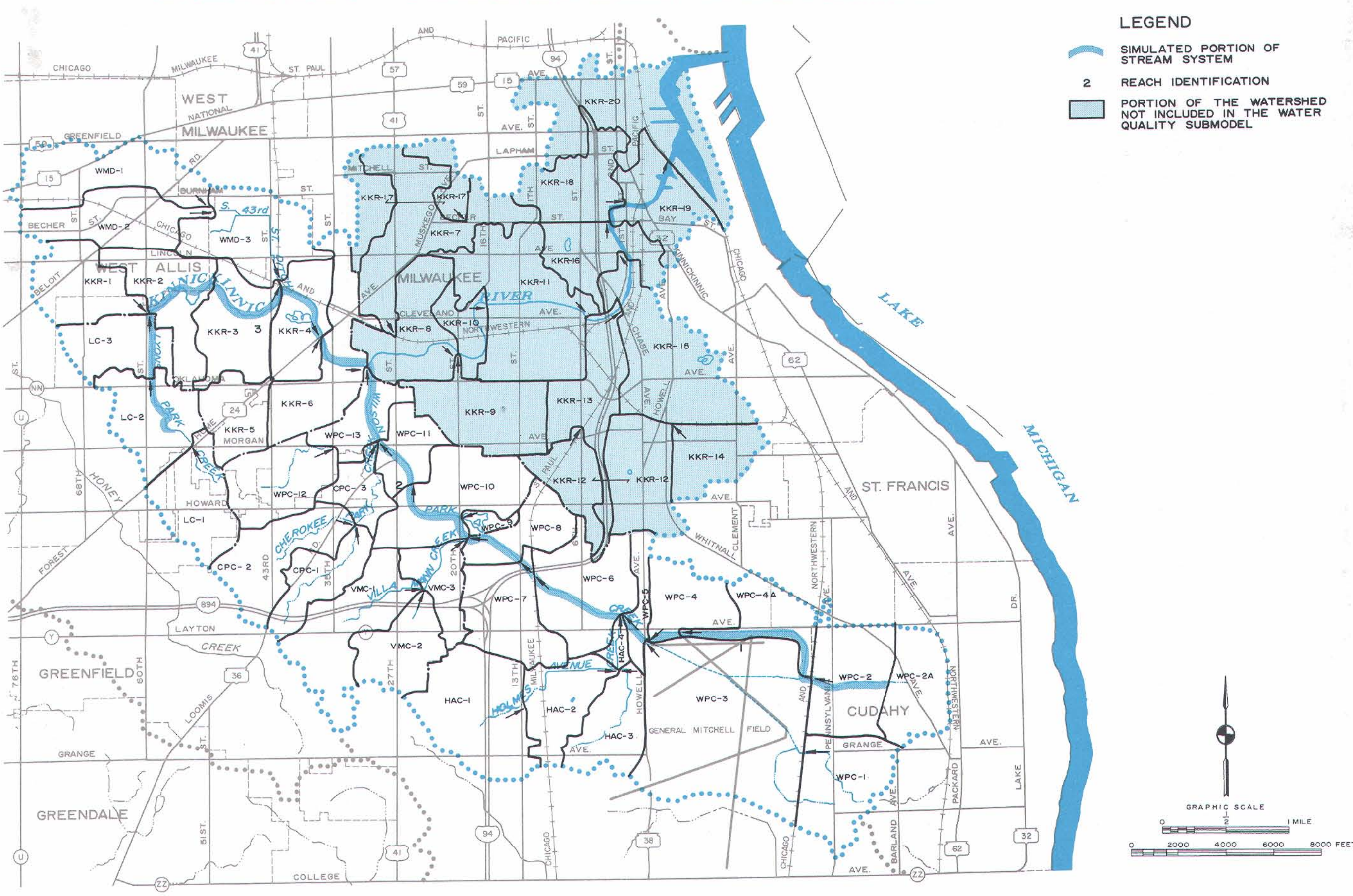
[a] *Further described in Table 55.*

[b] *Except fecal coliforms which are in Mffcc/100 ml.*

Source: SEWRPC

Map 42

REPRESENTATION OF THE KINNICKINNIC RIVER WATERSHED FOR WATER QUALITY SIMULATION



For purposes of water quality modeling the watershed stream system was subdivided into three reaches, and each reach was partitioned into three hydrologic-water quality land segments. The hydrologic-water quality land segments were the basis for simulating the transport of potential pollutants from the land to the stream system via surface runoff, groundwater flow, or point sources. Each stream reach, as represented by a set of parameters, was used to simulate the accumulation of potential pollutants in the channel system and the resulting instream biochemical and advection processes.

Source: SEWRPC.

Metropolitan Sewerage District in conjunction with the Regional Planning Commission and U. S. Geological Survey. A discussion of this stream gaging station is presented in Chapter V. Although the stream gaging station continued to operate after May 5, 1977, the model calibration work had, by mid-1977, progressed to the point where only the data available at that time could be used. The streamflow data available at that time consisted of discharges for the approximately eight-month period from September 13, 1976 through May 5, 1977 and reflect the stage-discharge relationship that had been developed as of May 1977 by the U. S. Geological Survey. Commission and Geological Survey staff determined that certain portions of the available eight-month record were likely to be inaccurate, and therefore unacceptable for model calibration purposes, as a result of factors such as monitoring station malfunction and backwater due to ice accumulation immediately downstream of the station location. Accordingly, the November 28, 1976 to February 28, 1977 portion of the available eight-month record was not used for model calibration.

Daily and hourly flow data for the Kinnickinnic River gaging station were coded and placed on a magnetic disk file for ready recall and for comparison–by computer-generated tables and graphs--to simulated daily streamflows at that location. This streamflow information was supplemented with streamflow estimates derived from stage measurements made by the Wisconsin Department of Natural Resources at two locations on the Kinnickinnic River and one location on Wilson Park Creek at approximately monthly intervals from May 1975 through April 1976.

Flood Stage Data: As described in Chapter V, 33 crest or staff gages are maintained on the watershed stream system by the Metropolitan Sewerage District and the City of Milwaukee. Information on historic high water levels obtained from this network of gages, supplemented with information provided by public officials, consulting engineers, private citizens, and the staff of the Regional Planning Commission, was plotted on profiles of the stream system and used to check the validity of simulated flood stage profiles. Additional information on the source and characteristics of historic flood stage information is presented in Chapter VI.

Water Quality Data: The principal source of stream water quality data is the stream water index site sampling program conducted by the Commission in cooperation with the Wisconsin Department of Natural Resources and the U. S. Geological Survey under the areawide water quality management planning program, as described in Chapter VII. Under this program, stream water quality determinations were made at approximately one-day intervals from September 7, 1977 to October 5, 1977 at two locations: the S. 7th Street crossing of the Kinnickinnic River and the Kinnickinnic River Parkway Drive crossing of the Kinnickinnic River within Jackson Park. In addition, on those days in which runoff occurred as the result of rainfall events, several water quality samples were taken for the purpose of defining the instream pollutographs. Water quality determinations were also made on February 10, 1977 at the downstream location during a snowmelt event caused by unusually high air temperatures. Each of these water quality determinations were based on measurements of physical, chemical, and biological quality indicators as well as streamflow measurements.

MODEL CALIBRATION

Need for Model Calibration

Many of the algorithms contained in the model are mathematical approximations of complex natural phenomena. Therefore, before the model could be reliably used to simulate streamflow behavior and water quality conditions under alternative hypothetical watershed development conditions, it was necessary to calibrate the model--that is, to compare simulation model results with actual historic data and, if a significant difference was found, to make parameter adjustments so as to adjust the model to the specific natural and man-made features of the watershed. While the model is general in that it is applicable to a wide range of geographic and climatic conditions, its successful application to any given water resource system--such as the Kinnickinnic River watershed--very much depends on the calibration process in which pertinent data on the natural resource and man-made features of the watershed are used to adapt the model to the local conditions. A schematic representation of the calibration process as used for the hydrologic-hydraulic-water quality modeling in the Kinnickinnic River watershed planning program is shown on Figure 50. Once the watershed simulation model is calibrated for a particular water resource system, the basic premise of subsequent simulation is that the model will respond accurately to a variety of model inputs representing hypothetical watershed conditions, such as land use changes and channel modifications, and thereby provide a powerful analytic tool in the watershed planning process.

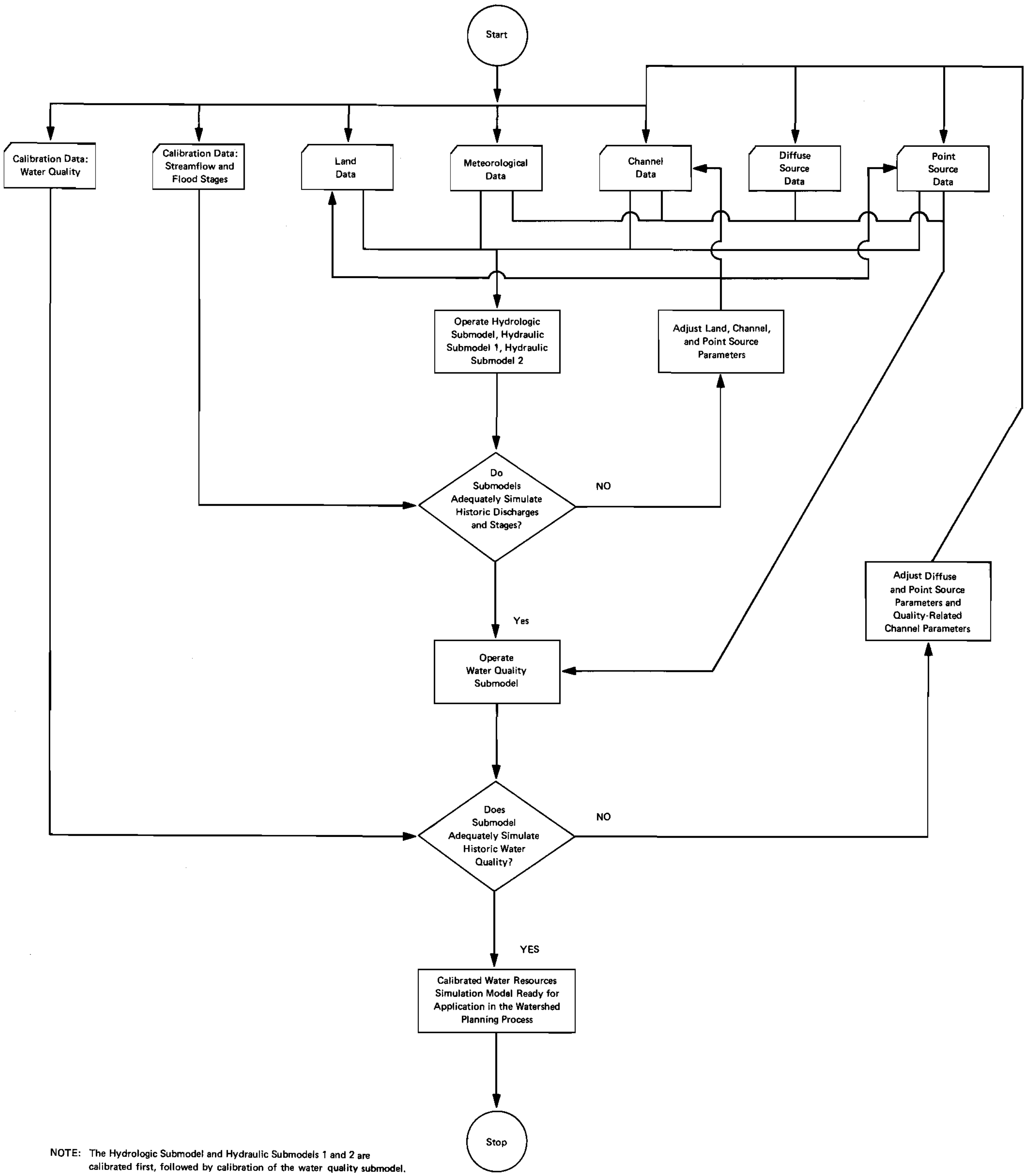
In a strict sense, no data are available for the systematic, watershedwide calibration of the Flood Economics Submodel. This is not a serious limitation of that submodel, however, since the relationships used in this submodel are based on recognized stage-damage relationships for various structure types. Furthermore, an analysis conducted under the Menomonee River watershed planning program of scattered and diverse information on the number of structures affected and monetary looses incurred verified the accuracy of the results obtained through application of the Flood Economics Submodel.[17]

Successful calibration and testing of the first three submodels are of utmost importance because output from these submodels has direct bearing on the testing

[17] *See SEWRPC Staff Memorandum to the Menomonee River Watershed Committee entitled, "Flood Damage Computation Procedures in the Menomonee River Watershed," February 18, 1976.*

Figure 50

CALIBRATION PROCESS USED FOR HYDROLOGIC-HYDRAULIC WATER QUALITY MODELING



NOTE: The Hydrologic Submodel and Hydraulic Submodels 1 and 2 are calibrated first, followed by calibration of the water quality submodel.

Source: SEWRPC.

and evaluation of the floodland management elements of the watershed plan. Furthermore, the validity of results from the other two submodels--the Water Quality Submodel and the Flood Economics Submodel--are determined, in part, by the quality of the output of the first three submodels.

Previous Calibration Efforts

Prior to the modeling phase of the Kinnickinnic River watershed planning program, the Commission staff had completed calibration of the hydrologic-hydraulic portions of the water resources model on other watersheds and subwatersheds, namely the Oak Creek watershed, the Root River Canal subwatershed, the East Branch of the Milwaukee River subwatershed, and the Menomonee River watershed. The Water Quality Submodel had been calibrated on the Menomonee River watershed. Most of these watersheds and subwatersheds contained some combinations of soil type, ground slope, and land use-cover similar to those within the Kinnickinnic River watershed. Therefore, numerical values of input parameters for the hydrologic-hydraulic-water quality submodels as successfully used in these earlier simulation studies provided a basis for numerical values to be used in the Kinnickinnic River watershed modeling. In addition to the calibration work completed prior to that carried out under the Kinnickinnic River watershed study, calibration of the hydrologic-hydraulic-water quality submodels was being carried out concurrently with the Kinnickinnic River watershed study on other watersheds in the Region under the areawide water quality management planning program.

Once experience is gained using hydrologic-hydraulic-water quality submodels on watersheds having a variety of land segment types and channel systems and located within a given physiographic and climatic area such as the Southeastern Wisconsin Region, subsequent applications of the submodels in that same physiographic and climatic area can benefit immensely with respect to use of numerical values of parameters from the earlier studies. While model parameters may be expected to vary significantly from one part of the United States to another, they may be expected to exhibit a strong similarity within climatically and physiographically homogeneous areas such as southeastern Wisconsin. Thus, rather then "start from scratch," subsequent modeling work can concentrate on refinements to preceding efforts.

One refinement was carried out under the Kinnickinnic River watershed planning program, thus adding to the modeling experience gained under preceding studies. This refinement addressed the hydrologic-hydraulic modeling of small urban catchments such as those which dominate the Kinnickinnic River watershed and for which only limited data had previously been available in the planning Region. This special study was facilitated by the availability of streamflow data from small urban catchments in the Menomonee River watershed as the result of the International Joint Commission Menomonee River pilot watershed study.[18]

Hydrologic-Hydraulic Calibration on the Kinnickinnic River Watershed

After completing calibration refinements of the Hydrologic Submodel and Hydraulic Submodel 1 on the two small homogeneous subwatersheds, these two submodels and Hydraulic Submodel 2 were calibrated on the heterogeneous Kinnickinnic River watershed.

Hydrologic Submodel and Hydraulic Submodel 1: Meterological data sets, data sets for hydrologic land segment types, point source data, and channel data sets for stream reaches were prepared using the procedures described earlier in this chapter. The choice of numerical values for 28 parameters in each of the land data sets was strongly influenced by parameter values established under previous calibration efforts. This was feasible since, as noted above, combinations of soil type, slope and land use-cover present in the Kinnickinnic River watershed are similar to those in previous watersheds and subwatersheds on which calibration work had been conducted.

The Hydrologic Submodel and Hydraulic Submodel 1 were operated during the 10-month period from July 1976 through April 1977 for the 18.1-square-mile area--73 percent of the total area of the watershed--tributary to the continuous recorder gage on the Kinnickinnic River located at S. 7th Street. The calibration interval for this run was the period extending from September 14, 1976 through April 30, 1977, excluding the periods discussed above because of apparent monitoring malfunctions.

The 2.5-month period prior to mid-September 1976 was used for model initialization and start-up purposes. The results obtained in the calibration process for the Kinnickinnic River gaging station are presented below by comparing recorded and simulated monthly runoff volumes, recorded or simulated flow-duration curves, and recorded and simulated hydrographs for major runoff events:

- Figure 51 presents a graphic comparison of recorded and simulated monthly runoff volumes for five months. Simulated monthly runoff volumes range from 15 percent below to

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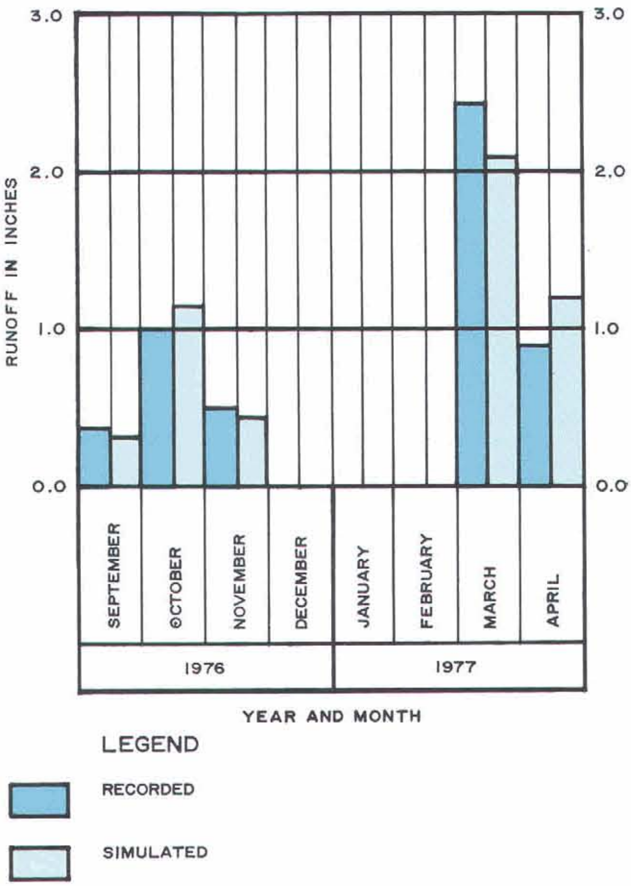
[18] *See Wisconsin Department of Natural Resources, University of Wisconsin System--Water Resources Center, and Southeastern Wisconsin Regional Planning Commission, International Joint Commission Menomonee River Pilot Watershed Study--Semi-Annual Report, October 1976; and SEWRPC Staff Memorandum, "Calibration of Hydrologic-Hydraulic Submodels on the Noyes Creek and Honey Creek Subwatersheds of the Menomonee River Watershed," October 1977.*

Figure 51

RECORDED AND SIMULATED MONTHLY RUNOFF VOLUMES FOR THE KINNICKINNIC RIVER AT THE S. 7TH STREET GAGE SEPTEMBER 14, 1976 TO APRIL 30, 1977[a]

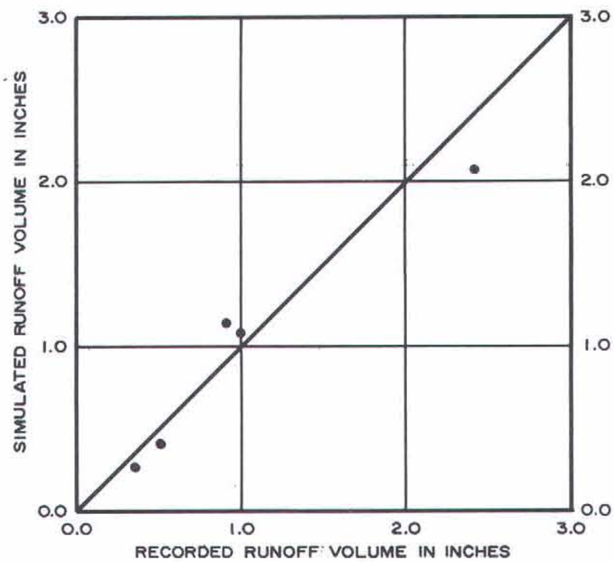


[a] EXCLUDED ARE DECEMBER OF 1976 AND JANUARY AND FEBRUARY OF 1977 DUE TO A LACK OF VALID DATA. SEPTEMBER AND NOVEMBER ARE BASED ON PARTIAL MONTHS.

Source: SEWRPC.

Figure 52

LINEAR CORRELATION BETWEEN RECORDED AND SIMULATED MONTHLY RUNOFF VOLUMES FOR THE KINNICKINNIC RIVER AT THE S. 7TH STREET GAGE SEPTEMBER 14, 1976 TO APRIL 30, 1977[a]



[a] EXCLUDED ARE DECEMBER 1976, JANUARY 1977, AND FEBRUARY 1977, DUE TO LACK OF VALID RECORDED DATA.

Source: SEWRPC.

31 percent above recorded values. The simulated cumulative monthly runoff volume for the five months is 0.06 inch, or 1 percent less than the 5.21-inch cumulative recorded runoff volume for that same period.

- Recorded and simulated monthly runoff volumes are also compared on Figure 52. Monthly runoff data are seen to be closely grouped about a 45-degree line, indicating a tendency to exhibit the desired one-to-one correlation between the recorded and simulated monthly runoff volumes.

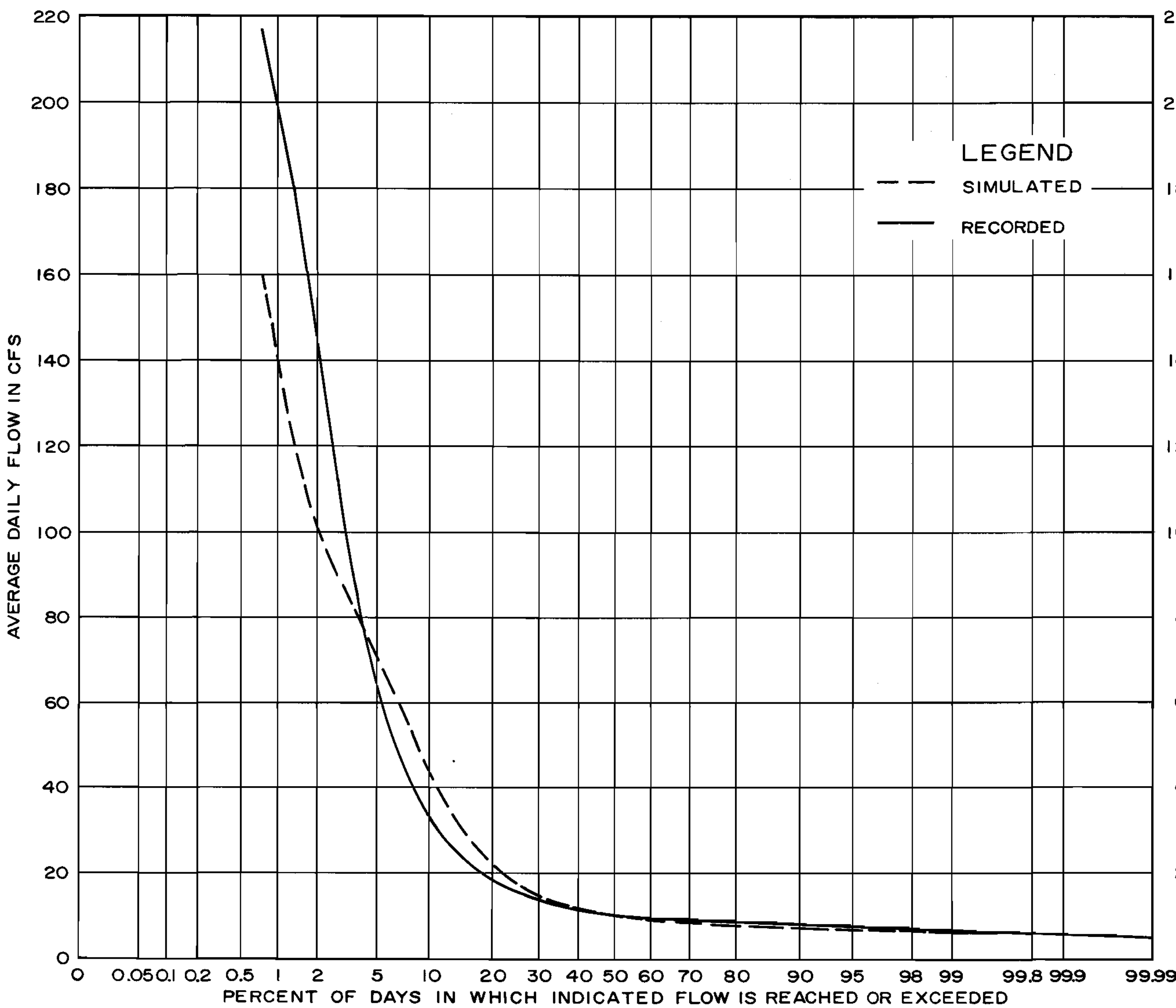
- Recorded and simulated flow duration curves based on average daily flows for the five months for which adequate recorded discharge data are available are shown on Figure 53. Each of the two flow duration curves indicates the percentage of time that specified average daily discharges may be expected to be equaled or exceeded. The flow duration curves based on simulated and recorded discharges generally exhibit close agreement. This finding, in light of the above good correlation between monthly runoff volumes, suggests that the Hydrologic Submodel, in addition to reproducing long-term--monthly or more--runoff volumes, is capable of reproducing the frequency distribution of discharges.

- Recorded and simulated hydrographs for four runoff events drawn from various times of the year are shown on Figure 54. These four events were selected so as to illustrate the full range of correlations between recorded and simulated flows. Overall, the recorded and simulated hydrographs for rainfall and rainfall-snowmelt events occurring during the calibration period exhibited generally close agreement.

Over-simulation of flood discharges such as occurred during October 4-6, 1976 or under-simulation such as occurred during March 3-5, 1977 may be attributable to spatial variations in the amount of rainfall occurring over the subwatershed. That is, even though the two precipitation observation stations used to provide input data are located in or near the watershed and even though the watershed is small, it is possible for portions of the basin to receive

Figure 53

RECORDED AND SIMULATED FLOW DURATION CURVES FOR THE KINNICKINNIC RIVER AT THE S. 7TH STREET GAGE: SEPTEMBER 1976 TO APRIL 1977



Source: SEWRPC.

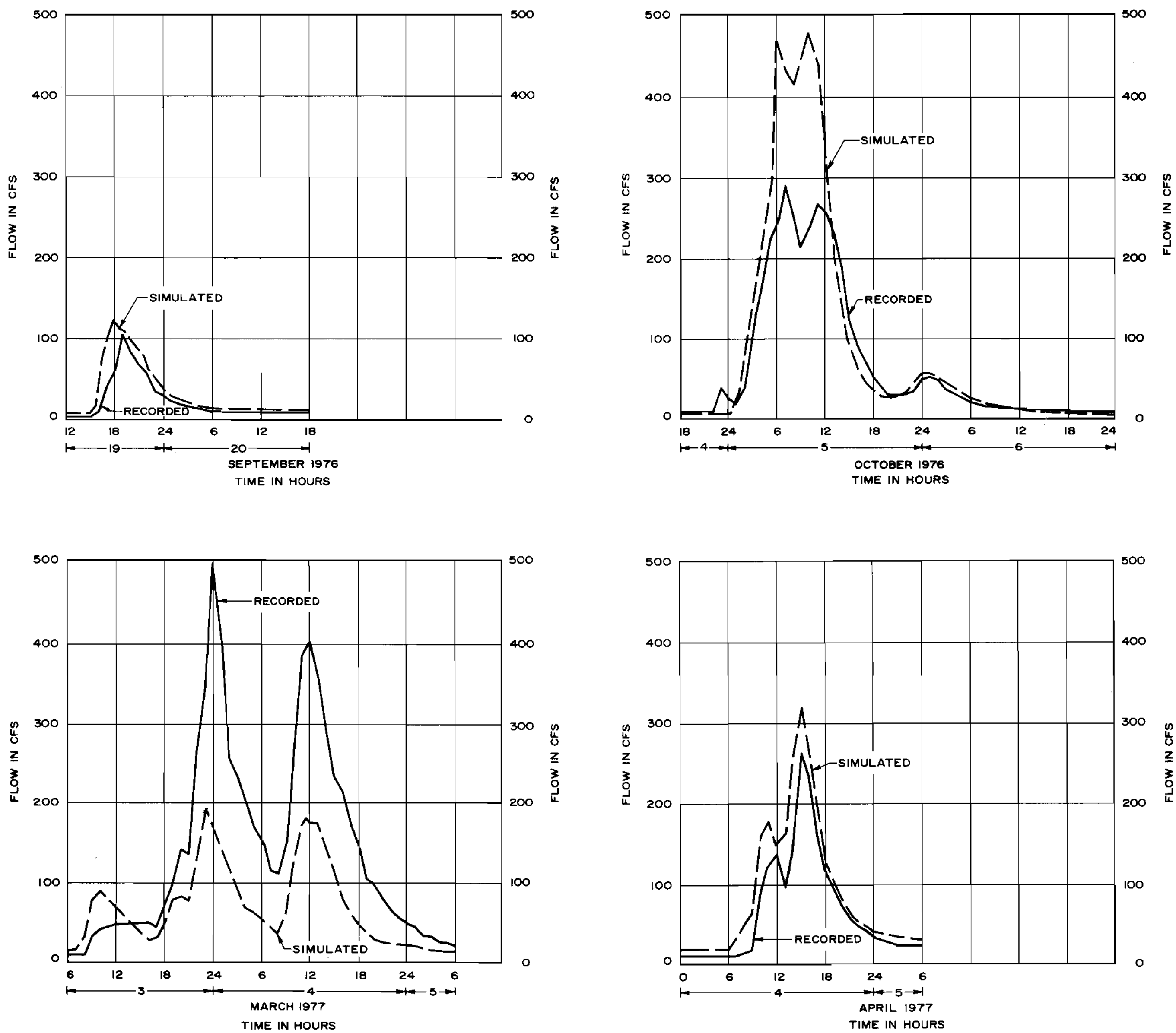
precipitation amounts, especially during brief events such as thunderstorms, that are significantly different from those recorded at the observation station.

Deviations between recorded and simulated flows--particularly high flows--may also be partly due to gaging station problems associated with a new gaging installation. During the early history of a gaging station operation, the high-flow portion of the stage-discharge rating curve is usually not well-defined because of insufficient measured high flows.

Comparison of Flows Obtained by Hydrological-Hydraulic Modeling and by the Rational Method for Small Urban Areas: Under the Kinnickinnic River watershed planning program, the hydrologic-hydraulic model was used to develop instream flood flows for urban headwater areas smaller than those used in previous modeling studies. More specifically, the model was used to determine 5-, 10-, 50-, 100-, and 500-year flood flows on the extreme headwater areas of Wilson Park Creek (Edgerton Ditch) at Nicholson Road (River Mile 5.99), where the total tributary area is only 0.41 square mile, and downstream at the Chicago & North Western Railway bridge (River Mile 5.34), where the total tributary area is only 0.97

Figure 54

RECORDED AND SIMULATED HYDROGRAPHS FOR THE KINNICKINNIC RIVER AT THE S. 7TH STREET GAGE FOR SELECTED EVENTS: SEPTEMBER 1976 TO APRIL 1977



Source: SEWRPC.

square mile. The model was also used to determine flood flows on the extreme headwater areas of Lyons Park Creek at W. Forest Home Avenue (River Mile 1.31), where the total tributary area is only 0.46 square mile, and downstream at the confluence with the Kinnickinnic River (River Mile 0.00), where the total tributary area is only 1.32 square miles. In the previous watershed study--the Menomonee River study--the smallest urban headwater tributary area for which an instream flood flow was computed with the model was the 1.15-square-mile urban area tributary to the upstream end of Underwood Creek.

Caution must be used in applying the hydrologic-hydraulic model to small urban headwater catchments for two reasons. First, the model uses generalized parameters to represent the runoff characteristics of the urban land surface rather than explicitly accounting for hydraulic elements such as swales, ponds, curbs and gutters, and storm sewers. This approach, commonly referred to as the "lumped" parameter representation, has proven to be generally satisfactory for simulating the runoff from urban areas one or more square miles in size. However, as smaller and smaller urban catchments are considered for given meteorologic conditions and events, hydraulic elements such as the above are likely to have a greater effect on direct runoff, particularly on the temporal distribution of runoff. That is, while hydraulic elements such as swales, ponds, curbs and gutters, and storm sewers are not likely to affect the total volume of direct storm water runoff from small urban catchments, they are likely to influence the timing of that runoff.

Second, the hydrologic-hydraulic model, as it was applied to the Kinnickinnic River watershed, uses historic precipitation data at one-hour intervals as input. Use of precipitation averaged over one-hour intervals has proven to be acceptable for simulating instream flood flow hydrographs for urban areas that are one or more square miles in size and have a response time in excess of one hour. This is apparently so because the effect of very short--less than one hour--fluctuations in actual precipitation are attenuated by overland and channel flow. Thus for tributary areas in excess of about one square mile, the influence of such fluctuations on the shape of a hydrograph is minimal. However, as smaller and smaller urban catchments are considered for given meteorologic conditions and events, the precipitation fluctuations are less likely to be attenuated; that is, precipitation fluctuations are more likely to generate significant corresponding hydrograph fluctuations. Therefore, if precipitation amounts averaged on an hourly basis--thus eliminating short periods of intense precipitation--are used to simulate direct runoff from small urban catchments having a response time of less than one hour, the simulated peak flows are likely to be less than actual flows.

In order to check the reasonableness of the flood flows obtained by the simulation results on small urban areas, and in the absence of historic measured streamflows, flood flows for comparable recurrence intervals were also calculated by the rational method. The rational method, which was selected because it is a widely accepted and used hydrologic technique for small urban catchments, was applied in accordance with the procedures set forth in SEWRPC Technical Record Volume 2, No. 4, "Determination of Runoff for Urban Storm Water Drainage System Design," April-May 1965.

For the two locations on Wilson Park Creek and two locations on Lyons Park Creek, Table 58 sets forth the characteristics of the tributary areas needed for application of the rational method including size, runoff coefficient, and time of concentration; the rainfall intensity for 10-, 50-, and 100-year recurrence interval rainfall periods having a duration equal to the time of concentration; and the 10-, 50-, and 100-year recurrence interval discharges computed by the rational method. Table 58 also includes a comparison between the 10-, 50-, and 100-year recurrence interval discharges for the four locations obtained from rational method calculations and those obtained hydrologic-hydraulic modeling.

For the two smallest catchments--about 0.5 square mile or less--flood flows obtained from hydrologic-hydraulic modeling are seen to be less than flood flows obtained from rational method calculations. For example, the 100-year recurrence interval discharges obtained from hydrologic-hydraulic modeling at the Nicholson Road crossing of Wilson Park Creek and at the W. Forest Home crossing of Lyons Park Creek are 68 percent and 56 percent, respectively, of the 100-year recurrence interval discharges obtained from the rational method at the two locations. For the two larger catchments--about 1.0 square mile or more--flood flows obtained using the model are close to those obtained using the rational method. For example, the 100-year recurrence interval discharges obtained from modeling at the Chicago & North Western Railway crossing on Wilson Park Creek and at the confluence with the Kinnickinnic River on Lyons Park Creek are 90 percent and 100 percent, respectively, of the 100-year recurrence interval discharges obtained by the rational method.

A comparison of discharges obtained from two analytic methods--hydrologic-hydraulic modeling versus the rational method--is not as desirable as a comparison of results obtained using an analytic method to measured stream flows. However, in the absence of measured flows, the above comparison suggests that the hydrologic-hydraulic model may understimate peak discharges from small--less than about one-half square mile--urban catchments. Accordingly, flood flows calculated using the rational method were used in place of flood flows obtained using the model at Nicholson Road on Wilson Park Creek and at W. Forest Home Avenue on Lyons Park Creek.

Hydraulic Submodel 2: After successful calibration of the Hydrologic Submodel and Hydraulic Submodel 1 on the Kinnickinnic River watershed, annual instantaneous peak discharges from the output of Hydraulic Submodel 1 were used in a log-Pearson Type III analysis to obtain 10-, 50-, 100-, and 500-year recurrence interval discharges throughout the watershed under existing conditions. These discharges were used as input to Hydraulic Submodel 2 for the purpose of calibrating it against historic flood stage information. The historic flood inventory described in Chapter VI resulted in the acquisition of historic high water data for streams in the Kinnickinnic River watershed, including the main stem of the Kinnickinnic River, Wilson Park Creek, and Lyons Park Creek.

The calibration process involved comparing the plotted 10-, 50-, 100-, and 500-year flood stage profiles obtained using Hydraulic Submodel 2 to historic high water marks for primarily the September 1972 and April 1973 flood events. The relative position of the recorded and simulated flood stages was examined for consistency. For example, because the April 1973 flood was determined to be approximately a 60-year recurrence interval event along the lower Kinnickinnic River, a close correlation would be expected between existing land use-floodland development 50-year recurrence interval flood stage profiles obtained from Hydraulic Submodel 2 and actual high water marks obtained during or immediately after that event.

Table 58

COMPARISON OF EXISTING CONDITION FLOOD FLOWS ON THE UPPER END OF WILSON PARK CREEK AND LYONS PARK CREEK AS OBTAINED FROM THE RATIONAL METHOD AND FROM THE HYDROLOGIC-HYDRAULIC MODEL

Location				Rational Method						
Stream	River Mile	Structure Name	Tributary Area (square mile)	Runoff Coefficient	Time of Concentration (hours)	Recurrence Interval (years)	Rainfall Intensity Corresponding to Time of Concentration (in hour)	Discharge Cubic Feet per second	Hydrologic-Hydraulic Model Discharges Cubic Feet per second	Ratio of Model Discharges to Rational Method Discharges
Wilson Park Creek	5.99	E. Nicholson Road	0.41	0.46	0.8	10	2.19	245	195	0.80
						50	2.88	350	260	0.74
						100	3.15	380	285	0.75
	5.34	Chicago & North Western Railway	0.97	0.40	1.7	10	1.24	285	255	0.89
						50	1.64	405	365	0.90
						100	1.84	455	410	0.90
Lyons Park Creek	1.31	W. Forest Home Avenue	0.45	0.49	0.4	10	3.42	475	235	0.49
						50	4.44	640	345	0.54
						100	4.92	710	395	0.56
	0.00	Confluence with Kinnickinnic River	1.32	0.51	1.0	10	1.86	740	670	0.91
						50	2.45	1050	980	0.93
						100	2.70	1150	1150	1.00

Source: SEWRPC

In those instances in which an inconsistent relationship existed between simulated and historic flood stages, the problem was normally resolved by an adjustment in the channel or floodplain Manning roughness coefficient. In some cases, improvements were made in the manner in which the channel-floodplain shape or bridge or culvert geometry was represented.

Sensitivity Study of the Effect of Channel Constrictions on Flood Flows: The Kinnickinnic River watershed contains five rather unique hydraulic structures, four of which are located on Wilson Park Creek and one of which is on the Kinnickinnic River. There was concern early in the analysis phase of the watershed study that one or more of these structures may constrict flood flows so as to attenuate flood flow peaks significantly more than would occur--and as already represented in the hydrologic-hydraulic model by kinematic routing--as a result of channel-floodplain storage in the absence of the structures. The five structures, listed in downstream order, and their locations on Wilson Park Creek and the Kinnickinnic River are as follows:

- A bulkhead wall containing 4 four-foot diameter holes with the bottom-most point of each hole located one foot above the channel bottom. The bulkhead wall is located within a concrete box conduit on Wilson Park Creek that passes beneath the northernmost edge of General Mitchell Field. This conduit consists of two parallel concrete box structures each having an inside width of 15 feet and an inside depth of 10 feet.

- An abrupt, approximately two-foot channel rise in the channel invert immediately upstream of the S. 6th Street crossing of Wilson Park Creek. The channel break separates the upstream, concrete-lined channel from the downstream, turf-lined channel that will ultimately be further modified by reducing the invert to match the upstream invert and by lining the invert and a portion of the sidewalls with concrete.

- A 994-foot-long conduit extending from River Mile 0.68 to River Mile 0.87 on Wilson Park Creek that passes beneath a portion of the Point Loomis Shopping Center near the intersection of S. 27th Street and Point Loomis Road. This conduit consists of three parallel concrete box structures each having an inside width of 10 feet and an inside depth of 11 feet; three parallel corrugated metal pipes each having an inside diameter of 11.5 feet; and three parallel concrete box structures each having an inside width of 11.5 feet and an inside depth of 11 feet.

- A 1,410-foot-long conduit extending from River Mile 0.05 to River Mile 0.32 on Wilson Park Creek that passes beneath the St. Lukes Hospital complex immediately above the confluence of Wilson Park Creek and the Kinnickinnic River. This conduit consists of two parallel concrete box structures each having an inside width of 15 feet and inside depth of 10 feet.

- The S. 6th Street crossing of the Kinnickinnic River which provides a hydraulic restriction under high flows because of the unusually large vertical distance between the crown of the waterway opening and the elevation of the roadway--about 10 feet at the center of the waterway.

It is important to note that the backwater effect of each of these hydraulic structures was, as is the case with all potentially significant hydraulic structures, explicitly incorporated in the modeling by representing the structures in Hydraulic Submodel 2. This, for a given discharge and downstream stage at any of these structures, the backwater effect of the structure is calculated to arrive at the upstream stage.

The matter of concern, however, was not the effect that the structures would have on a given discharge stage but whether or not these structures could actually alter discharge by acting as a series of outlet control structures on impoundments on Wilson Park Creek and the Kinnickinnic River, the integrated effect of which could substantially reduce flood flows in Wilson Park Creek or Kinnickinnic River reaches downstream of one or more of the structures. It is important to emphasize that instead of representing each structure as an outlet control on an impoundment, the hydrologic-hydraulic model uses the kinematic routing technique to calculate hydrograph attenuation in a reach associated with channel-floodplain storage caused by flow resistance. Thus the focus of concern is not whether hydrograph attenuation should be considered in reaches upstream of the selected structures, but whether the storage effects of structures are adequately represented by natural channel-floodplain storage so as to obviate the need to model the selected structures as outlet controls on impoundments.

Accordingly, an initial set of two simulation runs were conducted to test the sensitivity of flood flow discharges to two of the five hydraulic structures: the bulkhead wall and Point Loomis Shopping Center conduit on Wilson Park Creek. The initial hydrologic-hydraulic simulation assumed that these two structures and all other similar structures would not have a significant effect on flood flows--relative to that effect which would occur as a result of channel-floodplain storage in the absence of the structures--and, therefore, provided a baseline or benchmark against which the sensitivity analysis could be conducted. The causative meteorological events associated with the two relatively severe flood events in the watershed--the August 3, 1960 and April 21, 1973 events--were used in the sensitivity analysis. The meteorological conditions for each of these events were input to Hydraulic Submodel 1 and the resulting flood flow hydrographs were simulated at six locations along Wilson Park Creek and two locations along the Kinnickinnic River downstream of its confluence with Wilson Park Creek with and without representation of the two hydraulic structures as reservoirs.

The resulting hydrographs, all of which are located downstream of one or both of the structures, are shown on Figure 55 and clearly indicate that representation of the two structures as reservoirs has no significant effect on downstream flood stages for the two selected events, even at locations immediately downstream of the structures. The sensitivity study was not extended to include the other two structures on Wilson Park Creek and the structure on the Kinnickinnic River because the individual and combined effect of the two structures selected for the study was insignificant and because the storage available upstream of any of the other three structures is less than that available at either of the structures used in the study. Based on this sensitivity analysis and in light of previously conducted backwater calculations using Hydraulic Submodel 2, it was concluded that although the five hydraulic structures may cause significant backwater effects, which are included in the modeling, they produce no significant attenuation of flood flows relative to that which will occur as a result of channel-floodplain storage in the absence of the constrictions.

Water Quality Calibrations on the Kinnickinnic River Watershed

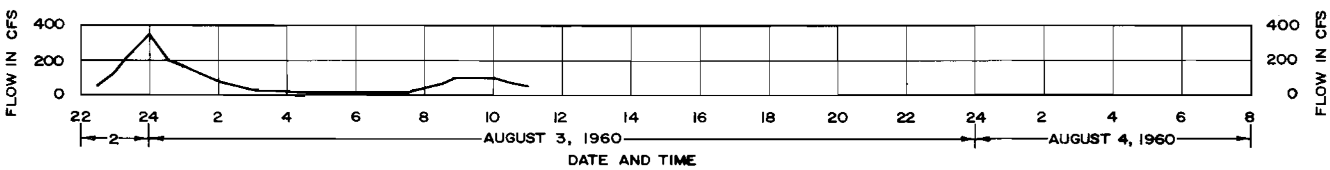
After completing calibration of the Hydrologic Submodel and Hydraulic Submodel 1, the Water Quality Submodel calibration process was initiated. This sequential approach was used since successful water quality simulation is contingent upon effective hydrologic-hydraulic modeling because runoff from the land surface and flow in the streams provide the transport mechanisms for water quality constituents. Meteorologic, channel, point source, and diffuse source input data sets were prepared using the procedures described earlier in this chapter. For the purpose of calibration, the simulated portion of the stream system was extended downstream by the addition of a fourth reach to include the stream reach between the S. 27th Street terminus previously described and the S. 7th Street sampling site location. With respect to calibration data, the Water Quality Submodel was calibrated using the results of the stream water index site sampling program conducted under the areawide water quality management planning program.

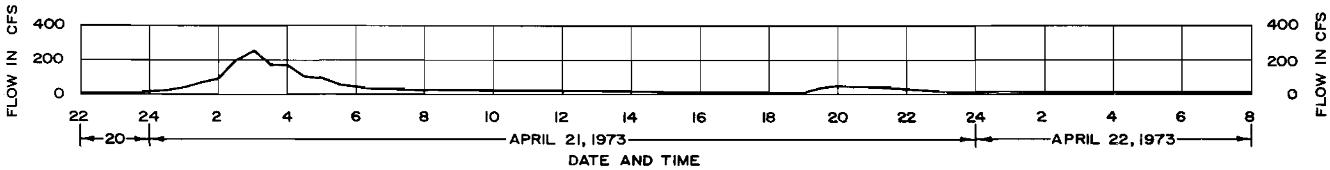
The fall calibration period, September 7, 1977 to October 5, 1977, provided the primary data for calibration of the Water Quality Submodel at the two sampling stations. The calibration process consisted of comparison of the observed water quality and the model results for the upstream sampling location, and when acceptable results were achieved at that location, the downstream location was analyzed. After achieving successful calibration with emphasis on six parameters--temperatures, dissolved oxygen, phosphate-phosphorus, the nitrogen forms, fecal coliform, and carbonaceous biochemical oxygen demand--the remaining simulated parameters--chlorides and total dissolved solids--were examined for reasonableness. Once acceptable results were obtained for a selected portion of the fall calibration period, the period through February 10, 1978 was simulated for

Figure 55

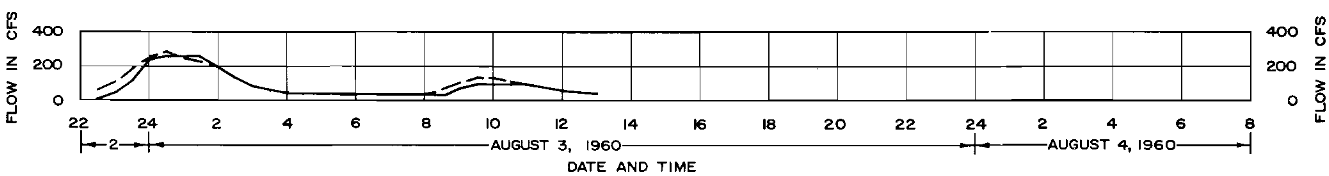
EFFECT OF WILSON PARK CREEK CHANNEL CONSTRICTIONS ON FLOOD FLOWS FOR SELECTED EVENTS: AUGUST 3, 1960 AND APRIL 21, 1973

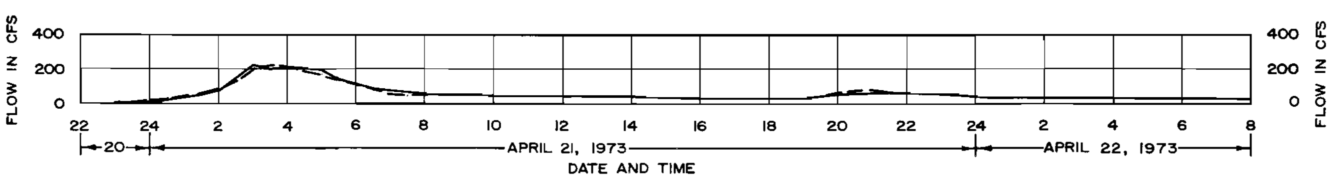
Wilson Park Creek at Chicago & North Western Railway—River Mile 5.34



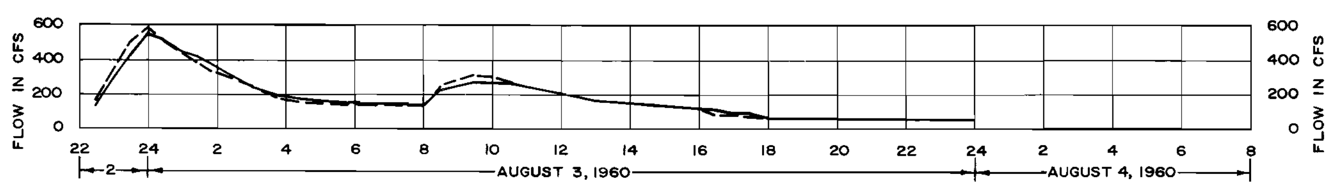


Wilson Park Creek at Airport Tunnel Outlet—River Mile 3.85





Wilson Park Creek at W. Layton Avenue Tunnel—River Mile 3.51



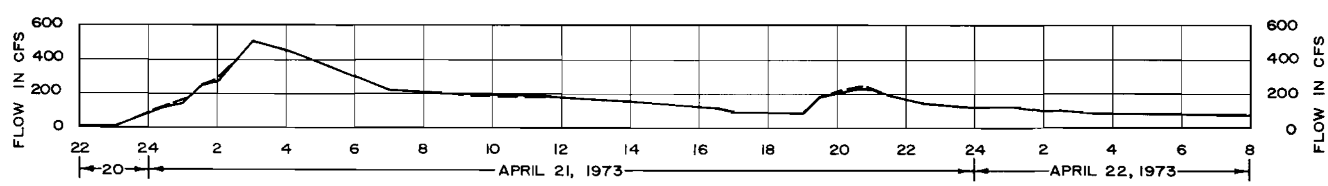
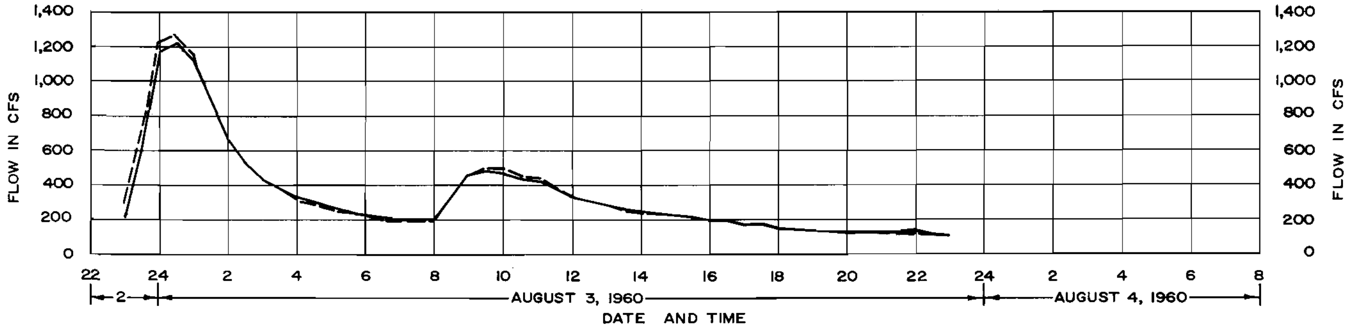
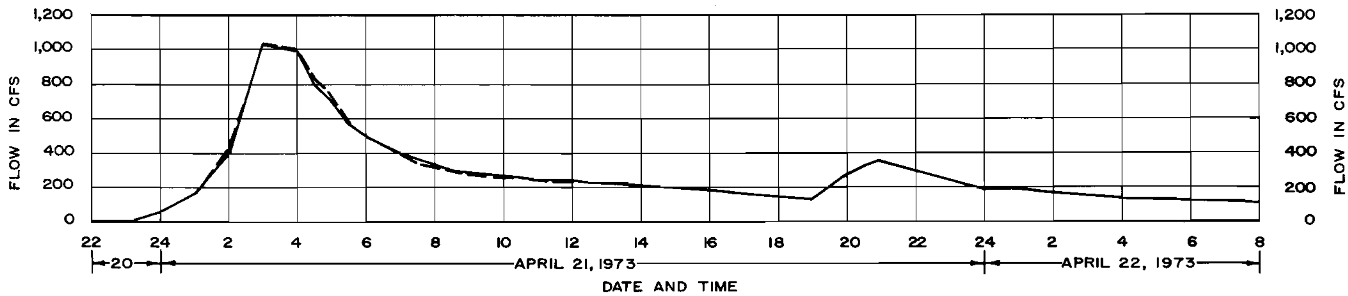


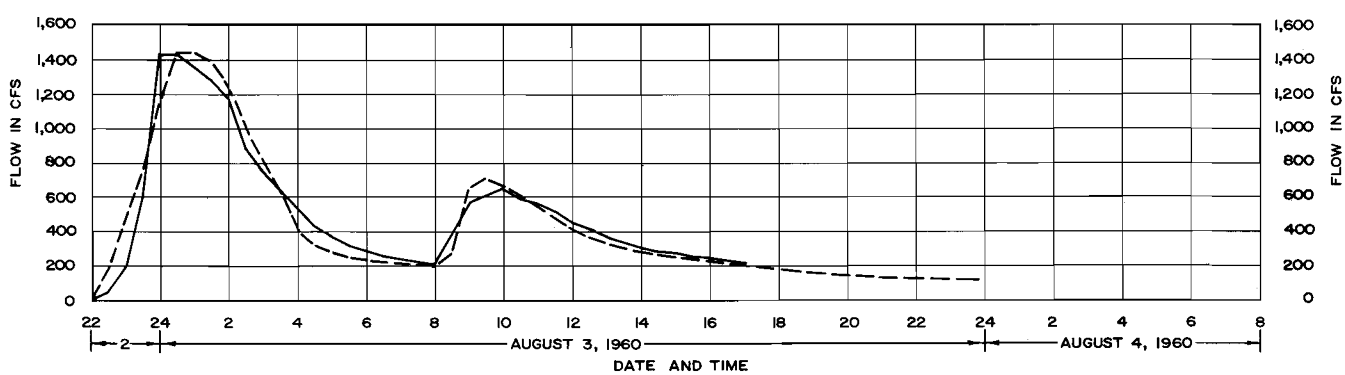
Figure 55 (continued)

Wilson Park Creek Immediately Upstream of the Confluence of Villa Mann Creek—River Mile 1.88





Wilson Park Creek at W. Morgan Avenue Tunnel Outlet—River Mile 0.68



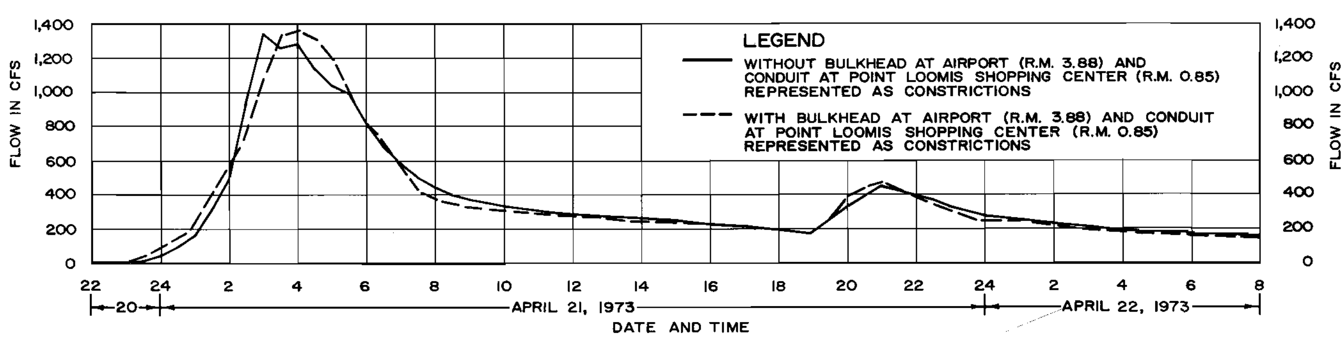
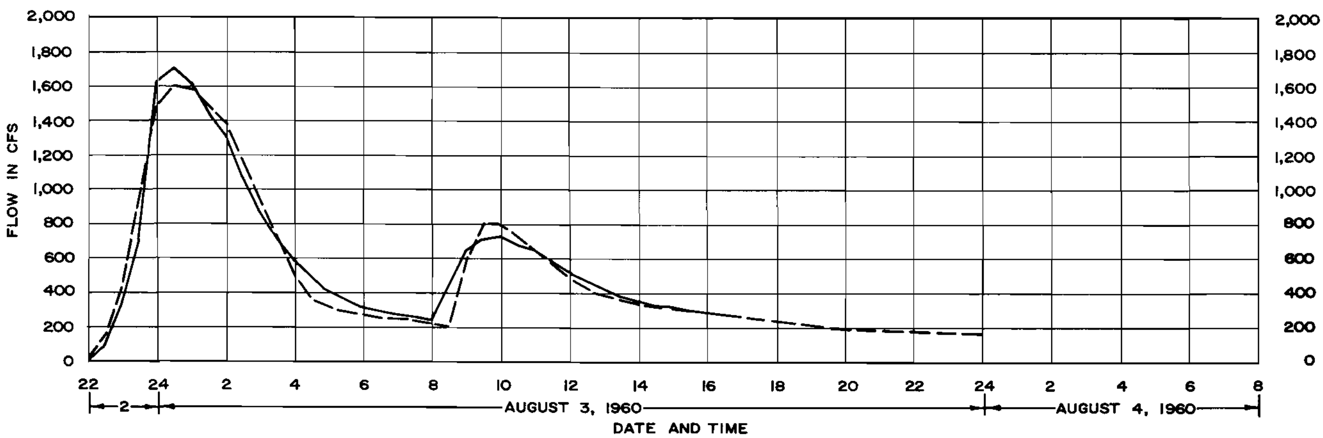
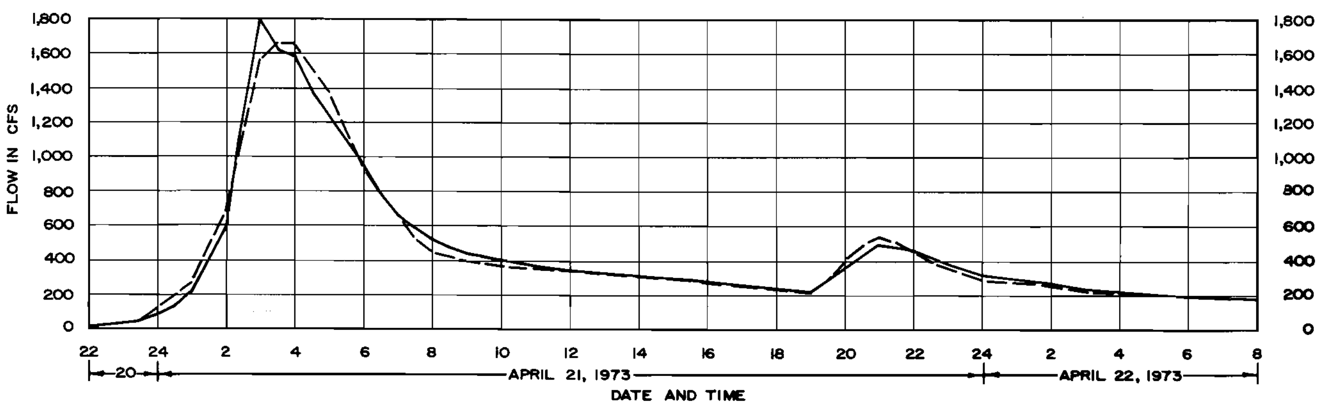


Figure 55 (continued)

Wilson Park Creek at Confluence with Kinnickinnic River—River Mile 0.00





verification of the submodel. After minor adjustments were made in the diffuse loading rates for chlorides and total dissolved solids, the model produced acceptable results for both the fall and winter calibration periods.

The recorded constituent values for the S. 7th Street sampling site on the Kinnickinnic River for the calibration period are presented in Figure 56 along with the simulation results. The figure indicates that the model well simulates flow, temperature, dissolved oxygen, phosphate-phosphorus, the nitrogen forms, and carbonaceous biochemical oxygen demand while yielding overall acceptable results with respect to fecal coliform counts, chlorides, and total dissolved solids.

SUMMARY

A quantitative analysis of stream flow and water quality conditions under existing and possible alternative future conditions is a fundamental requirement of any comprehensive watershed planning effort. Discharge, stage, and water quality at any point and time within the stream system of a watershed are a function of three factors: meteorological conditions and events, the nature and use of the land, and the characteristics of the stream system.

Hydrologic-hydraulic-water quality-flood economics simulation, accomplished with a set of interrelated digital computer programs, is an effective way to conduct the quantitative analysis required for watershed planning. Such a water resource model was developed for and used in the Kinnickinnic River watershed planning program. The various submodels comprising the model were selected from existing computer programs or were developed by the Commission staff so that the composite model would meet the watershed study needs as stated in the form of nine criteria. The Water Resource Simulation Model used in the Kinnickinnic River watershed planning program consists of the following five submodels: the Hydrologic Submodel, Hydraulic Submodel 1, Hydraulic Submodel 2, the Water Quality Submodel, and the Flood Economics Submodel.

Figure 55 (continued)

Kinnickinnic River at S. 16th Street—River Mile 3.58

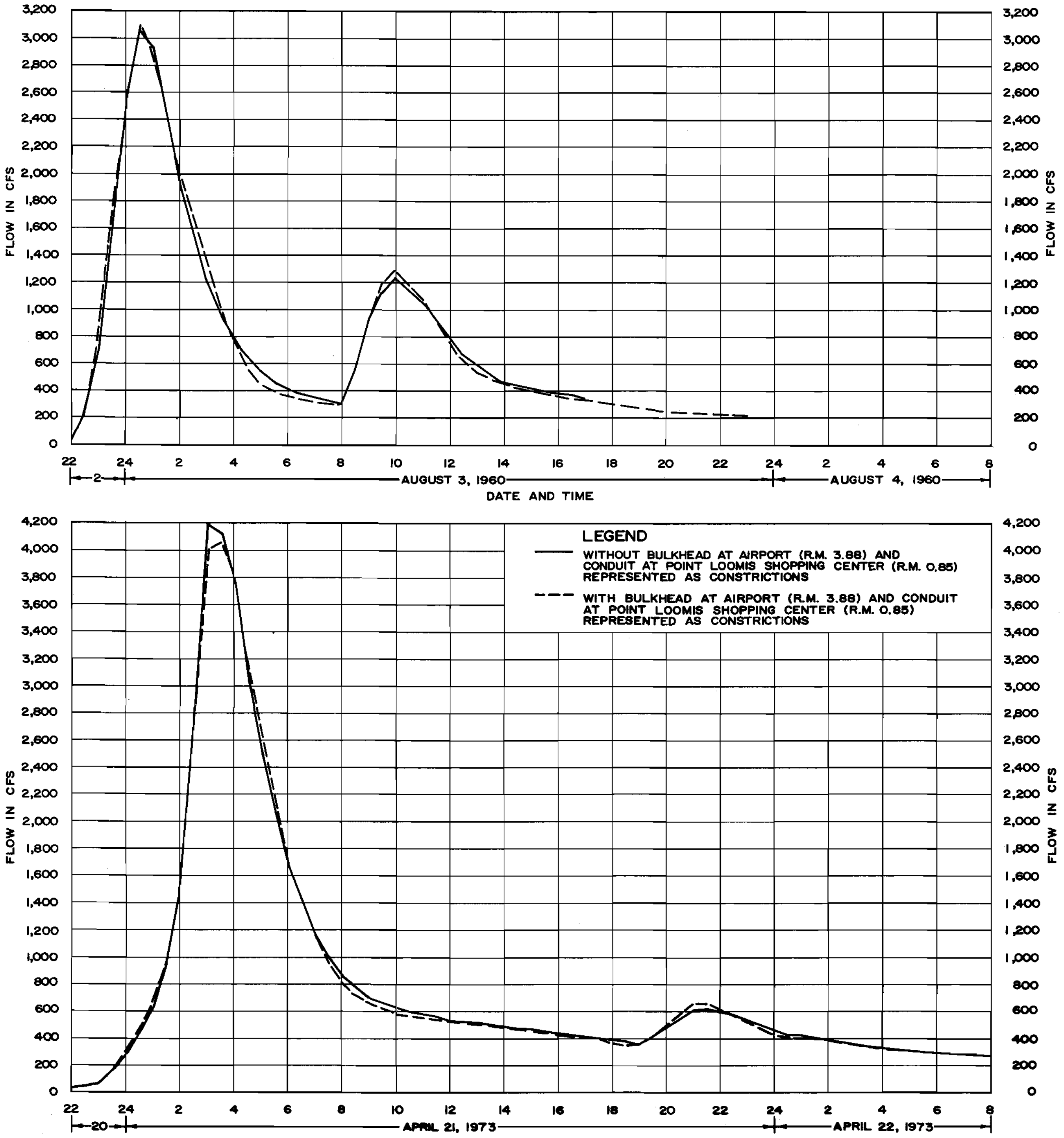
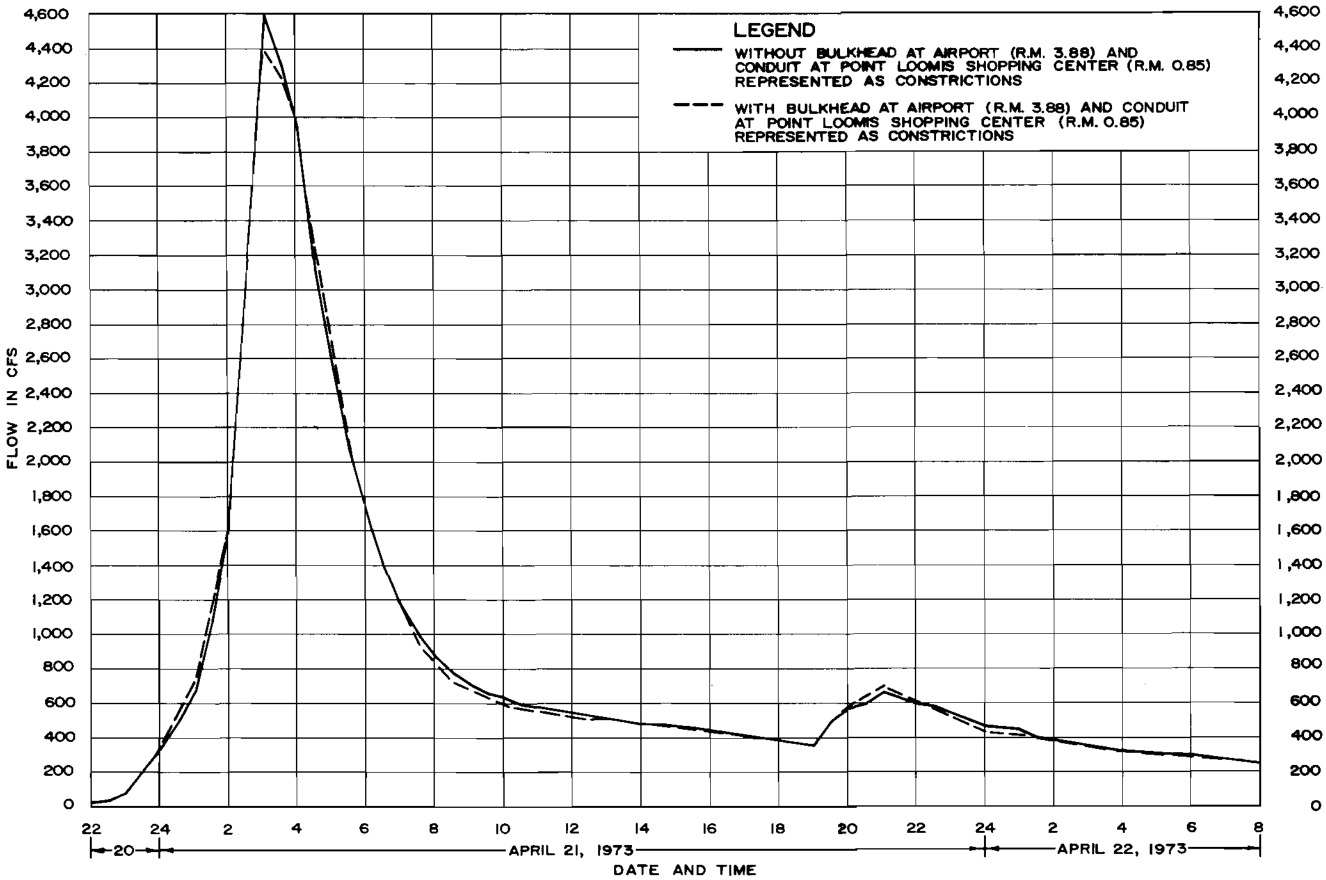
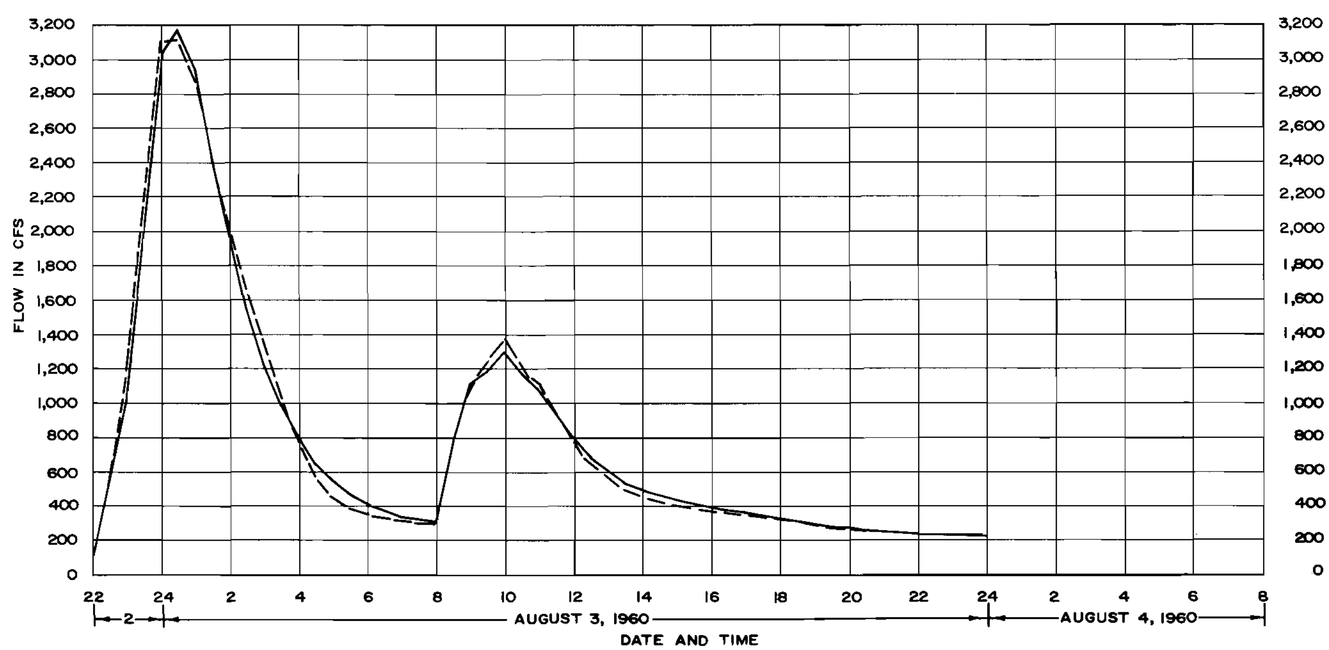


Figure 55 (continued)

Kinnickinnic River at Old North Shore Railroad—River Mile 2.72





Source: SEWRPC.

Figure 56

RECORDED AND SIMULATED WATER QUALITY DATA FOR THE KINNICKINNIC RIVER AT THE S. 7TH STREET GAGE: OCTOBER 1, 1976 TO OCTOBER 5, 1976 AND FEBRUARY 10, 1977

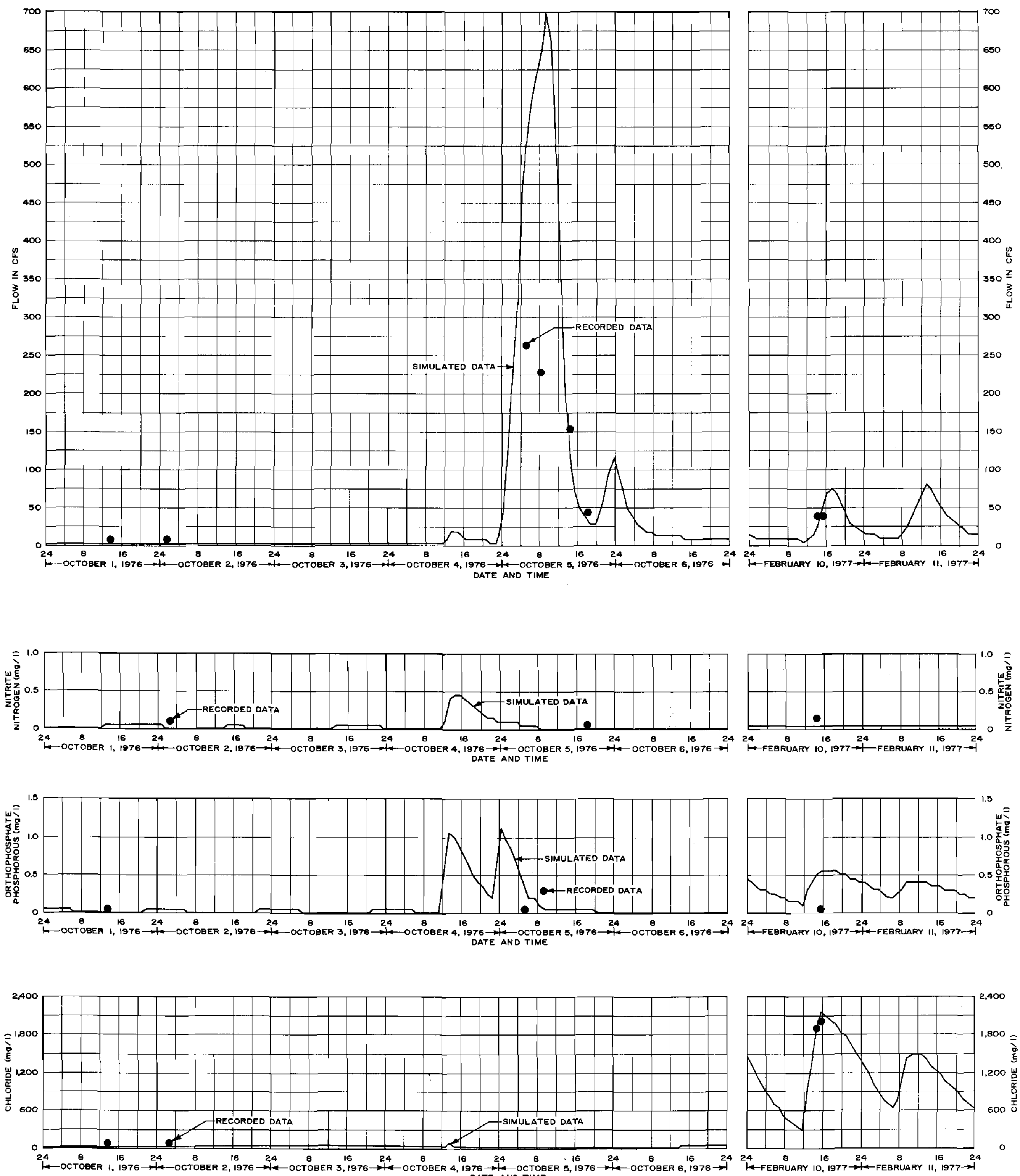


Figure 56 (continued)

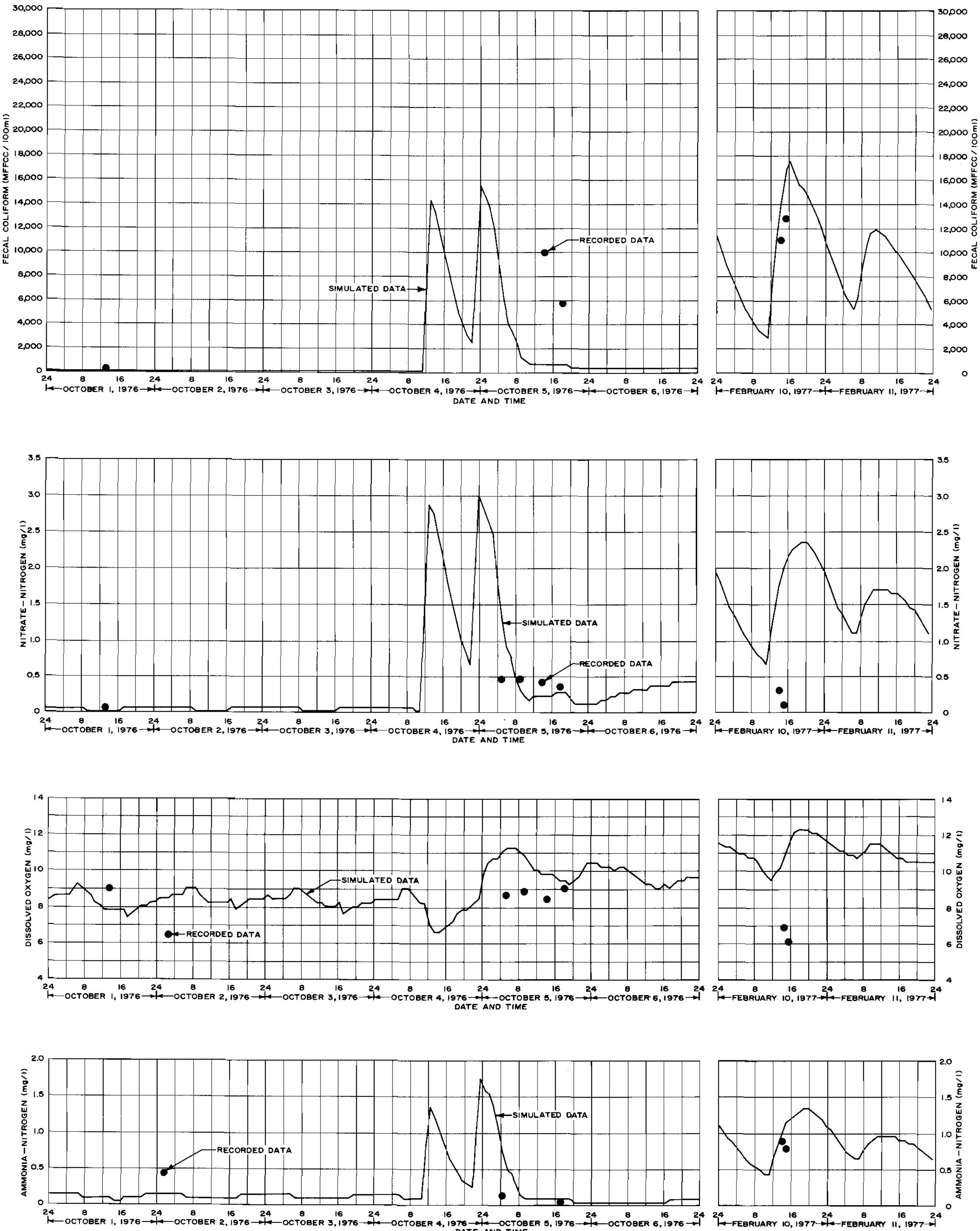
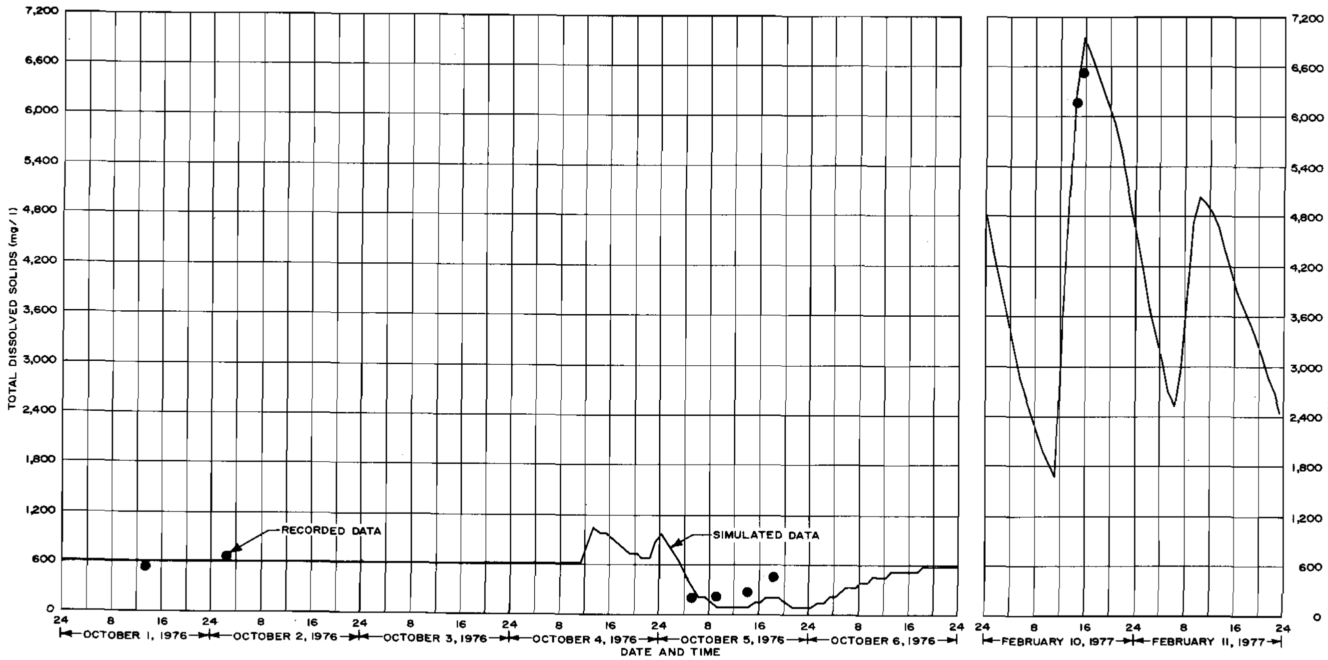


Figure 56 (continued)



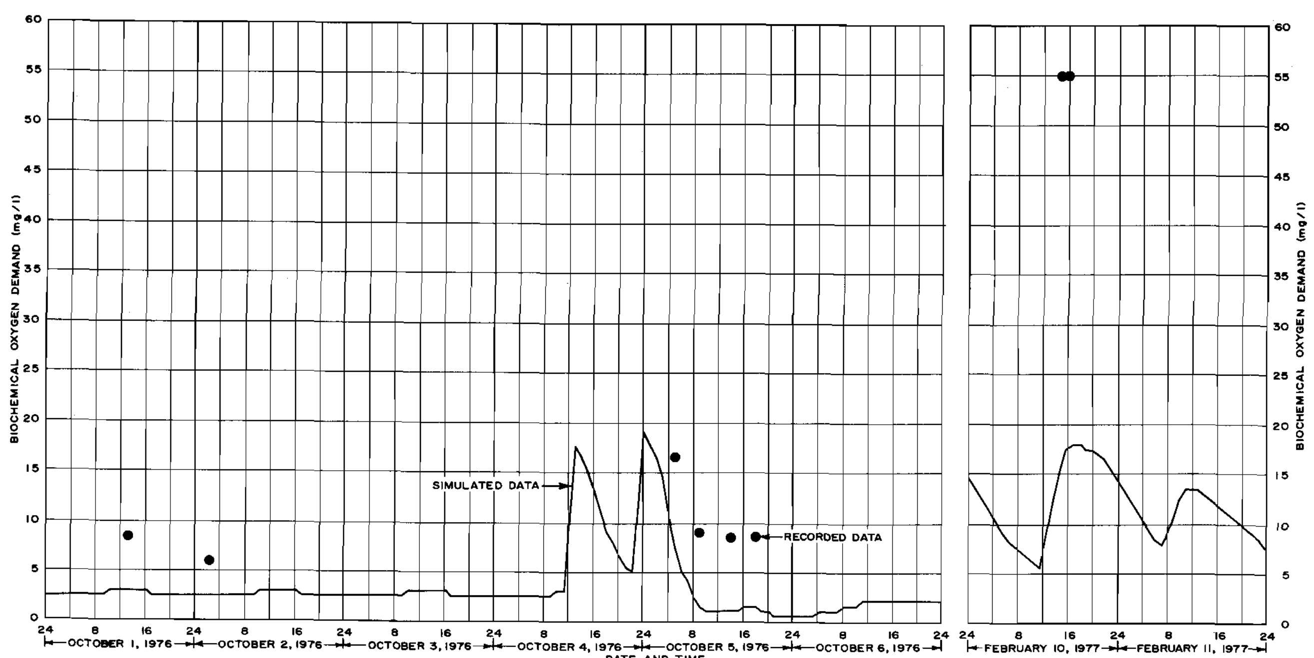
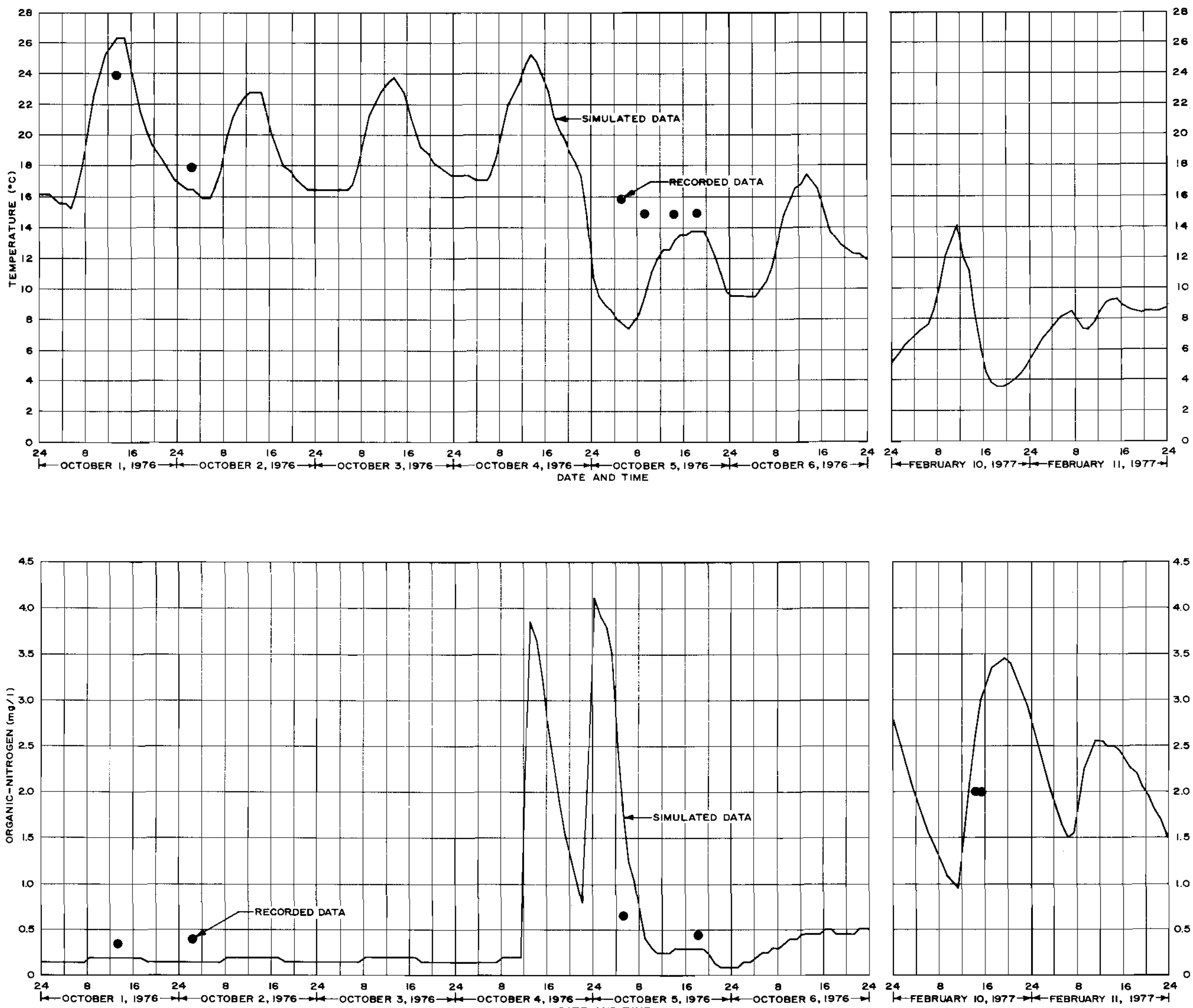


Figure 56 (continued)



Source: SEWRPC.

The principal function of the Hydrologic Submodel is to determine the volume and temporal distribution of runoff from the land to the stream system. The basic physical unit on which this submodel operates is the hydrologic land segment which is defined as a land drainage unit exhibiting a unique combination of meteorological factors, land use-cover, and soils. The submodel, operating on a time interval of one hour or less, continuously and sequentially maintains a water balance within and between the various interrelated hydrological processes as they occur with respect to the land segment. Meteorologic and land data constitute the two principal types of input for operation of the Hydrologic Submodel. The key output from the submodel consists of a continuous series of runoff quantities for each hydrologic and land segment type in the watershed.

The function of Hydraulic Submodel 1 is to accept as input the runoff from the land surface as produced by the Hydrologic Submodel in combination with point and groundwater source discharges, to aggregate it, and to route it through the stream system, thereby producing a continuous series of discharge values at predetermined locations along the surface water system of the watershed. Application of this submodel requires that the stream system be divided into reaches and impoundment sites. Input for Hydraulic Submodel 1 consists of parameters describing the reaches and impoundment sites as well as the output from the Hydrologic Submodel and point source discharges.

Hydraulic Submodel 2 computes flood stages attendant to flood flows of specified recurrence intervals as produced by Hydraulic Submodel 1. Use of this submodel requires, in addition to the output of Hydraulic Submodel 1, a very detailed description of the watershed stream system including channel-floodplain cross sections, Manning roughness coefficients, and complete physical descriptions of all hydraulically significant culverts, bridges, and dams. The principal output from Hydraulic Submodel 2 consists of flood stage profiles which are used to delineate flood hazard areas and to provide input to the Flood Economics Submodel.

The Flood Economics Submodel performs two principal functions: calculation of average annual flood damages to floodland structures and computation of the costs of alternative flood control and floodland management measures such as floodproofing and removal of structures, earthen dikes and concrete floodwalls, and major channelization works. In addition to flood stage and probability information obtained from Hydraulic Submodel 2, input to the Flood Economics Submodel includes basic cost data and parameters describing the physical aspects of riverine area structures, dikes and floodwalls, and channelized reaches. Output from the model consists of the monetary costs and benefits of each floodland management alternative that is formulated and tested.

The Water Quality Submodel simulates the time-varying concentration, or levels, of the following water quality indicators at selected points throughout the surface water system: temperature, dissolved oxygen, fecal coliform bacteria, phosphate-phosphorus, total dissolved solids, carbonaceous biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen and organic nitrogen. Operating on a reach-by-reach basis, the submodel continuously determines water quality as a function of reach inflow and outflow, dilution, and biochemical processes. Input to the Water Quality Submodel consists of output from the Hydrologic Submodel, channel data, meteorologic data, and diffuse and point source data. Output from the submodel consists of a continuous series of water quality levels at selected points on the watershed stream system.

Data base development includes the acquisition, verification, and coding of the data needed to operate, calibrate, test, and apply the model. The model data base for the watershed consists of a large, primarily computer-based file divided into six categories: meteorological data, land data, channel data, riverine area structure data, diffuse source data, and point source data. The meteorological data set is the largest because it contains 37 years of daily or hourly information for eight types of meteorological data. The data base was assembled using data collected under other Commission planning programs, inventory data collected by the Commission and consultants under the Kinnickinnic River watershed planning program, and data from other sources such as the National Weather Service.

Many of the algorithms incorporated within the Water Resource Simulation Model are approximations of complex natural phenomena. Therefore, before the model could be used to simulate hypothetical watershed conditions, it was necessary to calibrate the model. Calibration consists of comparing model results with factual historic data and, if a significant difference is found, making parameter adjustments to adapt the model to the effects of the natural and man-made features of the planning region and the watershed. The three types of validation data available for calibration of the Water Resources Simulation Model were steamflow data, flood stage data, and water quality data.

The Hydrologic Submodel and Hydraulic Submodels 1 and 2 were successfully calibrated by comparing the simulated discharges to daily steamflows at the cooperatively maintained stream gaging station on the Kinnickinnic River at S. 7th Street and by comparing simulated stages to historic stages available at many locations around the watershed.

The rational method was used to obtain flood flows for small urban catchments--about 0.5 square mile or less--because of the tendency for the model to underestimate peak flows from very small watersheds. A model sensitivity study indicated that there were no hydraulic structures on the simulated portion of the stream system that would constrict flood flows to the extent that peak discharges would be attenuated.

The Water Quality Submodel was then calibrated to the surface water system of the Kinnickinnic River watershed by means of data obtained from the stream water index site sampling program conducted by the Commission. These data represented a range of meteorologic, hydrologic, and hydraulic conditions. When these data were used in conjunction with model input parameters already reported, an acceptable calibration was achieved.

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Chapter IX

WATER LAW

INTRODUCTION

In any sound planning and engineering effort, it is necessary to investigate the legal as well as the physical and economic factors affecting the problem under consideration. In comprehensive watershed planning, the law can be as important as the hydrology of the basin or the benefits and costs of proposed water quantity and quality control facilities in determining the ultimate feasibility of a given watershed plan. If the legal constraints bearing on the planning problem are ignored during plan formulation, serious obstacles may be encountered during plan implementation. This is particularly true in the area of water resources.

Water constitutes one of the most important natural resources. It is essential not only to many of the primary economic activities of man but also to life itself. The available quantity and quality of this important resource are, therefore, amoung the most vital concerns of a host of interest groups representing agriculture, commerce, manufacturing, conservation, and government. The rights to availability and use of water are of vital concern to a broad spectrum of public and private interest groups, and the body of law regulating these rights is far from simple or static. Moreover, changes in this complex, dynamic body of law will take place even more rapidly as pressure on regional, state, and national water resources becomes more intense. For example, the Wisconsin Supreme Court in recent years has expressly overruled the historic common law doctrine on both groundwater law[1] and diffuse surface water law,[2] finding the historic doctrines in these areas no longer applicable to modern water resource problems and conflicts.

To provide the basis for a careful analysis of existing water law in southeastern Wisconsin, a survey was undertaken of the legal framework of public and private water rights affecting water resources management, planning, and engineering. This undertaking was one of the important work elements of the first comprehensive watershed planning program in the Southeastern Wisconsin Region, that for the Root River watershed. The findings of this initial legal study, conducted under the direction of the late Professor J. H. Beuscher of the University of Wisconsin Law School, were set forth in the initial edition of SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin, published in January 1966. This initial water law study included an inventory of existing powers and responsibilities of the various levels and agencies of government involved in water resource management, as well as a discussion of the structure of public and private water rights which must necessarily be considered in the formulation of a comprehensive watershed plan. Because of the dynamic nature of water law, including not only case law decisions but increasing intervention into the area of water law by both the U. S. Congress and the Wisconsin legislature, the Commission in 1977 updated the findings of the legal study set forth in SEWRPC Technical Report No. 2. The results of this updated study of water law have been set forth in the second edition of SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin.

This chapter consists of a summary presentation of a portion of the more detailed information concerning water law set forth in the technical report. For a detailed discussion of water law concepts and principles including legal classifications of water, principal divisions of water law, riparian and public rights law, and diffuse surface water law, the reader is advised to consult SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin, Second Edition. The major purpose of this chapter is to summarize the salient legal factors bearing on the water-related problems of the Kinnickinnic River watershed and on plans for their solution, thereby laying the basis for intelligent future action. This chapter does not, however, dispense with the need for continuing legal study with respect to water law, since this aspect of the overall planning effort becomes increasingly important as plan proposals reach the implementation stage.

Attention in this chapter is focused first on those aspects of water law generally pertinent to the planning and management of the water resources of any watershed in Southeastern Wisconsin. Included in this section are a discussion of the machinery for water quality management of the federal, state, and local levels of government; a discussion of floodland regulation and the construction of flood control facilities by local units of goverment; and a discussion of the development and operation of harbors. Finally, more detailed consideration is given to those aspects of water law that relate more specifically to the problems of the Kinnickinnic River watershed, including inventory findings on state water regulatory permits and state water pollution abatement orders and permits.

WATER QUALITY MANAGEMENT

Because the Kinnickinnic River watershed study is intended to deal with problems of water quality as well as water quantity, and to recommend water use objectives and water quality standards for the Kinnickinnic River basin, it is necessary to examine the existing and potential legal machinery through which attainment of water quality goals may be sought at various levels of government and through private action.

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[1] *State v. Michels Pipeline Construction, Inc., 63 Wis. 2d 278 (1974).*

[2] *State v. Deetz, 66 Wis. 2d 1, 224 N.W. 2d 407 (1974).*

Federal Water Quality Management

The federal government has long been involved in water quality management efforts, although it is only in recent years that the U. S. Congress has acted to secure the establishment of water use objectives and supporting standards for navigable waters. The 1899 Refuse Act prohibited the discharge of refuse matter of any kind, other than that flowing from streets and sewers, into any navigable waters of the United States or tributaries thereto without first obtaining a permit from the Secretary of the Army. The Secretary was directed to make a specific finding that the discharge of any refuse matter would not adversely affect anchorage and navigation; no finding on water quality was, however, required. This act and the permits issued thereunder were largely ignored until enactment of the National Environmental Policy Act of 1969 (NEPA), which required all federal agencies to consider the environmental impact in the administration of all public laws, and the Water Quality Improvement Act of 1970, which required applicants for federal permits to file a certification from the appropriate state that the proposed discharge would not violate any applicable state-adopted water quality standard.

A broader federal approach to water quality management began with the passage of the Federal Water Pollution Control Act on June 30, 1948. With the passage of this Act, the federal government began to take effective steps toward controlling and preventing pollution of the navigable waters of the United States. Initially, the Act was primarily directed at establishing a federal grant-in-aid program for the construction of publicly owned waste treatment facilities. In the mid-1960's, requirements were added relating to the establishment of interstate water quality standards. The Act was substantially revised by the Federal Water Pollution Control Act amendments of 1972, enacted into law on October 18, 1972. In general, the revised Act provides for an increased emphasis on enhancing the quality of all of the navigable waters of the United States, whether interstate or intrastate, and further places an increased emphasis on planning and on examining alternative courses of action to meet stated water use objectives and supporting water quality standards. The Act declares it to be a national goal to eliminate the discharge of pollutants into the navigable waters of the United States by 1985 and stipulates that, wherever obtainable, an interim goal of water quality be achieved by 1983 providing for the protection and propagation of fish and natural wildlife and for human recreation in and on the water; that substantial federal financial assistance be provided to construct publicly owned waste treatment works; and that areawide waste treatment management planning processes be developed and implemented to assure adequate control of sources of pollutants within each state. The requirements of the Act may be categorized under the following headings; water quality standards and effluent limitations, pollutant discharge permit system, continuing statewide water quality management planning processes, areawide waste treatment planning and management, and waste treatment works construction. In the following discussion, attention is focused on these relevant portions of the Federal Water Pollution Control Act, as well as on the requirements of the National Environmental Policy Act of 1969.

Water Quality Standards and Effluent Limitations: Since 1965, the Federal Water Pollution Control Act has required states to adopt water use objectives and supporting water quality standards for all interstate waters. The Act as amended in 1972 incorporates by reference all existing interstate water quality standards and requires for the first time the adoption and submittal to the U. S. Environmental Protection Agency (EPA) for approval of all intrastate water use objectives and supporting water quality standards. Wisconsin, through the Natural Resources Board and the Department of Natural Resources, has adopted the required interstate and intrastate water use objectives and supporting water quality standards. These objectives and standards as related to streams and watercourses in the Kinnickinnic River watershed are discussed below. Under the new federal law, state governors are required to hold public hearings every three years for the purpose of reviewing the adopted water use objectives and supporting water quality standards and, in light of such hearings, appropriately modify and readopt such objectives and standards.

In addition to water use objectives and standards, the Act requires the establishment of specific effluent limitations for all point sources of water pollution. Such limitations require the application of the best practicable water pollution control technology currently available, as defined by the EPA Administrator. In addition, any waste source which discharges into a publicly owned treatment works must comply with applicable pretreatment requirements, also to be established by the EPA Administrator. By July 1, 1977, all publicly owned treatment works were to meet effluent limitations based upon a secondary level of treatment and through application of the best applicable waste treatment knowledge. In addition to these uniform or national effluent limitations, the Act further provides that any waste source must meet any more stringent effluent limitations as required to implement any applicable water use objective and supporting standard established pursuant to any state law or regulation or any other federal law or regulation.

Pollutant Discharge Permit System: The Federal Water Pollution Control Act, as amended in 1972, establishes a national pollutant discharge elimination system. Under this system the EPA Administrator, or a state upon approval of the EPA Administrator, may issue permits for the dishcarge of any pollutant or combination of pollutants upon the condition that the discharge will meet all applicable effluent limitations or upon such additional conditions as are necessary to carry out the provision of the Act. All such permits must contain conditions to assure compliance with all of the requirements of the Act, including conditions on data and information collection and reporting. For facilities other than publicly owned treatment works, Section 301 of the Act requires the application not later than July 1, 1983 of the best available technology economically achievable for each class of point sources which will result in reasonable further progress toward the national goal of elimination of the discharge of all pollutants into navigable waters. Publicly owned treatment works must provide for the application of the best practicable waste treatment technology over the life of the works no later than July 1, 1983. In essence, the Act stipulates that all dischargers into navigable waters must obtain a federal permit or, where a state is authorized to issue permits, a state permit. The intent of the permit system is to include in the permit, where appropriate, a schedule of compliance which will set forth the dates by which various stages of the requirements imposed in the permit shall be achieved. As discussed below, Wisconsin has an approved permit system operating under the national pollutant discharge elimination system.

Continuing Statewide Water Quality Management Planning Process: The Federal Water Pollution Control Act stipulates that each state must have a continuing planning process consistent with the objectives of the Act. States are required to submit a proposed continuing planning process to the EPA Administrator for his approval. The Administrator is prohibited from approving any state discharge permit program under the pollutant discharge elimination system for any state which does not have an approved continuing planning process.

The state continuing planning process must result in water quality management plans for the navigable waters within the state. Such plans must include at least the following items: effluent limitations and schedules of compliance to meet water use objectives and supporting water quality standards; the elements of any areawide wastewater management plan prepared for metropolitan areas; the total maximum daily pollutant load to all waters identified by the state for which the uniform or national effluent limitations are not stringent enough to implement the water use objectives and supporting water quality standards; adequate procedures for revision of plans; adequate authority for intergovernmental cooperation; adequate steps for implementation, including schedules of compliance of any water use objectives and supporting water quality standards; adequate control over the disposition of all residual waste from any water treatment processing; and an inventory and ranking in order of priority of needs for the construction of waste treatment works within the state.

In effect, the state planning process is designed to result in the preparation of comprehensive water quality management plans for natural drainage basins or watersheds. Such basin plans, however, are likely to be less comprehensive in scope than the comprehensive watershed plans prepared by the Regional Planning Commission. The statewide planning process is largely envisioned as one of synthesizing the various basin, watershed, and regional planning elements prepared throughout the State by various levels and agencies of government. The state planning process should become the vehicle for coordinating all state and local activities directed at securing compliance with the requirements of the Federal Water Pollution Control Act.

Areawide Waste Treatment Planning and Management: Section 208 of the Federal Water Pollution Control Act, as amended in 1972, provides for the development and implementation of areawide waste treatment management plans. Such plans are intended to become the basis upon which the EPA approves grants to local units of government for the construction of waste treatment works. The Act envisions that the Section 208 planning process would be most appropriately applied in the nation's metropolitan areas which, as a result of urban and industrial concentrations and other development factors, have substantial water quality control problems. Accordingly, the Act envisions the formal designation of a Section 208 planning agency for substate areas that are largely metropolitan in nature and the preparation of the required areawide water quality management plan by that agency within a two-year planning period.

Any areawide plan prepared under the Section 208 planning process must include at least the following elements:

1. The identification of waste treatment works necessary to meet the anticipated municipal and industrial waste treatment needs for the area for a 20-year period. This identification must include an analysis of alternative waste treatment systems, an identification of any requirements for the acquisition of land for treatment purposes, an identification of any necessary wastewater collection and urban storm water drainage systems, and the development of a program to provide the necessary financial arrangements for the development of any treatment works.

2. The establishment of construction priorities and time schedules for all treatment works included in the plan.

3. The establishment of a regulatory program to provide for the location, modification, and construction of any facilities within the planning area which may result in pollutant discharges and to ensure that any industrial and commercial wastes discharged into any treatment works meet applicable pretreatment requirements.

4. The identification of all agencies necessary to construct, operate, and maintain the facilities included within the plan and to otherwise carry out the recommendations in the plan.

5. The identification of the measures necessary to carry out the plan, including financing; the

period of time necessary to carry out the plan; the cost of carrying out the plan; and the economic, social, and environmental impact of carrying out the plan.

6. The identification of agriculturally and silviculturally related nonpoint sources of pollution and the procedures and methods, including land use controls, necessary to control to the maximum extent feasible such pollution sources.

7. The identification, as appropriate, of all mine-related sources of pollution, construction-related sources of pollution, and salt water intrusion, and the procedures and methods necessary to control to the maximum extent feasible such pollution point sources.

8. Recommendations for the control of the disposition of all residual wastes generated in the planning area which may affect water quality, such as sludge.

9. The establishment of a process to control the disposal of pollutants on land or in subsurface excavations.

All areawide waste treatment management plans must be updated annually and certified annually by the state governor to the EPA Administrator as being consistent with any applicable basin plans prepared under the continuing statewide water quality management planning process.

On September 27, 1974, the seven-county Southeastern Wisconsin Region and the Southeastern Wisconsin Regional Planning Commission were formally designated as a Section 208 planning area and planning agency pursuant to the terms of the Federal Water Pollution Control Act. This designation was made after a public hearing concerning the matter held jointly by the Wisconsin Department of Natural Resources and the SEWRPC on June 18, 1974. On December 26, 1974, the Administrator of the U. S. Environmental Protection Agency formally approved the designation and authorized the Regional Planning Commission to proceed with the preparation of an application for federal funds in support of the conduct of the proposed Section 208 areawide water quality and management planning program for the Region. On March 6, 1975, the Regional Planning Commission authorized the preparation of the necessary study design for the proposed Section 208 planning program and acted to create a new Technical and Citizens Advisory Committee on Areawide Water Quality Planning and Management to provide for guidance in preparation of the study design and the conduct of the actual study. The necessary study design was completed in April 1975 and served to support a federal grant application by the Commission for Section 208 planning funds. On December 26, 1975, the EPA approved the Commission's application and awarded the Commission a federal planning grant to conduct the proposed Section 208 planning program. The program was then mounted and is scheduled to be completed by December 1978, nearly concurrently with the Kinnickinnic River watershed study.

In general, the Commission expects the Section 208 water quality planning and management program for southeastern Wisconsin to be used to update, extend, and refine the previous studies and plans completed by the Commission, and in so doing to fully meet the requirements of the Federal Water Pollution Control Act. Furthermore, the Commission anticipates that any water quality-related plan recommendations set forth in the 208 areawide water quality planning program will be fully integrated into and coordinated with the recommendations to be formulated under the Kinnickinnic River watershed plan.

Waste Treatment Works Construction: One of the basic goals of the Federal Water Pollution Control Act is to provide for federal funding of publicly owned waste treatment works. Such funding must be based upon an approved areawide waste treatment management plan designed to provide for control of all point and nonpoint sources of pollution. The Act further encourages waste treatment management at specific treatment works which provide for the recycling of potential pollutants; the confined and contained disposal of any pollutants not recycled; the reclamation of wastewater; and the ultimate disposal of any sludge in an environmentally safe manner.

The Act stipulates that the EPA Administrator may not approve any grant unless the applicant demonstrates that the sewage collection system discharging into the sewage treatment facility is not subject to excessive infiltration or clear water inflow. In addition, the EPA Administrator is required to find that alternative waste management techniques for a particular facility have been studied and evaluated and that the specific works proposed for federal assistance will provide for the application of the best practicable waste treatment technology over the life of the works. Federal funding for any grant for waste treatment works has been set at 75 percent of the construction costs. The applicant for federal funding must adopt a system of charges to assure that each recipient of waste treatment services within the applicant's jurisdiction will pay its proportionate share of the operation and maintenance costs of any waste treatment services provided. In addition, industrial users of treatment works must pay to the applicant that portion of the cost of construction which is allocable to the treatment of industrial wastes.

National Environmental Policy Act: One of the significant pieces of national legislation in recent years is the National Environmental Policy Act of 1969. This Act broadly declares that it is national policy to encourage a productive and enjoyable relationship between man and his environment; to promote efforts which will prevent or eliminate damage to the environment; and to enrich the understanding of the ecological systems and natural resources important to the nation. This Act has broad application to all projects in any way related to federal action. The mechanism for carrying out the intent of the National Environmental Policy Act of 1969 is the preparation of an environmental impact statement for each project. This statement must include documentation of the environmental impact of the proposed project; any adverse environmental effects which cannot be avoided should the project be constructed; any alternative to the proposed project; the relationship between the local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented. As discussed below, Wisconsin has a similar environmental policy accompanying state governmental action of all kinds within the State, whether or not such action is federally aided.

State Water Quality Management

Responsibility for water quality management in Wisconsin is centered in the Wisconsin Department of Natural Recources (DNR). Pursuant to the State Water Resources Act of 1965, the Department of Natural Resources acts as the central unit of State government to protect, maintain, and improve the quality and management of the ground and surface waters of the State. The only substantive water quality management authority not located in the Wisconsin Department of Natural Resources is the authority to regulate private septic tank sewage disposal systems, a function that joins general plumbing supervision as the responsibility of the Wisconsin Department of Health and Social Services, Division of Health. Attention in this section of the chapter will be focused on those specific functions of the Wisconsin Department of Natural Resources which directly bear upon water quality management and, hence, upon the preparation of those elements of the Kinnickinnic River watershed plan pertaining to water pollution control.

Water Resources Planning: Section 144.025(2)(a) of the Wisconsin Statutes requires that the Department of Natural Resources formulate a long-range comprehensive state water resources plan of each region in the State. The seven-county Southeastern Wisconsin Planning Region coincides with one of the water resources districts established by the Department. This section of the statutes also stipulates that the Department formulate plans and programs for the prevention and abatement of water pollution and for the maintenance and improvement of water quality. In addition, Section 144.02 of the Wisconsin Statutes authorizes the Department to conduct drainage basin surveys. This statutory authority enables the Department of Natural Resources to conduct the continuing state water quality management planning process required by the Federal Water Pollution Control act.

Water Use Objectives and Water Quality Standards: Section 144.025(2)(b) of the Wisconsin Statutes also 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 that such objectives and standards be established for all navigable waters in the United States. Water use objective and supporting water quality standards were initially adopted for interstate waters in Wisconsin on June 1, 1967, and for interstate 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 NR102, 103, and 104. On October 1, 1976, Administrative Code Chapter NR104 was further revised.

Revised water quality standards have been formulated for the following major water uses: ecological and environmental preserves use; recreational use; restricted recreational use; public water supply; warmwater fishery; trout fishery; salmon spawning fishery; limited fishery (intermediate aquatic life); and marginal aquatic life. In addition there are minimum standards which apply to all waters. The revised state standards are set forth in Table 59. 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. According to the chapter, 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."[3]

Minimum Standards: All surface waters must meet certain conditions at all times and under certain flow conditions. "Practices attributable to municipal, industrial, commercial, domestic, agricultural, land development or other activities shall be controlled so that all waters including the mixing zone and the effluent channel meet the following conditions at all times and under all flow conditions:

(a) 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.

(b) 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.

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

Table 59

WATER USE OBJECTIVES AND WATER QUALITY STANDARDS FOR LAKES AND STREAMS IN THE SOUTHEASTERN WISCONSIN REGION: 1977[a]

Water Quality Parameters	Individual Water Use Objectives[b,c]								Combinations of Water Use Objectives Adopted for Southeastern Wisconsin Inland Lakes and Streams					
				Fish and Aquatic Life										
	Recreational Use	[x]Restricted Use[q]	Public Water Supply	Warmwater Fishery	Trout Fishery	Salmon Spawning Fishery	Limited Fishery[w,x] (Intermediate Aquatic Life)	Marginal Aquatic Life[d,w]	Restricted Use and Minimum Standards[b]	[x]Marginal Aquatic Life, Recreational Use, and Minimum Standards[b]	Limited Fishery (Intermediate Aquatic Life) Recreational Use, and Minimum Standards[b]	Warmwater Fishery and Aquatic Life, Recreational Use, and Minimum Standards[b]	Trout Fishery and Aquatic Life, Recreational Use, and Minimum Standards[b]	Salmon Spawning Fishery and Aquatic Life, Recreational Use, and Minimum Standards[b]
Maximum Temperature (°F)	–[e]	–[e]	–[e]	89[e,h]	–[e,f]	–[e,f]	89[e]	89[e]	–[e]	–[e]	89[e]	89[e]	–[e,f]	–[e,f]
pH Range (standard units)	–	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]	6.0-9.0[g]
Minimum Dissolved Oxygen (mg/l)	–	2.0	–	5.0[h]	6.0[i]	5.0[j]	3.0	2.0	2.0	2.0	3.0	5.0[h]	6.0[i]	5.0[j]
Maximum Fecal Coliform (counts/100 ml)	200-400[k]	1,000-2,000[l]	200-400[k]	–	–	–	–	200-400[k]	1,000-2,000[l]	200-400[k]	200-400[k]	200-400[k]	200-400[k]	200-400[k]
Maximum Total Residue Chlorine (mg/l)	–	–	–	.002[y]	.002[y]	.002[y]	0.5	0.5	–	0.5	0.5	.002[y]	.002[y]	.002[y]
Maximum Un-ionized Amonia-Nitrogen (mg/l)	–	–	–	0.02[u]	0.02[u]	0.02[u]	0.2[v]	–	–	–	0.2[v]	0.02[u]	0.02[u]	0.02[u]
Maximum Nitrate-Nitrogen (mg/l)	–	–	10	–	–	–	–	–	–	–	–	–	–	–
Maximum Total Dissolved Solids (mg/l)	–	–	500/700[m]	–	–	–	–	–	–	–	–	–	–	–
Other[r,s,t]	–	–	–[n]	–[p]	–[o,p]	–[p]	–[p]	–	–[q]	–	–[p]	–[p]	–[o,p]	–[p]

a *Includes SEWRPC interpretations of all basic water use categories established by the Wisconsin Department of Natural Resources 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 a reasonable length of time without damaging the overall health of the stream.*

b *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.*

c *Standards presented in the table are applicable to lakes over 50 acres in surface area and to major streams of the Region, and to all other surface waters of the Region.*

d *Includes all effluent channels used predominantly for waste carriage and assimilation, wetlands, and diffuse surface waters and includes selected continuous and noncontinuous streams as specified by the DNR on the basis of field surveys and identified as "marginal surface waters." (See Wisconsin Administrative Code Chapter NR 104.02(3)(b), and the effluent criteria specified there.)*

e *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.*

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

g *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.*

h *Dissolved oxygen and temperature standards apply to continuous 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.*

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

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

k *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.*

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

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

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

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

p *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, United States Environmental Protection Agency, Washington, D. C. 1976, and Water Quality Criteria 1972, EPA-R3-73-033, National Academy of Sciences, National Academy of Engineering, United States 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.*

q *The parametric values presented are those typically assigned; although the term "restricted" best describes the intended use, the specific chemical parameters may vary from one such reach of stream to another, since these criteria are established by the Wisconsin Department of Natural Resources on a case-by-case basis, as noted in Wisconsin Administrative Code Chapter NR 104.*

r,s *Waters important for environmental integrity and ecological preserves use, including trout streams, scientific areas, wild and scenic areas, endangered species habitat, and waters of high recreational potential, are all 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 designated under this category as of 1977.*

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 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.

u *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 USEPA 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.*

v *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 USEPA 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.*

w *May include explicitly designated agricultural drainage ditches.*

x *Includes selected continuous and noncontinuous streams as specified by the DNR on the basis of field surveys and identified as "surface waters not supporting a balanced aquatic community (intermediate aquatic life)." (See Wisconsin Administrative Code Chapter NR 104.02(3)(a), and the effluent criteria specified there.)*

Source: Wisconsin Department of Natural Resources and SEWRPC.

(c) Materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the State.

(d) Substances in concentrations or combinations which are toxic or harmful to humans 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."[4]

Ecological and Environmental Preserves Use: A body of surface water may be placed under this classification if it is determined by the Department of Natural Resources that the specified water is important to the overall environmental integrity of the area. For such waters the Department of Natural Resources may require other effluent limitations including allocations of wastelands for organic material, toxicants, and chlorine residuals. In waters identified as trout streams or located in scientific, wild, or scenic areas, or of high recreation potential, effluent criteria will be evaluated on a case-by-case basis.

Recreational Use: Waters to be used for recreational purposes should be aesthetically attractive, free of substances that are toxic upon ingestion or irritating to the skin upon contact, and void of pathogenic organisms. The first two conditions are satisfied if the water meets the minimum standards for all waters as previously described, whereas the third condition requires that a standard be set to ensure the safety of water from the standpoint of health. The concentration of fecal bacteria is the indicator now used for this purpose. Since the fecal coliform count is only an indicator of a potential public health hazard, the Wisconsin Standards specify that a thorough sanitary survey to assure protection from fecal contamination be the chief criterion for determining recreational suitability.

Restricted Recreational Use: This objective applies to continuous and noncontinuous streams for restricted use downstream from an area of intense urban development or where wastewater has a predominant influence. The significant characteristics of this category are the maximum fecal coliform level of 1,000/100 milliliters (ml) based on not less than five samples per month, or 2,000/100 ml in more than 10 percent of all samples during any month, and a minimum dissolved oxygen level of 2.0 mg/l. The restricted recreational use objective is used to signify conditions which may be hazardous to health upon whole or partial body contact.

Public Water Supply: The principal criterion of quality standards in raw water intended to be used for public water supply is that the water, after appropriate treatment, be able to meet Wisconsin Department of Natural Resources drinking water standards established in 1974. The DNR standards of raw water to be used for water supply include an allowable pH range and maximum limits on temperature, dissolved solids, and fecal coliform.

Warmwater Fishery: As indicated in Table 59, this objective is intended to result in water quality adequate to support fish and aquatic life and whole body contact recreational use. The most significant characteristics of this category are the inclusion of an 89°F maximum temperature and a minimum dissolved oxygen requirement of 5.0 milligrams per liter (mg/l).

Trout Fishery: Standards for water to be used for the preservation and enhancement of fish and aquatic life generally are specified in terms of parameters that affect the physiological condition of the fish, the food chain that sustains the fish, and the aquatic environment. The DNR standards for the trout fishery are set forth in Table 59. This category requires that no significant artificial temperature increases occur where natural trout reproduction occurs, and requires minimum dissolved oxygen levels of not less than 7.0 mg/l during spawning season.

Salmon Spawning Fishery: This standard is applicable to those continuous streams used by stocked salmonids for spawning runs. No significant artificial temperature increases from background levels will be allowed where natural salmon spawning occurs. In contrast to the trout fishery objective, a minimum dissolved oxygen level of 5.0 mg/l is allowed. This level is not to be lowered below natural background levels during period of habitation.

Limited Fishery (Intermediate Aquatic Life): This water use objective is applied to continuous and noncontinuous streams for intermediate aquatic life not supporting a balanced aquatic community. This intermediate aquatic life objective is one of the variance categories provided by Wisconsin Administrative Code Section NR104.02(3). The most significant characteristics of this intermediate aquatic life objective are the maximum un-ionized ammonia-nitrogen level of 0.2 mg/l.

Marginal Aquatic Life: This objective applies to continuous and noncontinuous streams and effluent channels, wetlands, and surface waters. Marginal uses supporting only very tolerant life forms are allowed. The most significant standards supporting the marginal aquatic life objective, as shown in Table 59, are a maximum temperature of 89°F, a minimum dissolved oxygen level of 2.0 mg/l, a maximum fecal coliform count of 200/100 ml based on not less than five samples per month or 400/100 ml in more than 10 percent of all samples during any month, and a maximum total residual chlorine level of 0.5 mg/l.

Application of the Water Use Objectives to the Kinnickinnic River Watershed: The application of the aforementioned 10 basic categories of water use objectives

[4]*Wisconsin Administrative Code Chapter NR 102.02.*

required specification of a design low flow at or above which the water quality standards commensurate with each water use objective are to be met. The water use objectives state that compliance with the supporting standards is to be evaluated on the basis of stream flow as low as the 7 day-10 year low flow, which is defined as the minimum 7-day mean low flow expected to occur once on the average of every 10 years. That is, for a given water use objective, the stream water quality is to be such as to satisfy the supporting standards for all stream flow conditions at or above the 7 day-10 year low flow.

The water use objectives established by the Wisconsin Department of Natural Resources for the surface waters of the Kinnickinnic River watershed include restricted recreational use and minimum standards. The established water use objectives are applied to all perennial and intermittent streams in the watershed as well as to storm water runoff. Named streams with perennial or intermittent reaches to which the objectives apply are the Kinnickinnic River, Wilson Park Creek, Lyons Park Creek, S. 43rd Street Ditch, Cherokee Park Creek, Villa Mann Creek, and Holmes Avenue Creek.

Water Pollution Abatement Orders: Pursuant to Section 144.025(2)(c) of the Wisconsin Statutes, the Department of Natural Resources is given authority to issue general orders applicable throughout the State to the construction, installation, use, and operation of systems, methods, and means for preventing and abating water pollution. This section also stipulates that the Department may adopt specific rules relating to the installation of water pollution abatement systems. Pursuant to this authority, the Department has adopted requirements for sewage disposal in Chapter NR 108 of the Wisconsin Administrative Code and for the design and operation of sewerage systems in Chapter NR 110 of the Wisconsin Administrative Code.

Special pollution abatement orders directing particular polluters to secure appropriate operating results at sewage treatment facilities in order to control water pollution or to cease the discharge of pollutants at a particular point are authorized to be issued by the Department in Section 144.025(2)(d) of the Wisconsin Statutes. Such orders may prescribe a specified time for compliance with provisions of the order. Such orders are directed not only at municipal units of government that operate sewage treatment plants but also at private corporations and individuals who in any way discharge wastes to the surface or groundwaters of the State. The Department has the power to make such investigations and inspections as are necessary to ensure compliance with any pollution abatement orders which it issues. In cases of noncompliance with any pollution abatement order, the Department has the authority to take any action directed by the order and to collect the costs thereof from the owner to whom the order was directed. Such charges become a lien against the properly involved.

To a large extent, the issuance of waste discharge permits as discussed below has become a substitute for the issuance of water pollution abatement orders by the Department, since such permits contain specified performance and operating standards.

Effluent Reporting and Monitoring System: Section 144.54 of the Wisconsin Statutes directs the Department of Natural Resources to require by rule that persons discharging industrial wastes, toxic and hazardous substances, or air contaminants submit a report on such discharges to the Department. The law further specifically exempts municipalities from the rules and establishes an annual monitoring fee to provide for the cost of administering the program. In response to this statutory mandate, the Department prepared and adopted Chapter NR 101 of the Wisconsin Administrative Code setting forth specific rules by which the reporting and monitoring program is to be conducted. Of particular importance to water quality management are the effluent reports required in this chapter.

The rules require every person discharging industrial wastes or toxic and hazardous substances to file an effluent report with the Department if 1) treated or untreated effluent is discharged directly to surface waters; 2) a minimum of 10,000 gallons of effluent per day one or more days a year is discharged to a land disposal system or to a municipal sewerage system; 3) less than 10,000 gallons per day is discharged to a land disposal system or a municipal sewerage system if the Department finds that reporting is necessary to protect the environment; and 4) more than 1,000,000 British thermal units are contributed per day one or more days per year to the effluent discharged to surface waters. Certain discharges are exempted from reporting, primarily if the discharge contributes none of the particular industrial wastes or toxic and hazardous substances specified in the Code. In addition, agricultural land runoff from land used exclusively for crop production need not be reported. Generally, the reports required by the Department must provide specific locations where effluent is being discharged to either surface waters, a sanitary sewerage system, or a land disposal system; estimates of the annual and average daily quantity of effluent discharged; concentrations and quantities of industrial wastes or toxic and hazardous substances contributed to the effluent in excess of the required reporting level; temperatures and volumes of thermal discharges; pH range of effluent; and a brief description of the manner and amount of raw materials used to produce wastes being reported.

Pollutant Discharge Permit System: Section 147.02 of the Wisconsin Statutes requires a permit for the legal discharge of any pollutant into the waters of the State, including groundwaters. This state pollutant discharge permit system was established by the Wisconsin Legislature in direct response to the requirements of the Federal Water Pollution Control Act of 1972, as discussed above. While the federal law envisioned requiring a permit only for the discharge of pollutants into navigable waters, in Wisconsin permits are required for discharges from point sources of pollution to all surface waters of the State and, additionally, to land areas where pollutants may percolate or seep to, or be leached to, groundwaters. Rules relating to the pollutant discharge elimination system are set forth in Chapter NR 200 of the Wisconsin Administrative Code.

Discharges for which permits are required include the following:

1. The direct discharge of any pollutant to any surface water.

2. The discharge of any pollutant, including cooling waters, to any surface water through any storm sewer system not discharging to publicly owned treatment works.

3. The discharge of pollutants other than from agriculture for the purpose of disposal, treatment, or containment on land areas, including land disposal systems such as ridge and furrow, irrigation, and ponding systems.

Certain discharges are exempt from the permit system, including discharges to publicly owned sewerage works; discharges from vessels; discharges from properly functioning marine engines; and discharges of domestic sewage to septic tanks and drain fields, which are regulated under another chapter of the Wisconsin Administrative Code. Also exempted are the disposal of septic tank pumpage and other domestic waste, also regulated by another chapter of the Wisconsin Administrative Code, and the disposal of solid wastes, including wet or semiliquid wastes, when disposed of at a site licensed pursuant to another chapter of the Wisconsin Administrative Code.

The establishment of the Wisconsin pollution discharge permit system (WPDES) is a significant step both in terms of the data provided concerning point sources of pollution and in terms of the regulatory aspects of the permit system, including a listing of the treatment requirements and a schedule of compliance setting forth dates by which various stages of the requirements imposed by the permit shall be achieved. It is envisioned that the water quality management plans prepared pursuant to the terms of the Federal Water Pollution Control Act will be fully reflected in the permits issued under the pollutant discharge elimination system. As such, the pollutant discharge permit system is the primary vehicle for implementation of the basic goal of the Federal Water Pollution Control Act--namely, that of achieving the water use objectives for the receiving waters.

Septic Tank Regulation: In performing its functions of maintaining and promoting the public health, the Wisconsin Division of Health is charged with the responsibility of regulating installation of private septic tank seweage disposal systems. Such systems often contribute to the pollution of surface and groundwaters. Pursuant to Chapter 236 of the Wisconsin Statutes, the Division of Health reviews plats of all land subdivisions not served by public sanitary sewerage systems and may object to such plats if sanitary waste disposal facilities are not properly provided for in the layout of the plat. The Division has promulgated regulations governing lot size and elevation in Chapter H-65 of the Wisconsin Administrative Code. Basic regulations governing the installation of septic tank systems are set forth in Chapter H-62 of the Wisconsin Administrative Code. The Wisconsin Department of Natural Resources, however, must approve the provisions of the state plumbing code which sets specifications for septic tank systems and their installation. That Department also may prohibit the installation or use of septic tanks in any area of the State where the Department finds that the use of septic tanks would impair water quality. All septic tanks in the State must be registered by permit pursuant to Section 144.03 of the Wisconsin Statutes.

State Environmental Policy Act: The Wisconsin Legislature in April 1972 created Section 1.11 of the Wisconsin Statutes relating to governmental consideration of environmental impact. In many ways the state legislation parallels the National Environmental Policy Act of 1969 discussed earlier in this chapter. Under this state legislation, all agencies of the State must include a detailed environmental impact statement in every recommendation or report on proposals for legislation or other major actions which would significantly affect the quality of the human environment. The required contents of this statement parallel the contents required in the federal environmental impact statements. The effect of the state legislation is, therefore, to extend the environmental impact statement concept to all state action not already covered under the federal legislation.

Local Water Quality Management

All towns, villages, and cities in Wisconsin have, as part of the broad grant of authority by which they exist, sufficient police power to regulate by ordinance any condition or set of circumstances bearing upon the health, safety, and welfare of the community. Presumably, the water quality of a receiving stream or the polluting capability of effluent generated within the municipal unit would fall within the regulative sphere by virtue of its potential danger to health and welfare. Such local ordinances could not, however, conflict with the federal and state legislation in this area.

Local and county boards of health have powers to adopt and enforce rules and regulations designed to improve the public health. This broad grant of authority includes regulatory controls relating to environmental sanitation and, hence, water pollution. County boards of health, established by action of the county board of supervisors pursuant to Section 140.09 of the Wisconsin Statutes, can provide an effective vehicle for the enactment of countrywide regulations designed in part to prevent and control further pollution of surface waters and groundwaters.

County park commissions established pursuant to Section 27.02 of the Wisconsin Statutes have powers to investigate the pollution of streams and lakes throughout the entire county and to engage in weed control and treatment practices in order to ameliorate one effect of such pollution: weed growth. In so doing, county park commissions may cooperate and contract with other counties and municipalities to provide for pollution control and lake and stream treatment.

Special Units of Government: In addition to the broad grant of authority to general purpose units of local government, the Wisconsin Statutes currently provide for the creation of five types of special purpose units of government through which water pollution can be abated and water quality protected. These are: 1) the Metropolitan Sewerage District of the County of Milwaukee; 2) other metropolitan sewerage districts; 3) utility districts; 4) joint sewerage systems; and 5) cooperative action by contract.

Metropolitan Sewerage District of the County of Milwaukee: The Metropolitan Sewerage District of the County of Milwaukee was established and operates under the provisions of Section 59.96 of the Wisconsin Statutes. It operates through the agency of the Sewerage Commission of the City of Milwaukee, which was established pursuant to Chapter 608, Laws of Wisconsin 1913, and the Metropolitan Sewerage Commission of the County of Milwaukee, which operates and exists pursuant to the provisions of Section 59.96 of the Wisconsin Statutes. The Metropolitan Sewerage Commission has the power to project, plan, and construct main sewers as well as pumping and temporary disposal works for the collection and transmission of house, industrial, and other sanitary sewage to and into the intercepting sewerage systems of such District. Also, the Commission may improve any watercourse within the District by deepening, widening, or otherwise changing the same where, in the judgment of the Commission, it may be necessary to carry off surface or drainage waters. The Metropolitan Sewerage Commission may only exercise its powers outside of the City of Milwaukee. The Sewerage Commission of the City of Milwaukee, on the other hand, may build treatment plants and main and intercepting sewers and may improve watercourses within its area of operation, which is within the City of Milwaukee.

In order to coordinate the activities of the two Commissions, the Statutes stipulate that the Metropolitan Sewerage Commission must secure the approval of the Sewerage Commission of the City of Milwaukee before it can engage in any work and, when it has completed the work it proposes to do, it must turn over all of the facilities to the Sewerage Commission of the City of Milwaukee for operation and maintenance. Rules and regulations adopted by the Sewerage Commissions pursuant to the Statutes further provide for the coordination of the sewer improvement programs in the District by requiring that all cities and villages lying within the District and in contract service areas adjacent to the District must submit their sewerage system and construction plans for approval before they can connect to the main and intercepting system owned by the District. The two Commissions have the power to promulgate and enforce reasonable rules for the supervision, protection, management, and use of the entire sewerage system.

The District at the present time includes all of the cities and villages within the County of Milwaukee, except for the City of South Milwaukee, which elected not to become part of the District. However, through its two Commissions, the District may enter into contracts with municipalities in the same general drainage area and adjacent to the District to furnish sewer service to those municipalities. The two Commissions have the power to inspect all sewers and sewerage systems which drain into the main or intercepting system. Furthermore, they have the power to require any town, city, or village or the occupant of any premises engaged in discharging sewage effluent from sewage plants, sewage refuse, factory wastes, or other materials into any river or canal within such County and within the drainage area to change or rebuild any such outlet, drain, or sewer so that the sewage waste or trade waste discharges into the sewers of said town, city, or village or into the main intercepting sewers owned by the District.

With regard to watercourse improvements, the District, through its two Commissions, has engaged in a broad program of improving watercourses by widening, deepening, or otherwise changing watercourses so as to accommodate the expected flow of storm and surface drainage waters from the area within the District and from the areas surrounding the District. In connection with this work, many unauthorized waste discharges to watercourses were uncovered and eliminated, thus reducing the discharge of objectionable materials into the rivers and streams in Milwaukee County, as well as providing greater capacity for such streams and rivers and providing for more rapid and efficient runoff of storm and drain waters. The term "same general drainage area" referred to above, has been defined by the two Commissions to include all of the Kinnickinnic, Menomonee, and Milwaukee River, and Oak Creek watersheds and those portions of the Root River watershed draining into Milwaukee County. At the present time, jurisdiction of the joint Commissions extends to all of the Kinnickinnic River watershed. For all practical purposes, then, the Metropolitan Sewerage District represents the single entity responsible for the conveyance and treatment of sanitary sewage in the Kinnickinnic River watershed.

Other Metropolitan Sewerage Districts: In 1972 the Wisconsin Legislature enacted into law new enabling legislation for the creation of metropolitan sewerage districts outside of Milwaukee County. This legislation is set forth in Sections 66.20 and 66.26 of the Wisconsin Statutes. This legislation stipulates that proceedings to create a metropolitan sewerage district may be initiated by resolution of the governmental body of any municipality. Such resolution, which must set forth a description of the territory proposed to be included in the district and a description of the functions proposed to be performed by the district, is directed at the Wisconsin

Department of Natural Resources. Upon receipt of the resolution, the Department is required to schedule a public hearing for the purpose of permitting any persons to present any information relating to the matter of the proposed metropolitan sewerage district. Within 90 days of the hearing, the Department must either order or deny the formation of the proposed district. The department must order the formation of the district if it finds that the district consists of at least one municipality in its entirety and all or part of other muncipalities; if the district is determined to be conducive to management of a unified system of sewage collection and treatment; if the formation of the district will promote sound sewerage management policies and operation and is consistent with adopted plans of municipal, regional, and state agencies; and if the formation of the district will promote the public health and welfare and effect efficiency and economy in sewerage management. No territory of a city or village jointly or separately owning or operating a sewage collection or disposal system may be included in the district, however, unless it has filed with the Department of Natural Resources a certified copy of a resolution of its governing body consenting to the inclusion of its territory within the proposed district.

While metropolitan sewerage districts outside of Milwaukee County have importance in the Southeastern Wisconsin Region in other watersheds, they have no practical importance in the Kinnickinnic River watershed because of the existing authority of the Metropolitan Sewerage District of the County of Milwaukee. Accordingly, from a practical point of view, such districts are not of significance to the implementation of either the regional sanitary sewerage system plan in the Kinnickinnic River watershed or to the Kinnickinnic River watershed plan itself.

Utility Districts: Section 66.072 of the Wisconsin Statutes permits towns, villages, and cities of the third and fourth class to establish utility districts for a number of municipal improvement functions, including the provision of sanitary sewer service. Funds for the provision of services within the district are provided by levying a tax upon all property within the district. The establishment of utility districts requires a majority vote in towns and a three-fourths vote in cities and villages. Prior to establishing such a district, the local governing bodies are required to hold a formal public hearing.

Joint Sewerage Systems: Section 144.07 of the Wisconsin Statutes provides the authority for a group of governmental units, including city, village, and town sanitary or utility districts, to construct and operate a joint sewerage system following hearing and approval by the Wisconsin Department of Natural Resources. The Statute stipulates that when one governmental unit renders such service as sewage conveyance and treatment to another unit under this section, reasonable compensation is to be paid. Such reasonable charges are to be determined by the governmental unit furnishing the service. If the governmental unit receiving this service deems the charge unreasonable, the Statutes provide for either binding arbitration by a panel of three reputable and experienced engineers or for judicial review in the circuit court of the county of the governmental unit furnishing the service. As an alternative, the jointly acting governmental units may create a sewerage commission to project, plan, construct, and maintain in the area sewerage facilities for the collection, transmission, and treatment of sewage. Such a sewerage commission becomes a municipal corporation and has all the powers of a common council and board of public works in carrying out its duties. However, all bond issues and appropriations made by such a sewerage commission are subject to approval by the governing bodies of the units of government which initially formed the commission. The Statutes stipulate that each governmental unit must pay its proportionate share of constructing, operating, and maintaining the joint sewerage system. Grievances concerning same may be taken to the circuit court of the county in which the aggrieved governmental unit is located.

Cooperative Action by Contract: Section 66.30 of the Wisconsin Statutes permits the joint exercise by municipalities, broadly defined to include the State or any department or agency thereof or any city, village, town, county, school district, public library system, sanitary district, or regional planning commission, of any power or duty required of or authorized to individual municipalities by statute. To jointly exercise any such power, such as the transmission, treatment, and disposal of sanitary sewage, municipalities would have to create a commission by contract. Appendix A of SEWRPC Technical Report No. 6, Planning Law in Southeastern Wisconsin, contains a model agreement creating such a cooperative contract commission.

Shoreland Regulation: The State Water Resources Act of 1965 provides for the regulation of shoreland uses along navigable waters to assist in water quality protection and pollution abatement and prevention. In Section 59.97(1) of the Wisconsin Statutes, the Legislature defines shorelands as all that area lying within the following distances from the normal high water elevation of all natural lakes and of all streams, ponds, sloughs, flowages, and other waters which are navigable under the laws of the State of Wisconsin: 1,000 feet from the shoreline of a lake, pond, flowage, or glacial pothole lake and 300 feet from the shoreline of a stream or to the landward side of the floodplain, whichever is greater.

Section 144.26 of the Wisconsin Statutes specifically authorizes municipal zoning regulations for shorelands. This Statute defines municipality as meaning a county, city, or village. The shoreland regulations authorized by this Statute have been defined by the Wisconsin Department of Natural Resources to include land subdivision controls and sanitary regulations. The purposes of zoning, land subdivision, and sanitary regulations in shoreland areas include the maintenance of safe and healthful conditions in riverine areas; the prevention and control of water pollution; the protection of spawning grounds, fish, and aquatic life; the control of building sites, placement of structures, and land use; and the preservation of shore cover and natural beauty. A more complete discussion of local shoreland regulatory powers is contained in SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide.

Private Steps for Water Pollution Control

The foregoing discussion deals exclusively with water pollution control machinery available to units and agencies of government. Direct action may also be taken, however, by private individuals or organizations to effectively abate water pollution. In seeking direct action for water pollution control there are two legal categories of private individuals: riparians, or owners of land along a natural body of water, and nonriparians.

Riparians: It is not enough for a riparian proprietor seeking an injunction to show simply that an upper riparian is polluting the stream and thus he, the lower riparian, is being damaged. Courts will often inquire as to the nature and the extent of the defendant's activity; its worth to the community; its suitability to the area; and his present attempts, if any, to treat wastes. The utility of the defendant's activity is weighed against the extent of the plaintiff's damage within the framework of reasonable alternatives open to both. On the plaintiff's side, the court may inquire into the size and scope of his operations, the degree of water purity that he actually requires, and the extent of his actual damages. This approach may cause the court to conclude that the plaintiff is entitled to a judicial remedy. Whether this remedy will be an injunction or merely an award of damages depends on the balance which the court strikes after reviewing all the evidence. For example, where a municipal treatment plant or industry is involved, the court, recognizing equities on both sides, might not grant an injunction stopping the defendant's activity but might compensate the plaintiff in damages. In addition, the court may order the defendant to install certain equipment or to take certain measures designed to minimize the future polluting effects of his waste disposal. It is not correct to characterize this balancing as simply a test of economic strengths. If it were simply a weighing of dollars and cents, the rights of small riparians would never receive protection. The balance that is struck is one of reasonable action under the circumstances, and small riparians can be and have been adequately protected by the courts.

Riparians along water bodies in the Southeastern Wisconsin Region are not prevented by the existence of federal, state, or local pollution control efforts from attempting to assert their common law rights in courts. The court may ask the Wisconsin Department of Natural Resources to act as its master in chancery, especially where unbiased technical evidence is necessary to determine the rights of litigants. The important point, however, is that nothing in the Wisconsin Statutes can be found which expressly states that, in an effort to control pollution, all administrative remedies must first be exhausted before an appeal to the courts may be had or that any derogation of common law judicial remedies was intended. Thus, the courts are not prevented from entertaining an original action brought by a riparian owner to abate pollution.

Nonriparians: The rights of nonriparians to take direct action through the courts are less well defined than in the case of riparians. The Wisconsin Supreme Court set forth a potentially far-reaching conclusion in Muench v. Public Service Commission[5] when it concluded that:

> The rights of the citizens of the state to enjoy our navigable streams for recreational purposes, including the enjoyment of scenic beauty, is a legal right that is entitled to all the protection which is given financial rights.

This language, however, was somewhat broader than necessary to meet the particular situation at hand, since the case involved an appeal from a state agency ruling. The case has not yet arisen where a private nonriparian citizen is directly suing to enforce his public rights in a stream. Only when such a case does arise can it be determined if the Court will stand behind the broad language quoted above or draw back from its implications. The more traditional view would be that a nonriparian citizen must show special damages in a suit to enforce his public rights.

It should be noted that Section 144.537 of the Wisconsin Statutes presently enables six or more citizens, whether riparian or not, to file a complaint leading to a full-scale public hearing by the Department of Natural Resources on alleged or potential acts of pollution. In addition, a review of Department orders may be had pursuant to Section 144.56 of the Wisconsin Statutes by "any owner or other person in interest." This review contemplates eventual court determination under Chapter 227 of the Wisconsin Statutes when necessary. The phrase "or other person" makes it clear that nonriparians may ask such judicial review.

The Federal Water Pollution Control Act also provides for citizen suits. Under this law, any citizen, meaning a person or persons having an interest which is or may be adversely affected, may commence a civil action on his or her own behalf against any person, including any governmental agency, alleged to be in violation of any effluent standard, limitation, or prohibition or any pollution discharge permit or condition thereof; or against the EPA Administrator when there is alleged failure by the Administrator to duly carry out any nondiscretionary duty or act under the Federal Water Pollution Control Act. Prior to bringing such action, however, the citizen commencing the action must give notice of the alleged violator. The courts when issuing final orders in any action under this section may award costs of litigation to any party.

FLOODLAND REGULATION AND CONSTRUCTION OF FLOOD CONTROL FACILITIES

Effective abatement of flooding can be achieved only by a comprehensive approach to the problem. Certainly, physical protection from flood hazards through the con-

[5] *261 Wis. 492, 53 N.W. 2d 514 (1952).*

struction of dams, flood control reservoirs, levees, channel improvements, and other water control facilities is not to be completely abandoned in favor of floodland regulation. As urbanization proceeds within a watershed, however, it becomes increasingly necessary to develop an integrated program of land use regulation of the floodlands within the entire watershed to supplement required water control facilities if efforts to provide such facilities are not to be self-defeating.

Definition of Floodlands

The precise delineation of floodlands is essential to the sound, effective, and legal administration of floodland regulations. This is particularly true in urban areas, such as the Kinnickinnic River watershed. A precise definition of floodlands is not found in the Wisconsin Statutes. Section 87.30(1) speaks only of those areas within a stream valley within which "serious (flood) damage may occur" or "appreciable (flood) damage. . .is likely to occur." This statutory description is not adequate per se for floodland determination. As a watershed urbanizes, and as the hydraulic characteristics of a stream are altered, additional areas of a stream valley become subject to flooding. It becomes necessary, therefore, to regulate the entire potential, as well as existing, floodland areas.

In planning for the proper use of floodlands, it is useful to subdivide the total floodland area on the basis of the hydraulic function which the various subareas are to perform, as well as on the basis of the differing degrees of flood hazard that may be present (see Figure 57). Under natural conditions, the floodlands may be considered as consisting of two components: the channel of the river or stream itself and the adjacent natural floodplains. The channel may be defined as the continuous linear area occupied by the river or stream in times of normal flow. The natural floodplain may be defined as the wide, flat-to-gently sloping area contiguous with and lying adjacent to the channel, usually on both sides. The floodplain is normally bounded on its outer edges by higher topography. A river may be expected to overflow its channel banks and occupy some portion of its floodplains on the average of once every two years. How much of the natural floodplain will be occupied by any given flood will depend upon the severity of that flood and, more particularly, upon its elevation or stage. Thus, an infinite number of outer limits of the natural floodplain may be delineated, each with delineation relating to a corresponding specified flood recurrence interval. The Commission has, therefore, recommended that the natural floodplains of a river or stream be specifically defined as those being confined to a flood having a recurrence interval of 100 years; that is, a flood having a 1 percent chance of occurring in any given year. This definition corresponds to the regulatory flood selected for use by the Wisconsin Department of Natural Resources in administering Wisconsin's floodplain management program set forth in Chapter NR 116 of the Wisconsin Administrative Code.

Under ideal regulatory conditions, the entire natural floodplains as defined above would be maintained in an open, essentially natural state, and, therefore, would not be filled and utilized for incompatible, intensive urban land uses. Conditions permitting an ideal approach to floodland regulation, however, generally occur only in rural areas. In areas which have already been developed for intensive urban use without proper recognition of the flood hazard, a practical regulatory approach must embrace the concept of a floodway. A floodway may be defined as a designated portion of the floodlands that will safely convey the 100-year recurrence interval flood discharge, with small upstream and downstream stage increases allowed, generally limited in Wisconsin to 0.5 foot if the stage increase does not increase the flood damage potential. The regulatory floodway includes the channel. Land use controls applied to the regulatory floodway should recognize that the designated floodway area is not suited for human habitation and should essentially prohibit all fill, structures, and other development that would impair floodwater conveyance by adversely increasing flood stages or velocities.

The floodplain fringe is that remaining portion of the floodlands lying outside of or beyond the floodway. Because the use of a regulatory floodway may result in increases in the stage of a flood of a specified occurrence interval that would not occur under natural conditions, the floodplain fringe may include at its very edges areas that would not be subject to inundation under natural conditions, but which would be subject to inundation under regulatory floodway conditions and, therefore, come within the scope of necessary floodplain fringe regulation. Normally, floodwater depths and velocities are low in the floodplain fringe, and accordingly, filling and urban development may be permitted although regulated to minimize flood damages. Under "real world" conditions, the floodplain fringe usually includes many existing buildings constructed in natural floodlands prior to the advent of sound floodland regulations.

The delineation of the limits of the floodland regulatory area should be based upon careful hydrologic and hydraulic studies such as have been conducted under the Kinnickinnic River watershed study for the Kinnickinnic River and its major tributaries.

Principles of Floodland Regulation

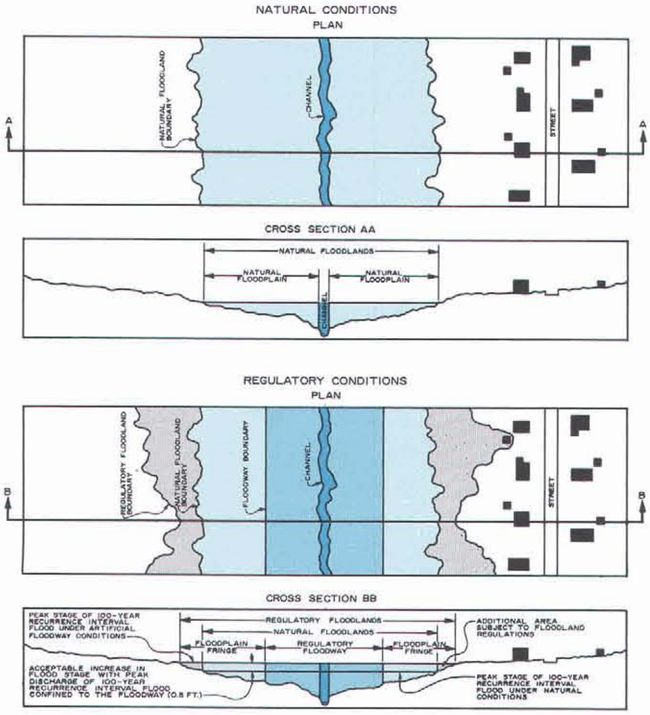
Certain legal principles must be recognized in the development of land use regulations that would be designed to implement a comprehensive watershed plan. With respect to the floodland areas of the watershed, those are as follows:

1. Sound floodland regulation must recognize that the flood hazard is not uniform over the entire floodland area. Restrictions and prohibitions in floodlands should, in general, be more rigorous in the channels themselves and in the floodways than in the floodplain fringe areas.

2. While it is most desirable that floodland regulations seek to retain floodlands in open space uses, sound floodland regulation may contemplate permitting certain buildings and structures at appropriate locations in the floodplain fringe.

Figure 57

FLOODLAND COMPONENTS UNDER NATURAL AND REGULATORY CONDITIONS



Source: SEWRPC.

Any such structure, however, should comply with special design, anchorage, and building material requirements.

3. Sound floodland regulation must recognize, and be adjusted to, existing land uses in the floodlands. Structures already may exist in the wrong places. Fills may be in place constricting flood flows or limiting the flood storage capacities of the river. The physical effects of such misplaced structures and materials on flood flows, stage, and velocities, can be determined. Floodland regulation based on such determinations must include legal measures to bring about the removal of at least the most troublesome of offenders.

4. In addition to the physical effects of structures and materials, sound floodland regulation must be concerned with the social and economic effects, particularly the promotion of public health and safety. Beyond this, sound floodland regulation must take into account such diverse and general welfare items as impact upon property values, the property tax base, human anguish, aesthetics, and the need for open space.

5. Sound floodland regulation must coordinate all forms of land use controls, including zoning, subdivision control, and official map ordinances and housing, building, and sanitary codes.

Land Use Regulation in Floodlands

Based upon the above principles and upon the definition of floodplains set forth above, the Commission has proposed that the local units of government within the entire Region utilize a variety of land use controls to effect proper floodland development. The use of these controls is discussed in SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, and, therefore, will not be repeated here. The following section, however, will summarize the various land use regulatory powers available to state, county, and local units of government for use in regulating floodland development.

Channel Regulation: Sections 30.11, 30.12, and 30.15 of the Wisconsin Statutes establish rules for the placement of material and structures on the bed of any navigable water and for the removal of material and structures illegally placed on such beds. With the approval of the Wisconsin Department of Natural Resources, pursuant to Section 30.11 of the Wisconsin Statutes, any town, village, city, or county may establish bulkhead lines along any section of the shore of any navigable water within its boundaries. Where a bulkhead line has been properly established, material may be deposited and structures built out to the bulkhead line, consistent with the appropriate floodway zoning ordinance. A Wisconsin Department of Natural Resources permit is required for deposit of material or erection of a structure beyond the bulkhead line. Where no bulkhead line has been established, it is unlawful to deposit any material or build any structure upon the bed of any navigable water unless a Wisconsin Department of Natural Resources permit has first been obtained.

The delineation of the outer boundary of the bed of a navigable lake or stream thus becomes a crucial legal issue, and the Statutes provide no assistance in this problem. Where the lake or stream has sharp and pronounced banks, it will ordinarily be possible, using stage records, the testimony of knowledgeable persons, and evidence relating to types of vegetation and physical characteristics of the bank, to establish the outer limits of the stream or lake bed. The task can present a difficult practical problem, however, particularly where the stream is bordered by low-lying wetlands. Where bulkhead lines have been established, however, or where the outer limits of navigable waters can be defined, existing encroachments in the beds of these navigable waters can be removed and new encroachments prevented under existing Wisconsin legislation.

Floodway and Floodplain Fringe Regulation: The regulation of floodlands in Wisconsin is governed primarily by the rules and regulations adopted by the Wisconsin Department of Natural Resources pursuant to Section 87.30 of the Wisconsin Statutes. In addition, with the advent of the federal flood insurance program, the enactment of floodland regulations in Wisconsin is further governed by rules promulgated by the U.S. Department of Housing and Urban Development. In essence, floodland regulation in Wisconsin is a partnership between the local, state, and federal levels of government.

State Floodplain Management Program: While the Wisconsin Legislature long ago recognized that the regulation of stream channel encroachments was an areawide problem transcending county and municipal boundaries and, therefore, provided for state regulation, it was not until passage of the State Water Resources Act in August 1966 that a similar need was recognized for floodway and floodplain fringe regulation. In that Act, the Legislature created Section 87.30 of the Wisconsin Statutes. This section authorizes and directs the Wisconsin Department of Natural Resources to enact floodland zoning regulations where it finds that a county, city, or village has not adopted reasonable and effective floodland regulations. The cost of the necessary floodplain determination and ordinance promulgation and enforcement by the State must, under the Statute, be assessed and collected as taxes from the county, city, or village by the State. Chapter NR 116 of the Wisconsin Administrative Code sets forth the general criteria for counties, cities, and villages to follow in enacting reasonable and effective floodland regulations. In addition to providing for the proper administration of a sound floodland zoning ordinance, the criteria include a stipulation that, where applicable, floodland zoning ordinances should be supplemented with land subdivision regulations, building codes, and sanitary regulations.

In practice, the Department of Natural Resources issues orders to counties, cities, and villages when sound flood hazard data become available for use in floodland regulation. In the Southeastern Wisconsin Region, this has generally meant that such orders are issued to communities upon completion of comprehensive watershed studies developed by the Regional Planning Commission, which include the definitive determination of flood hazard areas. These orders normally provide a period of six months upon receipt of the flood hazard data for the enactment of the necessary local regulations.

State Agency Coordination: On November 26, 1973, Governor's Executive Order No. 67 was issued. It was designed to promote a unified state policy of comprehensive floodplain and shoreland management. The key provisions of the executive order are as follows:

1. State agencies are now required to consider flooding and erosion dangers in the administration of grant, loan, mortgage insurance, and other financing programs.

2. All state agencies that are involved in land use planning are required to consider flooding and erosion hazards when preparing and evaluating plans. In addition, all state agencies directly responsible for new construction of state facilities, including buildings, roads, and other facilities, are required to evaluate existing and potential flood hazards associated with such contruction activities.

3. All state agencies that are responsible for the review and approval of subdivision plats, buildings, structures, roads, and other facilities are required to evaluate existing or potential flood hazards associated with such construction activities.

4. In its license review, suspension, and revocation procedures, the State Real Estate Examining Board must consider the failure of real estate brokers, salesmen, or agents to properly inform a potential purchaser that property under consideration lies within an area subject to flooding or erosion hazards.

The provisions of this executive order are extremely important in that all state agencies are now required to utilize the flood hazard data that have been and are being developed. Thus, the provisions will assist in assuring that state-aided action, such as highway construction, will not contribute to increasing flooding and erosion hazards or to changing the character of the flooding. The order also assures that state agency actions will be consistent with local floodland regulations.

Federal Flood Insurance Program: A program to enable property owners to purchase insurance to cover losses caused by floods was established by the U.S. Congress in the National Flood Insurance Act of 1968. Taking note that many years of installation of flood protection works had not reduced losses caused by flood damages, Congress sought to develop a reasonable method of sharing the risk of flood losses through a program of flood insurance, while at the same time setting in motion local government land use control activity that would seek to ensure, on a nationwide basis, that future urban development within floodlands would be held to a minimum.

The Act created a national flood insurance program under the direction of the Secretary of the U.S. Department of Housing and Urban Development (HUD). The Secretary was given broad authority to conduct all types of studies relating to determination of floodlands and the risks involved in insuring development that may be situated in natural floodland areas. The Act provided for the establishment of a national flood insurance fund, part of which would be established by congressional appropriations, designed to assist in subsidizing insurance rates where necessary to encourage the purchase of flood insurance by individual land owners and thus reduce the need for periodic federal disaster assistance. Congress emphasized, however, that the establishment of such a program was not intended to encourage additional future development in flood-prone areas, but rather to assist in spreading the risks created by existing floodland development while taking effective action to ensure that local land use control measures effectively reduce future flood losses by prohibiting unwise floodland development.

Participation in the national flood insurance program is on a voluntary community-by-community basis. A community must act affirmatively to make its residents eligible to purchase flood insurance. Once a community makes it known to the Secretary of the U.S. Department of Housing and Urban Development that it wishes to participate in the program, the Secretary authorizes appropriate studies to be made to determine the special flood hazard areas that may exist within the community and the rates at which flood insurance may be made available. In the Southeastern Wisconsin Region, such flood insurance studies build upon and at times supplement the flood hazard data made available by the Regional Planning Commission under the comprehensive watershed planning programs. When the federal studies are completed, the Secretary publishes a flood hazard boundary map or maps, which identify the areas of "special flood hazard," and a flood insurance rate map or maps, which divide the community into various zones for insurance purposes. A landowner is then eligible to go to any private insurance agent and purchase flood insurance up to certain specified maximums at the rates established by the Secretary. Such rates can be federally subsidized if the actuarial rates would result in a likelihood of widespread nonparticipation in the program. For its part, the community must enact land use controls which meet federal standards for floodland protection and development. For all practical purposes, once a community enacts floodland regulations that meet the state requirements set forth in Chapter NR 116 of the Wisconsin Administrative Code, it will have been deemed to meet all federal requirements for similar controls.

In 1973 the U.S. Congress expanded the national flood insurance program through enactment of the Federal Flood Disaster Protection Act of 1973. In addition to increasing the amount of both subsidized and unsubsidized flood insurance coverage available for all types of properties, this act expanded the insurance program to include erosion losses caused by abnormally high water levels. In addition, the Act stipulates that the purchase of flood insurance is required for all structures within flood hazard areas when a purchaser seeks a mortgage through a federally supervised lending institution. And, as a condition of future federal disaster assistance in flood hazard areas, the Act requires flood insurance to be purchased so as to ensure that the next time a property is damaged by floods, the losses will be covered by insurance and federal disaster assistance will not be needed.

On May 24, 1977, the President of the United States issued Executive Order 11988 concerning floodplain management. Appropriate federal agencies were directed to accomplish the following tasks:

- Evaluate the potential effects of any actions the agency may take in a floodplain;
- Ensure that the agency's planning programs and budget requests reflect consideration of flood hazards and floodplain management;
- Identify any proposed action to take place in a floodplain in any new requests for appropriations from the Office of Management and Budget;
- Consider floodplain management when formulating or evaluating any water resource use appropriate to the degree of hazard involved; and
- Issue new or amend existing regulations to comply with the Executive Order.

The Executive Order was issued in furtherance of the National Environmental Policy Act of 1969, the National Flood Insuarace Act of 1968, and the Flood Disaster Protection Act of 1973.

Construction of Flood Control Facilities

Sound physical planning principles dictate that a watershed be studied in its entirety if practical solutions are to be found to water-related problems, and that plans and plan implementation programs, including the construction of flood control facilities, be formulated to deal with the interrelated problems of the watershed as a whole. A watershed, however, typically is divided in a most haphazard fashion by a complex of man-made political boundaries--county, city, village, town, and special district. When public works projects such as flood control works, covering and serving an entire watershed, are required, these artificial demarcations become extremely important because they limit the jurisdiction--the physical area--within which any one particular arm of local government may act. Because the entire Kinnickinnic River watershed is served by the Metropolitan Sewerage District of the County of Milwaukee, however, none of the above-mentioned problems apply.

As noted earlier in this chapter under the discussion on local water quality management, the Metropolitan Sewerage District of the County of Milwaukee, operating through the agency of the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee, may improve water courses through deepening, widening, or otherwise changing when in the judgment of the Commissions such improvements are necessary in order to carry off surface or drainage waters. The District, through its two Commissions, has historically engaged in a broad program of improving watercourses so as to accommodate the expected flow of storm and surface drainage waters from the areas involved. In particular, as noted in Chapter V of this report, the District has improved the drainage characteristic through major channelization, or conduit construction, of Wilson Park Creek from the confluence with the Kinnickinnic to the eastern edge of the airport; the City of Milwaukee has improved the characteristics of Lyons Park Creek from the confluence with the Kinnickinnic to Forest Home Avenue, excluding that part flowing through Lyons Park; and the District has improved the drainage characteristics of the Kinnickinnic River from S. 6th Street to Jackson Park. Future channel improvement projects include channel reconstruction from the old North Shore Railroad embankment to S. 16th Street. In addition, it has been proposed that the grass channel along Wilson Park Creek from Euclid Avenue to S. 6th Street be reconstructed and deepened.

Interbasin Water Diversion

The legal problems encountered concerning interbasin water diversion are discussed in Chapter IX of SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin. The traditional common-law riparian doctrine, which for the most part is still in effect today in Wisconsin, forbade the transfer of water between watersheds. However, states via legislative action can and have created exceptions to this general doctrine. In contemplating a stream diversion two major groups of individuals may be in a position, depending upon the quantity of water involved and the duration of the diversion, to assert their private property rights against the private or municipal agencies carrying out the diversion. The first group consists of those riparians along the stream from which the diversion is made. The reasonableness of the diversion, the "taking" of private property involved, and the issue of compensation are all legal factors to be considered. The second group of individuals who may be in a position to assert legal rights are those whose lands abut the streams or lakeshore into which the diversion is made. Again, the diverter is liable to these riparians for land taken or damages caused as a consequence of the unnaturally increased flow.

Wisconsin Statutes Section 30.18 dealing with water diversions stipulates that ". . .no water shall be so diverted to the injury of public rights in the streams. . . ." The Statute also states that only "surplus water," i.e., any water of a stream which is not being beneficially used, can be diverted and such diversions can be made only for the purpose of maintaining normal stream or lake levels in other watercourses. The only apparent exception to this section applies to agricultural and irrigation purposes, for which water other than "surplus water" may be diverted but only with the consent of all of the riparians who would be injured by the diversion. To effect even these limited types of diversions, hearings would have to be held and permits issued by the Wisconsin Department of Natural Resources. The recent Wisconsin Supreme Court case of Omernik v. State stated that Section 30.18 applied to nonnavigable streams from which water was diverted as well as to navigable streams.[6] If the anticipated use of diverted water is other than for one of the categories stipulated under Section 30.18 of the Wisconsin Statutes, then the common law test of reasonableness will be invoked.

DEVELOPMENT AND OPERATION OF HARBORS

The authority to develop and operate harbors and make harbor improvements is granted to every municipality in Wisconsin having navigable waters within or adjoining its boundaries by Sections 30.30 through 30.38 of the Wisconsin Statutes. Such authority may be exercised directly by the governing body of the municipality or by a board of harbor commissioners created for that purpose, except that certain enumerated powers relating to the commercial aspects of harbor operation, such as the operation of publicly owned or leased wharf and terminal facilities, can only be exercised through a board of harbor commissioners. Boards of harbor commissioners are fiscally dependent upon the governing body of the municipality.

[6] *64 Wis 2d 6, 218 N.W. 2d 734 (1974).*

Under the statutory authority, boards of harbor commissioners are authorized to establish or improve any inner or outer harbor turning basins, slips, canals, and other waterways to construct, maintain, or repair dock walls and shore protection walls along any waterway adjoining or within the limits of the municipality; and to plan, construct, operate, and maintain docks, wharves, warehouses, piers, and related port facilities for the need of commerce and shipping, including the handling of freight and passenger traffic between the waterways of the harbor and air and land transportation terminals. Boards may acquire land, develop industrial sites, build service roads, and construct and enlarge harbor facilities. All plans for habor improvement projects, including the establishment of dock lines, must be approved by the governing body of the municipality.

A board of harbor commissioners may also serve as a regulatory and enforcement agency for the municipality with respect to such harbor-related matters as the movement of vessels, dock wall construction, and shoreline encroachment. In this respect it is important to note that boards of harbor commissioners, to promote the public health, safety, or welfare or to eliminate dilapidation, blight, or obsolescence, can determine by resolution that it is essential that dock walls or shore protection walls be improved, altered, repaired, or extended. Property owners affected by such resolution can appeal the finding and order of the board to make improvements to the courts. Should the court eventually order the work to be performed, the property owner may elect to do the work or let the municipality do the work and assess the cost of such work to the property involved.

With respect to the Kinnickinnic River watershed, it is noteworthy that the City of Milwaukee Common Council has acted to create a Board of Harbor Commissioners to exercise the authority set forth in Sections 30.30 through 30.38 of the Wisconsin Statutes. The Board is comprised of seven members who are appointed by the mayor for three-year terms and subject to confirmation by the Common Council. The Board retains its own staff to carry out its activities, but its annual budget for operation and facility construction is subject to approval of the Common Council. The Milwaukee Harbor Commission's jurisdiction in the Kinnickinnic River watershed encompasses the Kinnickinnic River to the fixed bridge across the river at W. Becher Street. City of Milwaukee jurisdiction and interest in the Kinnickinnic River portion date back to about 1870 when Chapter 107, Laws of 1870 was adopted empowering the Board of Public Works of the City of Milwaukee to establish dock lines on each side of the Kinnickinnic River. As discussed in a later section of this chapter, there is uncertainty as to the location of some dock and wharf lines as set forth in the city ordinance. The Harbor Commission is in the process of establishing modern bulkhead lines through an ordinance revision which would then be subject to review and approval by the Wisconsin Department of Natural Resources.

SPECIFIC LEGAL CONSIDERATIONS AND INVENTORY FINDINGS IN THE KINNICKINNIC RIVER WATERSHED

Inventories were conducted with respect to state water regulatory permits, state water pollution abatement orders and permits, federal water regulatory permits, floodland regulation, flood insurance eligibility, and other local water-related regulatory matters.

State Water Regulatory Permits

As noted earlier in this chapter, the Wisconsin Department of Natural Resources has broad authority under the Wisconsin Statutes to regulate the water resources of the State. An inventory was made under the Kinnickinnic River watershed study of all permits issued by the Department of Natural Resources in the Kinnickinnic River watershed with respect to water regulation.

Bulkhead Lines: Municipalities are authorized by Section 30.11 of the Wisconsin statutes to establish by ordinance bulkhead lines, subject to review and approval by the Wisconsin Department of Natural Resources. Bulkheads are required to conform as nearly as practicable to existing shores and must be found by the Department of Natural Resources to be in the public interest. Only the City of Milwaukee in the Kinnickinnic River watershed has established bulkhead lines. Chapter 8 of the City of Milwaukee code of ordinances describes the dock and wharf lines for the right and left banks of the Kinnickinnic River watershed. Five separate bulkhead lines have been established for the right bank of the Kinnickinnic River (see Table 60). These bulkhead lines are shown on Map 43. Interviews with officials of the Milwaukee Harbor Commission indicate that the description of the dock and wharf lines for the left bank is invalid due to references to location points not in current existence. The Harbor Commission is currently undertaking an ordinance revision to establish updated bulkhead lines.

Waterway Enlargement and Protection: Section 30.19 of the Wisconsin Statutes requires any person who wishes to establish artificial waterways, canals, channels, ditches, lagoons, ponds, lakes, or other waterways to first secure a permit from the Wisconsin Department of Natural Resources. Permits are also required to connect any natural or artificially constructed waterway with an existing body of navigable water. In addition, Section 30.195 requires permits for straightening or changing in any other way the course of navigable streams. Section 30.19 does not apply to navigable waters located in counties having a population of 500,000 or more and Section 30.195 excludes county or municipal lands located in counties having a population of 500,000 or more. Section 59.96(6) grants a metropolitan sewerage commission located in a county having 500,000 or more population the authority to improve any watercourse within the metropolitan sewerage district. Projects may include deepening, widening, or otherwise changing the navigable body of water where it is deemed to be necessary to carry off surface or drainage waters. Because the Kinnickinnic River watershed lies within Milwaukee County, jurisdiction over that watershed vis-a-vis improvements to that watershed is exercised by the Milwaukee-Metropolitan Sewerage Commissions.

Other Water Regulatory Permits: In a search of the records of the Wisconsin Department of Natural Resources, no permits were found for the Kinnickinnic River watershed for the following types of water-related activities: placement of structures and deposits in navigable waters (Wisconsin Statutes Section 30.12); placement of pierhead lines (Wisconsin Statutes Section 30.13); water diversion from lakes and streams (Wisconsin Statutes Section 30.18); dredging (Wisconsin Statutes Sections 30.20 and 30.205); dam and bridge construction, operation, and maintenance (Wisconsin Statutes Chapter 31); and the high installation Capacity wells (Wisconsin Statutes Section 144.025 (2)(e).

State Water Pollution Abatement Orders and Permits

An inventory was made of all effluent discharge permits and of all outstanding pollution abatement orders in the Kinnickinnic River watershed. The following section presents the results of that inventory.

Effluent Discharge Permits: As noted earlier in this chapter, a new Wisconsin pollution discharge elimination system permit structure has been established by the Wisconsin Department of Natural Resources pursuant to statutory authorization contained in Chapter 147 of the Wisconsin Statutes. A permit is required for all industrial and municipal waste discharges. The inventory revealed that to date (1977) a total of 30 industrial waste discharge permits covering 60 discharge outfalls have been applied for and/or issued in the Kinnickinnic River watershed and to date (1977) a total of nine municipal waste discharge permits covering 50 discharge points have been applied for and/or issued. Of the industrial discharge outfalls, 48 involved the discharge of cooling water. Pertinent characteristics pertaining to each of these permits are set forth in Tables 61 and 62, respectively.

Pollution Abatement Orders: In addition to the inventory of effluent discharge permits, an inventory was made to determine if outstanding pollution abatement orders in the Kinnickinnic River watershed existed. It was determined that no outstanding pollution abatement orders existed.

Federal Water Regulatory Permits

The U.S. Department of the Army, Corps of Engineers requires permits for work or structures in navigable waters of the U.S., waste outfalls in navigable waters, the discharge of dredged or fill materials into navigable waters, and the transportation of dredged material for the purpose of dumping into ocean waters. Federal laws prohibit such activities unless the activity is authorized by a Department of the Army permit. An inventory was made under the Kinnickinnic River watershed of all permits issued by the Department in the Kinnickinnic River watershed with respect to water regulation.

Table 60

BULKHEAD LINES IN THE KINNICKINNIC RIVER WATERSHED
DESCRIBED IN THE CITY OF MILWAUKEE ORDINANCE SECTION 8-4

Civil Division	Watercourse	Location				Length (feet)
		River Mile		Place Name		
		From	To	From	To	
City of Milwaukee	Kinnickinnic River, right bank	1.67	1.43	W. Becher Street	S. 1st Street	1,134
City of Milwaukee	Kinnickinnic River, right bank	1.43	1.28	S. 1st Street	S. Kinnickinnic Avenue	771
City of Milwaukee	Kinnickinnic River, right bank	1.28	0.85	S. Kinnickinnic Avenue	Chicago & North Western Railway	2,346
City of Milwaukee	Kinnickinnic River, right bank	0.85	0.58	Chicago & North Western Railway	Town line	1,745
City of Milwaukee	Kinnickinnic River, right bank	0.58	0.0	Town line	Harbor Entrance	3,016

Source: Chapter 8 of the City of Milwaukee Code of Ordinances and SEWRPC.

Permits for Placing Dredge or Fill Materials in Navigable Waters: Section 404 of the Federal Water Pollution Control Act, as amended in 1972, grants authority to the Corps of Engineers to establish a permit system for the discharge of dredged or fill material into navigable waters, including adjacent wetlands. Certification from the appropriate water pollution control authority that applicable effluent limitations and water quality standards will be met must be obtained in accordance with this Act before the permit can be issued. On July 19, 1977, the Corps published final regulations to carry out this new responsibility. As of July 1977, no permits for the discharge of dredged or fill material into the Kinnickinnic River watershed have been issued under Section 404. However, prior to the enactment of the Federal Water Pollution Control Act, numerous permits were granted by the Corps of Engineers for the disposal of dredged materials into authorized dumping grounds in Lake Michigan. These permits are shown in Table 63.

Waste Outfall Permits: Waste Outfall permits are required by the Corps of Engineers because of the potential impact of such waste discharge structures on anchorage and navigation. These permits for the watershed are summarized in Table 63.

Dredging Permits: Activities requiring a Corps of Engineers permit include excavation and commercial sand and gravel dredging. The dredging permits issued in the watershed are shown in Table 63.

Harbor Structure Permits: A Corps of Engineers permit is required for work or the placing of structures in navigable waters including the placing of retaining walls, and the placing of cables and tunnels under the water. Table 63 shows harbor structure permits issued for the watershed.

Floodland Regulation and Flood Insurance Eligibility

Of the six civil divisions within the Kinnickinnic watershed, only the City of Greenfield has adopted a floodplain zoning ordinance for those floodplains within the Kinnickinnic River watershed. Upon completion of the watershed study and consequent availability of more definite data on the extent of the 100-year recurrence interval floodplain in the watershed, it will be necessary for communities having riverine area in the watershed to take appropriate steps to more adequately protect the natural floodlands in the watershed. At the present time, every community in the watershed, with the exception of the Village of West Milwaukee, is participating in the federal flood insurance program.

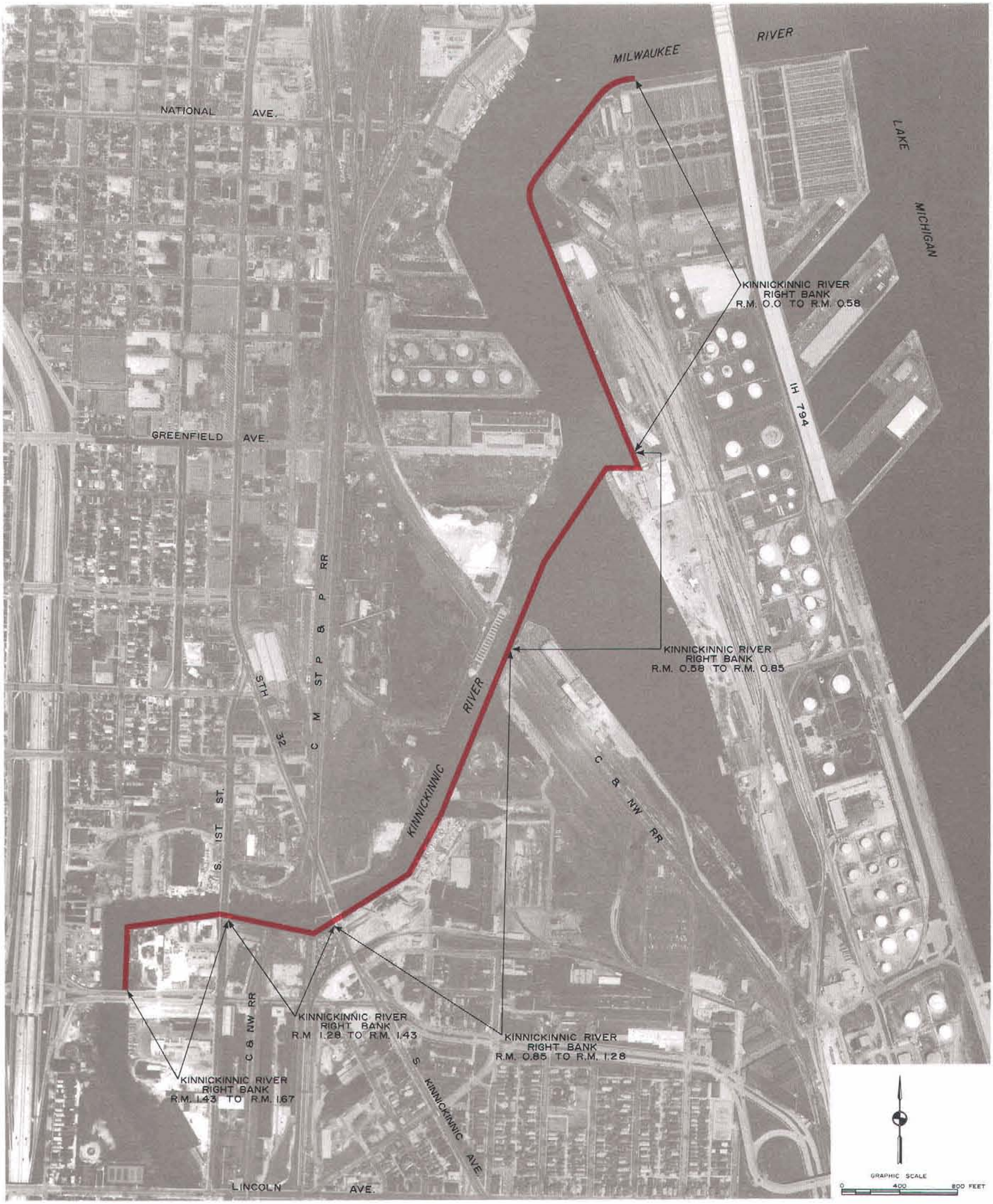
Local Water-Related Regulatory Matters

An inventory was conducted under the Kinnickinnic River watershed study of other local ordinances relating to water quality and water use. This inventory indicated that the rules of the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee prohibit the discharge of storm water and all other unpolluted drainage into the sanitary sewer system except that which is specifically designed as a part of a combined sewer system. In addition, the rules of the joint sewerage commissions require that every municipality contributing sanitary sewage to the metropolitan sewerage system adopt effective ordinances prohibiting the discharge of clear water into the sanitary sewerage system. The inventory further revealed that nearly all municipalities in the watershed have such clear water elimination ordinances in addition to ordinances prohibiting the discharge of deleterious materials and substances to the sanitary sewer system.

In addition, the inventory indicated that the Milwaukee County Board of Supervisors and the Milwaukee County Park Commission have adopted rules and regulations

Map 43

KNOWN BULKHEAD LINES IN THE KINNICKINNIC RIVER WATERSHED



Five separate bulkhead lines have been established by the City of Milwaukee for the right bank of the Kinnickinnic River. However, due to a conflict in the interpretation of the historic data describing the bulkhead lines for the left bank, the Harbor Commission is in the process of establishing updated bulkhead lines through an ordinance revision.

Source: SEWRPC.

Table 61

INDUSTRIAL WASTE DISCHARGE PERMITS ON FILE IN THE KINNICKINNIC RIVER WATERSHED: 1977

Permittee	Location		Type of Discharge[a]	Pretreatment[a] (if known)	Receiving Stream[a]	Permit Number[a]
	Address	Civil Division				
Allied Smelting Corporation	5116 W. Lincoln Avenue	City of Milwaukee	Cooling water and process water	None	Kinnickinnic River via storm sewer	WI-0038610
Badger Die Casting Corporation	201 W. Oklahoma Avenue	City of Milwaukee	Cooling water	None	Kinnickinnic River via storm sewer	WI-0041645-1
Briggs & Stratton Corporation						
Outfall 1	1706 S. 68th Street	City of West Allis	Cooling water	None	Kinnickinnic River via storm sewer	WI-0000493-1
Outfall 3	1706 S. 68th Street	City of West Allis	Cooling water	None	Kinnickinnic River via storm sewer	WI-0000493-1
Outfall 4	1706 S. 68th Street	City of West Allis	Cooling water	None	Kinnickinnic River via storm sewer	WI-0000493-1
Outfall 5	1706 S. 68th Street	City of West Allis	Cooling water	None	Kinnickinnic River via storm sewer	WI-0000493-1
Outfall 6	1706 S. 68th Street	City of West Allis	Cooling water	None	Kinnickinnic River via storm sewer	WI-0000493-1
Caterpillar Tractor Company						
Outfall 5	150 W. Holt Avenue	City of Milwaukee	Cooling water	None	Kinnickinnic River via storm sewer	WI-0026476
Outfall 6	150 W. Holt Avenue	City of Milwaukee	Process water	None	Kinnickinnic River via storm sewer	WI-0026476
Outfall 13	150 W. Holt Avenue	City of Milwaukee	Cooling water	None	Kinnickinnic River via storm sewer	WI-0026476
Outfall 16	150 W. Holt Avenue	City of Milwaukee	Process water	None	Kinnickinnic River via storm sewer	WI-0026476
Eaton Corporation						
Outfall 1	1903 S. 62nd Street	City of West Allis	Cooling water, process water, and boiler blowdown water	Oil separator	Kinnickinnic River via storm sewer then ditch	WI-0026484
Outfall 2	1903 S. 62nd Street	City of West Allis	Cooling water, process water, and boiler blowdown water	None	Kinnickinnic River via storm sewer then ditch	WI-0026484
Froedtert Malt Corporation	3830 W. Grant Street	Village of West Milwaukee	Cooling water	None	Kinnickinnic River via storm sewer	WI-0026166
General Electric Company (Dishwasher and Disposal Products Division)						
Outfall 1	2205 S. 43rd Street	Village of West Milwaukee	Cooling water	None	Kinnickinnic River via unnamed ditch and storm sewer	WI-0027499
Outfall 2	2205 S. 43rd Street	Village of West Milwaukee	Cooling water	None	Kinnickinnic River via unnamed ditch and storm sewer	WI-0027499
Outfall 3	2205 S. 43rd Street	Village of West Milwaukee	Cooling water	None	Kinnickinnic River via unnamed ditch and storm sewer	WI-0027499
Outfall 4	2205 S. 43rd Street	Village of West Milwaukee	Cooling water	None	Kinnickinnic River via unnamed ditch and storm sewer	WI-0027499
General Electric Company (Medical Systems Division)	4855 Electric Avenue	City of Milwaukee	Cooling water, cooling tower and blowdown	None	Kinnickinnic River via drainage ditch	WI-0027791
General Electric Company (West Edgerton)	315 W. Edgerton Avenue	City of Milwaukee	Cooling water	None	Kinnickinnic River via storm sewer	WI-0040070
Heil Company (Bulk Trailer Division, formerly Tank Division)						
Outfall 1	445 W. Oklahoma Avenue	City of Milwaukee	Test water and cooling water	None	Kinnickinnic River via storm sewer	WI-0001627
Outfall 2	445 W. Oklahoma Avenue	City of Milwaukee	Test water and cooling water	None	Kinnickinnic River via storm sewer	WI-0001627

Table 61 (continued)

Permittee	Location		Type of Discharge[a]	Pretreatment[a] (if known)	Receiving Stream[a]	Permit Number[a]
	Address	Civil Division				
Heil Company (Solid Waste System and Truck Equipment Division)						
Outfall 1	3000 W. Montana Avenue	City of Milwaukee	Cooling water	None	Kinnickinnic River	WI-0001619
Outfall 2	3000 W. Montana Avenue	City of Milwaukee	Cooling water	None	Kinnickinnic River	WI-0001619
Howmet Turbine Components Corporation (Crucible Steel Casting Division)						
Outfall 1	2850 S. 20th Street	City of Milwaukee	Cooling water	None	Kinnickinnic River	WI-0000167-2
Outfall 2	2850 S. 20th Street	City of Milwaukee	Cooling water and process water	None	Kinnickinnic River	WI-0000167-2
Outfall 3	2850 S. 20th Street	City of Milwaukee	Process water	Settling Pond	Kinnickinnic River	WI-0000167-2
Kurth Malting Corporation						
Outfall 1	2100 S. 43rd Street	Village of West Milwaukee	Cooling water	None	Kinnickinnic River via drainage ditch	WI-0027693
Outfall 2	2100 S 43rd Street	Village of West Milwaukee	Cooling water	None	Kinnickinnic River via drainage ditch	WI-0027693
Ladish Company						
Outfall 2	5481 S. Packard Avenue	City of Cudahy	Cooling water	N/A	Kinnickinnic River	WI-0000728
Outfall 3	5481 S. Packard Avenue	City of Cudahy	Cooling water	None	Kinnickinnic River	WI-0000728
Maynard Steel Casting Company	2856 S. 27th Street	City of Milwaukee	Cooling water and process water	Settling basin lagoon, and chemical precipitation	Kinnickinnic River	WI-0000272
Milwaukee County Park Commission Swimming Pools						
Holler Park	–	City of Milwaukee	Swimming pool overflow and emptying	None	Kinnickinnic River via storm sewer	None
Jackson Park	–	City of Milwaukee	Swimming pool overflow and emptying	None	Kinnickinnic River via storm sewer	None
Kosciuszko Park	–	City of Milwaukee	Swimming pool overflow and emptying	None	Kinnickinnic River via storm sewer	None
Wilson Park	–	City of Milwaukee	Swimming pool overflow and emptying	None	Kinnickinnic River via storm sewer	None
Milwaukee Solvay Coke Company						
Outfall 1	311 E. Greenfield Avenue	City of Milwaukee	Cooling water, process water, boiler blowdown water	None	Kinnickinnic River	WI-0026247
Outfall 2	311 E. Greenfield Avenue	City of Milwaukee	Cooling water, process water, boiler blowdown water	None	Kinnickinnic River	WI-0026247
Milwaukee Water Works—Howard Avenue Purification Plant	725 West Howard Avenue	City of Milwaukee	Filter backwash	None	Kinnickinnic River	WI-0001791
Milwaukee Spring Company	3400 South Nevada Street	City of Milwaukee	Cooling water	None	Kinnickinnic River via storm sewer	WI-0041335-1
Murphy Diesel Company						
Outfall 1	5317 W. Burnham	City of West Allis	Cooling water	None	Kinnickinnic River via storm sewer	WI-0026531
Outfall 2	5317 W. Burnham	City of West Allis	Cooling water	None	Kinnickinnic River via storm sewer	WI-0026531
Outfall 3	5317 W. Burnham	City of West Allis	Cooling water	None	Kinnickinnic River via storm sewer	WI-0026531
Outfall 4	5317 W..Burnham	City of West Allis	Cooling water	None	Kinnickinnic River via storm sewer	WI-0026531
Pelton Casteel, Inc.	148 W. Dewey Place	City of Milwaukee	Process water and cooling water	Settling basin oil separator pH adjustment	Kinnickinnic River via ditch	WI-0001481-2

Table 61 (continued)

Permittee	Location		Type of Discharge[a]	Pretreatment[a] (if known)	Receiving Stream[a]	Permit Number[a]
	Address	Civil Division				
Perfex Group-McQuay-Perfex Inc.	500 W. Oklahoma Avenue	City of Milwaukee	Cooling water, and test water	None	Kinnickinnic River via storm sewer	WI-0026395
Rexnord Inc. Nordburg Machinery Group						
Outfall 1	3703 S. Chase Avenue	City of Milwaukee	Cooling water, process water, and boiler blowdown	None	Kinnickinnic River via storm sewer	WI-0001414
Outfall 2	3703 S. Chase Avenue	City of Milwaukee	Cooling water and process water	None	Kinnickinnic River via storm sewer	WI-0001414
Outfall 3	3703 S. Chase Avenue	City of Milwaukee	Process water	None	Kinnickinnic River via storm sewer	WI-0001414
Outfall 4	3703 S. Chase Avenue	City of Milwaukee	Cooling water and process water	None	Kinnickinnic River via storm sewer	WI-0001414
Suburban South Car Wash, Inc.	160 W. Layton Avenue	City of Milwaukee	Auto Wash water	N/A	Kinnickinnic River	WI-0041467-1
Teledyne Wisconsin Motor						
Outfall 1	1910 S. 53rd Street	City of West Allis	Cooling water and process water	None	Kinnickinnic River via storm sewer	WI-0001457
Outfall 2	1910 S. 53rd Street	City of West Allis	Cooling water and process water	None	Kinnickinnic River via storm sewer	WI-0001457
Outfall 4	1910 S. 53rd Street	City of West Allis	Cooling water and process water	None	Kinnickinnic River via storm sewer	WI-0001457
Outfall 5	1910 S. 53rd Street	City of West Allis	Cooling water and process water	None	Kinnickinnic River via storm sewer	WI-0001457
Union Oil Company of California (General Mitchell Field Facility)	5300 S. Howell Avenue	City of Milwaukee	Oil contaminated storm water	Oil separator	Kinnickinnic River via storm sewer	WI-0038121
Wehr Steel Company						
Outfall 2	2100 S. 54th Street	City of West Allis	Cooling water	N/A	Kinnickinnic River	WI-0000582
Outfall 3	2100 S. 54th Street	City of West Allis	Cooling water	N/A	Kinnickinnic River	WI-0000582
Outfall 6	2100 S. 54th Street	City of West Allis	Process water	N/A	Kinnickinnic River	WI-0000582
Outfall 7	2100 S. 54th Street	City of West Allis	Cooling water	N/A	Kinnickinnic River	WI-0000582

NOTE: N/A indicates data not available.

[a] *Information taken directly from WPDES permit or permit application.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

affecting parks and parkways and the use of such areas relative to water-related recreational activities. These rules provide that, except upon the express permission of the Park Commission, no person shall fish the waters of the parks or the parkways. In addition, no person shall, without the express written permission of the Park Commission, place upon the lagoons, rivers, or any of the waters under the control of the Park Commission any float, boat, or other wood craft, nor may one land or go upon any of the islands of the lagoons or rivers nor land upon, or touch with a boat, any of the shoreline in a parkway not specifically designated as a landing place.

Under Section 30.77 of the Wisconsin Statutes, any town, village, or city may adopt local boating regulations not inconsistent with specified uniform statewide regulations set forth in Sections 30.50 through 30.71 of the Wisconsin Statutes. Such local supplementary boating regulations may pertain to the equipment, use, and operation of a boat on a navigable body of water, including rivers and streams. Such regulations must be found to be in the interest of public health, safety, or welfare. Under this basic statutory authorization, it would appear that any municipality in the Kinnickinnic River watershed could enact local boating regulations that would, for example, prohibit the operation of boats and other water craft during flooding periods. Such regulations would be related directly to public health and safety in that they would be designed to protect individuals from dangerous conditions during periods of flooding and consequent rapid water movement. The regulations could be so written as to be placed into effect when a prespecified flood stage or elevation was reached. Inventories conducted under the Kinnickinnic River watershed study did not reveal the existence of any such boating regulations in the watershed.

Table 62

MUNICIPAL WASTE DISCHARGE PERMITS IN THE KINNICKINNIC RIVER WATERSHED: JUNE 1977

Permittee	Location	Type of Discharge	Receiving Stream	Permit Number
City of Milwaukee	E. National Avenue	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	E. Walker Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	South of E. Walker Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	South of E. Washington Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	W. Becher Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	W. Becher Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	W. Cleveland Avenue	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	W. Cleveland Avenue	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	W. Lincoln Avenue	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	W. Rogers Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	S. Chase Avenue North	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	S. Kinnickinnic Avenue	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	S. Kinnickinnic Avenue	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	S. 1st Street North	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	S. 1st Street South	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	S. 2nd Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	S. 8th Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	S. 14th Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	S. 27th Street	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	E. Greenfield Avenue	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
City of Milwaukee	E. Lincoln Avenue	Combined Sewer Outfall	Kinnickinnic River	WI-0026875
Milwaukee-Metropolitan Sewer District	S. Howell Avenue at W. Grange Avenue	Relief Pumping Stations	Wilson Park Creek	WI-0024775
Milwaukee-Metropolitan Sewer District	S. 35th Street at W. Manitoba Street	Relief Pumping Stations	Kinnickinnic River	WI-0024775
Milwaukee-Metropolitan Sewer District	W. Layton Avenue at S. 1st Street	Bypass	Wilson Park Creek	WI-0024776
Milwaukee-Metropolitan Sewer District	S. 1st Street at the Kinnickinnic River	Bypass	Kinnickinnic River	WI-0024776
Milwaukee-Metropolitan Sewer District	W. Lincoln Avenue at 565 feet west of S. 43rd Street	Bypass	Kinnickinnic River	WI-0025775
Milwaukee-Metropolitan Sewer District	S. 60th Street of south side of the Kinnickinnic River	Bypass	Lyons Park Creek	WI-0024775
City of West Allis	61st Street and Mobile	Portable Pumping Station	Kinnickinnic River	WI-0030678
City of West Allis	61st Street and Mobile	Portable Pumping Station	Kinnickinnic River	WI-0030678
City of West Allis	69-70th Street and Burnham (south side)	Portable Pumping Station	Kinnickinnic River	WI-0030678
City of West Allis	69th Street and Burnham (north side)	Portable Pumping Station	Kinnickinnic River	WI-0030678
City of Milwaukee	E. Lincoln Avenue at south Burrell Street	Crossover-Combined Sewer	Kinnickinnic River	WI-0026875
City of Milwaukee	E. Lincoln Avenue 150 feet West of S. Greeley Street	Crossover-Combined Sewer	Kinnickinnic River	WI-0026875
City of Milwaukee	E. Lincoln Avenue 450 feet West of S. Greeley Street	Crossover-Combined Sewer	Kinnickinnic River	WI-0026875
City of Milwaukee	S. 5th Place at 175 feet south of W. Harrison Avenue	Crossover-Combined Sewer	Kinnickinnic River	WI-0026875
City of Milwaukee	S. 36th Street at W. Lakefield Drive	Crossover-Sanitary Sewer	Kinnickinnic River	WI-0026875
City of Milwaukee	W. Ruskin Street at S. 38th Street	Crossover-Sanitary Sewer	Kinnickinnic River	WI-0026875
City of Milwaukee	E. Armour Avenue 69 feet West of S. Austin Street	Crossover-Sanitary Sewer	Wilson Park Creek	WI-0026875
City of Milwaukee	S. Austin Street at W. Dakota Street	Crossover-Sanitary Sewer	Kinnickinnic River	WI-0026875
City of Milwaukee	E. Ohio Street and S. Quincy Avenue	Crossover-Sanitary Sewer	Kinnickinnic River	WI-0026875
City of Milwaukee	S. 43rd Street and W. Morgan Avenue	Crossover-Sanitary Sewer	Wilson Park Creek	WI-0026875
City of Milwaukee	S. 46th Street at W. Cleveland Avenue	Crossover-Sanitary Sewer	Kinnickinnic River	WI-0026875
City of Milwaukee	3253 S. 57th Street	Crossover-Sanitary Sewer	Lyons Park Creek	WI-0026875
City of Milwaukee	S. 54th Street at W. Midland Drive	Crossover-Sanitary Sewer	Lyons Park Creek	WI-0026875
City of Milwaukee	S. Howell Avenue at E. Edgerton Avenue	Crossover-Sanitary Sewer	Wilson Park Creek	WI-0026875
City of Milwaukee	S. Burrell Street at E. Van Norman Avenue	Crossover-Sanitary Sewer	Wilson Park Creek	WI-0026875
City of Milwaukee	S. 1st Place and W. Bolivar Avenue (south side)	Crossover-Sanitary Sewer	Wilson Park Creek	WI-0026875
City of Milwaukee	S. Pine Avenue and E. Cudahy Avenue	Crossover-Sanitary Sewer	Wilson Park Creek	WI-0026875
City of Milwaukee	W. Morgan at S. 57th Street	Crossover-Sanitary Sewer	Lyons Park Creek	WI-0026875
City of West Allis	S. 70th Street and W. Burnham Street (north side)	Crossover-Sanitary Sewer	Kinnickinnic River	WI-00300578
City of West Allis	S. 73rd Street and W. Burnham Street (south side)	Crossover-Sanitary Sewer	Kinnickinnic River	WI-00300578

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 63

U. S. ARMY CORPS OF ENGINEERS' PERMITS ISSUED IN THE KINNICKINNIC RIVER WATERSHED

Permittee	Date Permit Issued	Type of Project	Description of Work	River, Harbor, or Waterway Concerned
P & V Atlas Industrial Center, Inc. 647 W. Virginia Street Milwaukee, Wis.	April 28, 1959	Dredging	Dredge an area in front of property to a depth of 21 feet below low water datum, the dredged material, about 1500 cubic yards, to be deposited in the authorized dumping grounds in Lake Michigan	Kinnickinnic River
Edward E. Gillen Company 218 W. Becher Street Milwaukee, Wis.	October 21, 1960	Dredging	Dredge the approaches to the Afram Bros. Company wharf, the dredged material, approximately 2,000 cubic yards, to be deposited in the authorized dumping grounds in Lake Michigan	Kinnickinnic River, west bank
City of Milwaukee Harbor Commission City Hall Milwaukee, Wis.	March 21, 1961	Dredging	Dredge an area about 1,050 feet long by 100 feet wide to a depth of 25 feet, the dredged material about 9,000 cubic yards, to be deposited in the authorized dumping grounds in Lake Michigan	Municipal mooring basin
Edward E. Gillen Company 218 W. Becher Street Milwaukee, Wis.	March 21, 1961	Dredging	Dredge an area 45 feet wide by 160 feet long along the West side of the Kinnickinnic River and an area 30 feet wide by 500 feet long from Washington Slip to a depth of 21 feet; the dredged material, about 2,400 cubic yards, to be deposited in the authorized dumping grounds in Lake Michigan	Kinnickinnic River
Chicago & North Western Railway Company 400 W. Madison Street Chicago, Ill.	March 22, 1961	Dredging	Dredge an area 1,500 feet long by 150 feet wide to a depth of 28 feet; the dredged material, about 8,000 cubic yards, to be deposited in the authorized dumping grounds in Lake Michigan	Municipal mooring basin
City of Milwaukee Board of Harbor Commissioners City Hall Milwaukee, Wis.	February 20, 1963	Dredging	Dredge dock approaches; the dredged material, about 30,000 cubic yards, to be deposited in the authorized dumping grounds in Lake Michigan	Kinnickinnic River at the municipal open dock and in Milwaukee Harbor at the east berth and at south pier number 2
City of Milwaukee Board of Harbor Commissioners City Hall Milwaukee, Wis.	July 19, 1965	Dredging	Dredge the area in front of the municipal open dock and in the municipal mooring basin in the inner harbor to a depth of 27 feet below low water datum; the dredged material, about 57,000 cubic yards, to be deposited in authorized dumping grounds in Lake Michigan	Kinnickinnic River and Kinnickinnic basin
Chicago & North Western Railway Company 915 E. Wisconsin Avenue Milwaukee, Wis.	July 30, 1965	Dredging	Dredge to a depth of 28 feet the area alongside the grain elevator, south of the Kinnickinnic River, to the foot of Lapham Street adjacent to permittee's property; the dredged material, about 8,100 cubic yards, to be deposited in the authorized dumping grounds in Lake Michigan	Municipal mooring basin in Kinnickinnic River
Afram Bros. Company 314 N. Washington Street Dock Milwaukee, Wis.	April 25, 1967	Dredging	Dredge an area 75 feet wide by 600 feet long from Washington Slip to a depth of 25 feet; the dredged material, about 5,000 cubic yards, to be deposited in the authorized dumping grounds in Lake Michigan.	West side of Kinnickinnic River
City of Milwaukee Board of Harbor Commissioners City Hall Milwaukee, Wis.	May 16, 1967	Dredging	Dredge approximately 3,000 cubic yards of material from the municipal mooring basin; the dredged material to be deposited in the authorized dumping grounds in Lake Michigan	Kinnickinnic River

Table 63 (continued)

Permittee	Date Permit Issued	Type of Project	Description of Work	River, Harbor, or Waterway Concerned
Manitowoc Portland Cement Company 2006 S. Kinnickinnic Avenue Milwaukee, Wis.	July 12, 1967	Dredging	Dredge an area adjacent to the Manitowoc Portland Cement Dock; the dredged material, approximately 4,000 cubic yards, to be deposited in the authorized dumping grounds in Lake Michigan	Kinnickinnic River
Chicago & North Western Railway Company 400 W. Madison Street Chicago, Ill.	January 7, 1947	Harbor Structures	To construct five pile clusters and additional bracing in the drawopen protection pier of permittee's bridge across the Kinnickinnic River	Kinnickinnic River
The Chesapeake & Ohio Railroad Company Pere Marquette District General Motors Building Detroit, Mich.	October 10, 1952	Harbor Structures	To construct a 51-wood pile cluster in the Kinnickinnic River	Kinnickinnic River
The Chesapeake & Ohio Railroad Company Pere Marquette District General Motors Building Detroit, Mich.	April 14, 1953	Harbor Structures	To construct a 51-wood pile cluster in the Kinnickinnic River near the Maple Street Carferry Slip of the Chesapeake & Ohio Railroad Company at Milwaukee, Wisconsin about one and one-quarter mile from the mouth of the river	Kinnickinnic River
Great Lakes Dredge & Deck Company 228 N. La Salle Street Chicago, Ill.	October 16, 1958	Harbor Structures	To construct three temporary cofferdam wing walls and mark with lights at night	Kinnickinnic River
Edward E. Gillen Company 218 W. Becher Street Milwaukee, Wis.	January 12, 1959	Harbor Structures	To construct a temporary steel sheet piling cofferdam	Kinnickinnic River, west bank
Manitowoc Portland Cement Company Cleveland, Ohio	April 30, 1963	Harbor Structures	To reconstruct approximately 246 lineal feet of dock with concrete cap and dock wall; to construct approximately 300 lineal feet of steel sheet piling bulkhead, and to dredge an approach channel to a depth of 21 feet low water datum. The dredged material will be removed from the site	Kinnickinnic River, south bank
Sewerage Commission of the City of Milwaukee, Wis.	August 27, 1965	Harbor Structures	To construct a bulkhead consisting of 180.8 lineal feet of steel sheet piling and place fill landward of the proposed bulkhead	Kinnickinnic River
Chicago & North Western Railway Company Milwaukee, Wis.	June 14, 1967	Harbor Structures	To construct approximately 296 lineal feet of steel sheet piling bulkhead at three different locations	Municipal mooring basin (Kinnickinnic basin), southwesterly side
Allen-Bradley Company Milwaukee, Wis.	May 7, 1968	Harbor Structures	To construct approximately 203 lineal feet of steel bulkhead	Kinnickinnic River, west bank
Harbor Marine, Inc. 700 S. Water Street Milwaukee, Wis.	September 15, 1968	Harbor Structures	To construct nine timber piers, timber mooring piles, a catwalk 300 feet long and a fuel dock approximately 60 feet long	Kinnickinnic River, west side
Edward E. Gillen Company 218 W. Becher Street Milwaukee, Wis.	November 24, 1969	Harbor Structures	To reconstruct approximately 348.5 linear feet of dock on east bank just north of Becher Street	Kinnickinnic River
Chicago & North Western Railway Company Milwaukee, Wis.	October 16, 1970	Harbor Structures	To construct approximately 819 lineal feet of new steel sheet piling bulkhead on the southwesterly side of municipal mooring basin	Municipal mooring basin (Kinnickinnic basin)
Edward E. Gillen Company 218 W. Becher Street Milwaukee, Wis.	October 16, 1972	Harbor Structures	To construct a boat wall adjoining Kinnickinnic River at 1947 S. Hilbert Avenue, Milwaukee	Kinnickinnic River

Table 63 (continued)

Permittee	Date Permit Issued	Type of Project	Description of Work	River, Harbor, or Waterway Concerned
O'Connell Distributing Company 1551 S. Carferry Drive Milwaukee, Wis.	November 18, 1974	Harbor Structures	To construct two wooden pile clumps	Kinnickinnic River
City of Milwaukee Bureau of Engineers Sewer Construction Division Milwaukee, Wis.	January 6, 1959	Storm water and Wastewater Outfalls	To construct a reinforced concrete sewer outfall structure	Kinnickinnic River, left bank
Island Yachts, Inc. Milwaukee, Wis.	December 1, 1967	Storm water and Wastewater Outfalls	To construct 10-inch storm drain to Kinnickinnic River at 1431 S. Carferry Drive, Milwaukee	Kinnickinnic River
International Salt Company 4875 N. 32nd Street Milwaukee, Wis.	May 9, 1969	Storm water and Wastewater Outfalls	To install two 10-inch storm drains through existing steel bulkheads to mooring basin on Jones Island	Kinnickinnic basin, at south end
International Salt Company 4875 N. 32nd Street Milwaukee, Wis.	October 27, 1969	Storm water and Wastewater Outfalls	To construct a six-inch storm drain through the existing steel bulkhead to mooring basin on Jones Island	Kinnickinnic basin
Sewerage Commission of the City of Milwaukee Milwaukee, Wis.	March 11, 1971	Storm water and Wastewater Outfalls	To construct an 18-inch storm water discharge to replace an existing smaller size outfall through the bulkhead	Kinnickinnic River, east side
Advanced Renting & Real Estate Company 1739 S. Carferry Drive Milwaukee, Wis.	March 25, 1971	Storm water and Wastewater Outfalls	To construct an eight-inch diameter storm water drain through the existing steel bulkhead with no connections what-so-ever with any sanitary or industrial pipe line system, and waters of said drain will contain no polluting liquids	Kinnickinnic basin, east side
Advanced Renting & Real Estate Company 1739 S. Carferry Drive Milwaukee, Wis.	August 17, 1972	Storm water and Wastewater Outfalls	To construct a 10-inch diameter storm water drain through the existing steel bulkhead into municipal mooring basin	Kinnickinnic basin, east side
Milwaukee Electric Railway & Light Company	November 22, 1900	Underground cables, pipes, etc.	To dig trench and lay cables across Kinnickinnic River, at Kinnickinnic Avenue bridge	Kinnickinnic River
Fire & Police Alarm System City of Milwaukee	December 11, 1912	Underground cables, pipes, etc.	To lay three-inch galvanized iron pipe under the Kinnickinnic River at Lincoln Avenue	Kinnickinnic River
Wisconsin Telephone Company 845 N. 35th Street Milwaukee, Wis.	September 13, 1955	Underground cables, pipes, etc.	To construct a three-foot by four-foot tunnel in bedrock 73.29 feet below low water datum at S. 1st Street bridge	Kinnickinnic River
Chicago & North Western Railway Company 400 W. Madison Street Chicago, Ill.	September 28, 1955	Underground cables, pipes, etc.	To install a submarine cable under Kinnickinnic River at Chicago & North Western Railway bridge near east end of Greenfield Avenue	Kinnickinnic River
Wisconsin Electric Power Company Milwaukee, Wis.	August 9, 1956	Underground cables, pipes, etc.	To place four temporary electric cables in Kinnickinnic River at S. 1st Street	Kinnickinnic River
Wisconsin Electric Power Company Milwaukee, Wis.	February 28, 1957	Underground cables, pipes, etc.	To place nine five-inch wrought iron pipes to enclose electric power cables in Kinnickinnic River at S. 1st Street	Kinnickinnic River
City of Milwaukee Bureau of Bridges & Buildings Milwaukee, Wis.	January 20, 1958	Underground cables, pipes, etc.	To install submarine cable under and across Kinnickinnic River at S. Kinnickinnic Avenue	Kinnickinnic River
Chicago, Milwaukee, St. Paul & Pacific Railroad Company Chicago, Ill.	April 15, 1958	Underground cables, pipes, etc.	To install a submarine cable under and across Kinnickinnic River, west of S. Kinnickinnic Avenue	Kinnickinnic River
Wisconsin Electric Power Company Milwaukee, Wis.	September 23, 1958	Underground cables, pipes, etc.	To install six 6-5/8-inch diameter steel pipelines under and across Kinnickinnic River at E. Greenfield Avenue, extended	Kinnickinnic River

Source: U. S. Army Corps of Engineers and SEWRPC.

SUMMARY

This chapter has described in summary form the legal framework within which comprehensive watershed planning and plan implementation must take place in southeastern Wisconsin. The salient findings having particular importance for planning in the Kinnickinnic River watershed include the following:

Water law is not a simple or fixed body of law. It has historical roots which reach back beyond the common law. Three principal divisions of water law may be identified: riparian and public rights law, groundwater law, and diffuse surface water law. Riparian and public rights law applies to the use of surface water occurring in natural rivers, streams, lakes, and ponds. Groundwater law applies to the use of water occurring in the saturated zone below the water table. Diffuse surface water law applies to water draining over the surface of the land. The field of water law has never been in a greater or more continuous state of change than it is in today. In 1974 alone, the Wisconsin Supreme Court in landmark cases expressly overruled the historic common law doctrine with respect to both groundwater law and diffuse surface water law, finding that the historic doctrines no longer applied to modern water resource problems and conflicts.

With passage of the Federal Water Pollution Control Act amendments of 1972, the U. S. Congress set in motion a series of actions which will have many ramifications for water quality management within the Region and the Kinnickinnic River watershed. Water use objectives and supporting water quality standards now are required for all navigable waters in the United States. It is a national goal to eliminate the discharge of pollutants into the navigable waters of the United States by 1985. To meet this goal, the Act requires the enactment of specific effluent limitations for all point sources of water pollution. The Act also establishes a pollutant discharge permit system. Under such a system, permits are issued for the discharge of any pollutants with the stipulation that the discharge must meet all applicable effluent limitations and contribute toward achieving the water use objectives and supporting water quality standards.

Responsibility for water quality management in Wisconsin is centered in the Wisconsin Department of Natural Resources. The Department is given authority to prepare long-range water resources plans and to establish water use objectives and supporting water quality standards applicable to all waters of the State, to establish a pollutant discharge permit system, and to issue pollution abatement orders. New water use objectives and supporting water quality standards applicable to all the surface waters of the Kinnickinnic River watershed were adopted by the Wisconsin Natural Resources Board in 1973 and revised in 1976. With respect to the Kinnickinnic River watershed, the restricted recreational use category is applied to all surface waters of the Kinnickinnic River watershed including the mainstem of the Kinnickinnic River, Wilson Park Creek, Lyons Park Creek, S. 43rd Street Ditch, Cherokee Park Creek, Villa Mann Creek, and Holmes Avenue Creek.

In addition to the broad grant of authority to general purpose units of local government to regulate in the interests of health, safety, and welfare, Wisconsin Statutes currently provide for the creation of five types of special purpose units of government through which water pollution can be abated and water quality protected. These five types are the Metropolitan Sewerage District of the County of Milwaukee, other metropolitan sewerage districts, utility districts, joint sewerage systems, and cooperative action by contract. The Metropolitan Sewerage District of the County of Milwaukee has authority over the entire Kinnickinnic River watershed and represents for all practical purposes the single entity responsible for the conveyance and treatment of sanitary sewerage in the Kinnickinnic River watershed.

Flood control facilities may be constructed in the Kinnickinnic River watershed by the Metropolitan Sewerage District of the County of Milwaukee. The District, through its two Commissions--the Metropolitan Sewerage Commission and the Sewerage Commission of the City of Milwaukee--has historically engaged in a board program of improving watercourses in the Kinnickinnic River watershed by widening and deepening such watercourses so as to accommodate the expected flow of storm and surface drainage waters from the areas involved. Interbasin water diversions are regulated by several legal doctrines including the rights of riparian owners, state consent, Section 30.18 of the Wisconsin Statutes.

Inventories were conducted in the Kinnickinnic River watershed with respect to state water regulatory permits, state water pollution abatement orders and permits, federal water regulatory permits, floodland regulation, flood insurance eligibility, and local water-related regulatory matters. No state water regulatory permits were issued in the watershed under Chapters 30 and 31 of the Wisconsin Statutes. Updated bulkhead lines are in the process of being established through an ordinance by the Milwaukee Harbor Commission. A total of 39 state effluent discharge permits have been issued in the watershed, of which a total of 30 are industrial waste discharge permits. Under Federal Laws, the U. S. Department of the Army, Corps of Engineers has issued 41 permits for work or structures in navigable waters, waste outfalls in navigable waters, the discharge of dredged or fill materials into navigable waters, and the transportation of dredged materials for the purpose of dumping into ocean waters. Among the six civil divisions within the watershed, only the City of Greenfield has adopted a floodplain zoning ordinance for those floodplains within the watershed, and every community with the exception of the Village of West Milwaukee is presently participating in the federal flood insurance program.

Chapter X

WATERSHED DEVELOPMENT OBJECTIVES, PRINCIPLES, AND STANDARDS

INTRODUCTION

As noted in Chapter II of this report, the formulation of watershed development objectives and supporting standards is the second step in the SEWRPC seven-step watershed planning process. Soundly conceived watershed development objectives should incorporate the knowledge of many people who are informed not only about the watershed, but about the Region of which the watershed is an integral part. 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 development 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 an even broader 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 Kinnickinnic River Watershed Committee, the composition of which was discussed in Chapter I. One of the important functions of this Committee is to assist in the formulation of a set of watershed development objectives and standards which can provide a sound basis for watershed plan design, test, and evaluation.

This chapter sets forth the set of watershed development objectives and supporting principles and standards approved by the Committee. Some of these objectives, principles, and standards were originally adopted by the Commission under related regional planning programs but were deemed relevant to formulation of a comprehensive plan for the Kinnickinnic River watershed. Others were formulated as a basis for the preparation of the watershed plan.

In addition to presenting watershed development objectives, principles, and standards, this chapter discusses certain engineering design criteria and analytic procedures used in the watershed study to design alternative plan subelements, test the physical feasibility of those subelements, and make necessary economic comparisons between such subelements. The description of these criteria and procedures in this chapter is intended to document the level of detail entailed in the watershed plan preparation and thereby provide a better understanding by all concerned of the plan itself as well as of the need for refinement of some aspects of that plan prior to implementation. While the design criteria and analytic procedures as described herein were used in the preparation of the watershed plan, these criteria and procedures do not comprise standards as defined and discussed in this chapter. These criteria and procedures relate to the technical methods used in the inventory and analyses phases of the watershed study and in the plan design, test, and evaluation.

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 have, therefore, been adopted by the Commission in order to provide a common frame of reference:

1. Objective: a goal or end toward the attainment of which plans and policies are directed.
2. Principle: a fundamental, primary, or generally accepted tenet used to support objectives and prepare standards and plans.
3. Standard: a criterion used as a basis of comparison to determine the adequacy of plan proposals to attain objectives.
4. Plan: a design which seeks to achieve 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 watershed development objectives, principles, and standards.

WATERSHED DEVELOPMENT OBJECTIVES

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

The Southeastern Wisconsin Regional Planning Commission has, in its planning efforts to date, adopted, after careful review and recommendation by various advisory and coordinating committees, nine general regional development objectives, eight specific regional land use development objectives, seven specific regional transportation system development objectives, seven specific transit system development objectives, four specific water control facility development objectives, four specific sanitary sewerage system development objectives, two specific regional library development objectives, nine specific regional housing objectives, nine specific regional airport system development objectives, and seven specific regional outdoor recreation and open space development objectives. These, together with their supporting principles and standards, are set forth in previous Commission planning reports. Certain of these objectives and supporting standards are directly applicable to the Kinnickinnic River watershed planning effort, and are hereby recommended for adoption as development objectives for the Kinnickinnic River watershed.

Land Use Development Objectives

Seven of the eight specific regional land use development objectives adopted by the Commission under its regional land use-transportation planning program are directly applicable to the Kinnickinnic River watershed planning effort.[1] These are:

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

2. A spatial distribution of the various land uses which will result in a compatible arrangement of land uses.

3. A spatial distribution of the various land uses which will result in the protection and wise use of the natural resources of the Region, including its soils, inland lakes and streams, wetlands, woodlands, and wildlife.

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

5. The development and conservation of residential areas within a physical environment that is healthy, safe, convenient, and attractive.

6. The preservation, development, and redevelopment of a variety of suitable industrial and commercial sites both in terms of physical characteristics and location.

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

Sanitary Sewerage System Planning Objectives

All of the four specific sanitary sewerage system development objectives adopted by the Commission under its regional sanitary sewerage system planning effort are directly applicable to the Kinnickinnic River watershed planning effort. These are:

1. The development of sanitary sewerage systems which will effectively serve the existing regional urban development pattern and promote implementation of the regional land use plan, meeting the anticipated sanitary waste disposal demand generated by the existing and proposed land uses.

2. The development of sanitary sewerage systems so as to meet established water use objectives and supporting water quality standards.

3. The development of sanitary sewerage systems that are properly related to, and that will enhance the overall quality of, the natural and man-made environments.

4. The development of sanitary sewerage systems that are both economical and efficient, meeting all other objectives at the lowest cost possible.

Park and Open Space Objectives

Three of the seven specific park and open space objectives adopted by the Commission under its regional park

[1] *The other specific regional land use development objective is: The preservation of land areas for agricultural uses to provide for certain special types of agriculture, provide a reserve or holding zone for future needs, and ensure the preservation of those areas which provide wildlife habitat and which are essential to the shape and order of urban development. This agriculturally oriented land use objective is not applicable to the Kinnickinnic River watershed since agricultural and related land use encompass less than 1.5 percent of the watershed area in 1975.*

and open space planning program are directly applicable to the Kinnickinnic River watershed planning effort.[2] These 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.

Water Control Facility Development Objectives

Two of the four specific water control facility development objectives adopted by the Commission under its other comprehensive watershed planning programs are also applicable to the Kinnickinnic River watershed planning effort.[3] These are:

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 watershed land use plan, meeting the anticipated runoff loadings generated by the existing and proposed land uses.

2. An integrated system of land management and water quality control facilities and pollution abatement devices adequate to ensure 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 specific land use, sanitary sewerage system, 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 relative or absolute ability of alternative plan designs to meet the stated development objective. These principles and standards, as they apply to watershed planning and development, are set forth in Tables 64, 65, 66, and 67, and serve to facilitate quantitative application of the objectives during plan design, test, and evaluation.

With respect to water use objectives, the Wisconsin Department of Natural Resources currently classifies the waters of the Kinnickinnic River stream system for restricted use. The water quality standards attendant to the restricted use objective are intended only to protect the public health and to permit the maintenance of the most tolerant life forms. The water use objectives and supporting water quality standards set forth in Table 27 in Chapter VII are intended to permit use of the surface waters of the Kinnickinnic River watershed for full body contact recreation and to support a warmwater fishery and are in conformance with the national water use objectives cited in Public Law 92-500. While it may not be practicable, or even possible, to achieve these federally mandated water use objectives in the Kinnickinnic River system, it was deemed essential to use these objectives and corresponding standards as a basis in evaluating existing and potential future surface water quality problems in the Kinnickinnic River watershed. Public Law 92-500 does allow a lesser set of water use objectives and supporting standards to be established provided that

[2] *The other specific park and open space objectives are: 1) 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; 2) 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; 3) 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; and 4) 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 lake use and maintenance of good water quality. While these recreation facility-oriented park objectives are applicable to the watershed planning program, they should be applied at the local level as a joint effort by county, school districts, and local community recreation agencies.*

[3] *The other two specific water control facility development objectives are: 1) an integrated system of land management and water quality control facilities and pollution abatement devices adequate to ensure a quality of lake water necessary to achieve established water use objectives; and 2) the attainment of sound groundwater resource development and protective practices to minimize the possibility for pollution and depletion of the groundwater resources. The inland lake-oriented water control facility objective is not applicable to the Kinnickinnic River watershed planning program since there are no major lakes in the watershed. The groundwater-oriented objective is not applicable to the Kinnickinnic River watershed planning program since the study prospectus did not identify groundwater quantity or quality as being significant existing or potential problems in this watershed.*

Table 64

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

OBJECTIVE NO. 1

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

PRINCIPLE

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

STANDARDS

1. For each additional 100 dwelling units to be accommodated within the Region at each residential density, the following minimum amounts of residential land should be set aside:

No.	Residential Density Category	Net Area[a] (Acres/100 Dwelling Units)*	Gross Area[b] (Acres/100 Dwelling Units)*
1a	High-Density Urban[c]	8	13
1b	Medium-Density Urban[c]	23	32
1c	Low-Density Urban[c]	83	109
1d	Suburban[d]	167	204
1e	Rural[d]	500	588

*NOTE: In order to convert dwelling units to resident population, factors ranging from a minimum of 2.6 persons per dwelling unit in Milwaukee County to a maximum of 3.5 persons per dwelling unit in Waukesha and Ozaukee Counties were used. This represents an average of 2.9 persons per dwelling unit for the Region as a whole.

2. For each additional 1,000 persons to be accommodated within the Region, the following minimum amounts of public park and recreation land should be set aside:

No.	Public Park and Recreation Land Category[e]	Net Area[a] (Acres/1,000 Persons)	Gross Area[f] (Acres/1,000 Persons)
2a	Major	4	5
2b	Other	8	9

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

No.	Industrial Land Category	Net Area[a] (Acres/100 Employees)	Gross Area[g] (Acres/100 Employees)
3a	Major and Other	7	9

4. For each additional 100 commercial employees to be accommodated within the Region, the following minimum amounts of commercial land should be set aside:

No.	Commercial Land Category	Net Area[a] (Acres/100 Employees)	Gross Area[g] (Acres/100 Employees)
4a	Major	1	3
4b	Other	2	6

5. For each additional 1,000 persons to be accommodated within the Region, the following minimum amounts of governmental and institutional land should be set aside:

No.	Governmental and Institutional Land Category	Net Area[a] (Acres/1,000 Persons)	Gross Area[h] (Acres/1,000 Persons)
5a	Major and Other	9	12

OBJECTIVE NO. 2

A spatial distribution of the various land uses which will result in a compatible arrangement of land uses.

PRINCIPLE

The proper allocation of uses to land can avoid or minimize hazards and dangers to health, safety, and welfare and maximize amenity and convenience in terms of accessibility to supporting land uses.

STANDARDS

1. Urban high-, medium-, and low-density residential uses should be located within planning units which are served with centralized public sanitary sewerage and water supply facilities and contain, within a reasonable walking distance, necessary supporting local service uses, such as neighborhood park, local commercial, and elementary school facilities, and should have reasonable access through the appropriate component of the transportation system to employment, commercial, cultural, and governmental centers and secondary school and higher educational facilities.

2. Rural and suburban density residential uses should have reasonable access through the appropriate component of the transportation system to local service uses; employment, commercial, cultural, and governmental centers; and secondary school and higher educational facilities.

3. Industrial uses should be located to have direct access to arterial street and highway facilities and reasonable access through an appropriate component of the transportation system to residential areas and to railway, seaport, and airport facilities and should not be intermixed with commercial, residential, governmental, recreational, or institutional land uses.

4. Regional commercial uses should be located in centers of concentrated activity on only one side of an arterial street and should be afforded direct access[i] to the arterial street system.

OBJECTIVE NO. 3

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

PRINCIPLE

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

1. Soils

Principle

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

STANDARDS

1a. Sewered urban development, particularly for residential use, should not be located in areas covered by soils identified in the regional detailed operational soil survey as having severe or very severe limitations for such development.

1b. Unsewered suburban residential development should not be located in areas covered by soils identified in the regional detailed operational soil survey as having severe or very severe limitations for such development.

1c. Rural development, including agricultural and rural residential development, should not be located in areas covered by soils identified in the regional detailed operational soil survey as having severe or very severe limitations for such development.

2. Inland Lakes and Streams

Principle

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

STANDARDS

2a (1). A minimum of 25 percent of the perimeter or shoreline frontage of lakes having a surface area in excess of 50 acres should be maintained in a natural state.

2a (2). Not more than 50 percent of the length of the shoreline of inland lakes having a surface area in excess of 50 acres should be allocated to urban development, except for park and outdoor recreational uses.

2a (3). A minimum of 10 percent of the shoreline of each inland lake having a surface area in excess of 50 acres should be maintained for public uses, such as a beach area, pleasure craft marina, or park.

2b (1). It is desirable that 25 percent of the shoreline of each inland lake having a surface area less than 50 acres be maintained in either a natural state or some low-intensity public use, such as park land.

2c (1). A minimum of 25 percent of both banks of all perennial streams should be maintained in a natural state.

2c (2). Not more than 50 percent of the length of perennial streams should be allocated to urban development, except for park and outdoor recreational uses.

2d. Floodlands[j] should not be allocated to any urban development[k] which would cause or be subject to flood damage.

2e. No unauthorized structure or fill should be allowed to encroach upon and obstruct the flow of water in the perennial stream channels[l] and floodways.[m]

3. Wetlands

Principle

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

STANDARD

3a. All wetland areas[n] adjacent to streams or lakes, all wetlands within areas having special wildlife and other natural values, and all wetlands having an area in excess of 50 acres should not be allocated to any urban development except limited recreation and should not be drained or filled. Adjacent surrounding areas should be kept in open space use, such as agriculture or limited recreation.

4. Woodlands[o]

Principle

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

STANDARDS

4a. A minimum of 10 percent of the land area of each watershed[p] within the Region should be devoted to woodlands.

4b. For demonstration and educational purposes, the woodland cover within each county should include a minimum of 40 acres devoted to each major forest type: oak-hickory, northern hardwood, pine, and lowland forest. In addition, remaining examples of the native forest vegetation types representative of the presettlement vegetation should be maintained in a natural condition and be made available for research and educational use.

4c. A minimum regional aggregate of five acres of woodland per 1,000 population should be maintained for recreational pursuits.

5. Wildlife[q]

Principle

Wildlife, when provided with a suitable habitat, will supply the population with opportunities for certain scientific, educational, and recreational pursuits; comprises an integral component of the life systems which are vital to beneficial natural processes, including the control of harmful insects and other noxious pests and the promotion of plant pollination; provides a food source; offers an economic resource for the recreation industries; and serves as an indicator of environmental health.

STANDARD

5a. The most suitable habitat for wildlife—that is, the area wherein fish and game can best be fed, sheltered, and reproduced—is a natural habitat. Since the natural habitat for fish and game can best be achieved by preserving or maintaining in a wholesome state other resources such as soil, air, water, wetlands, and woodlands, the standards for each of these other resources, if met, would ensure the preservation of a suitable wildlife habitat and population.

OBJECTIVE NO. 4

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

PRINCIPLE

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

STANDARDS

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

2. The transportation system should be located and designed to provide access not only to all land presently devoted to urban development but to land proposed to be used for such urban development.

3. All land developed or proposed to be developed for urban medium-, high-, and low-density residential use should be located in areas serviceable by an existing or proposed public sanitary sewerage system and preferably within the gravity drainage area tributary to such a system.

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

5. All land developed or proposed to be developed for urban medium- and high-density residential use should be located in areas serviceable by existing or proposed primary, secondary, and tertiary mass transit facilities.

6. The transportation system should be located and designed to minimize the penetration of existing and proposed residential neighborhood units by through traffic.

7. Transportation terminal facilities, such as off-street parking, off-street truck loading, and mass transit loading facilities, should be located in close proximity to the principal land uses to which they are accessory.

OBJECTIVE NO. 5

The development and conservation of residential areas within a physical environment that is healthy, safe, convenient, and attractive.

PRINCIPLE

Residential areas developed in designed neighborhood units can assist in stabilizing community property values, preserving residential amenities, and promoting efficiency in the provision of public and community service facilities; can best provide a desirable environment for family life; and can supply the population with improved levels of safety and convenience.

STANDARDS

1. Urban high-, medium-, and low-density residential development should be located in neighborhood units which are physically self-contained within clearly defined and relatively permanent isolating boundaries, such as arterial streets and highways, major park and open space reservations, or significant natural features such as rivers, streams, or hills.

2. Urban residential neighborhood units should contain enough area to provide: housing for the population served by one elementary school and one neighborhood park; an internal street system which discourages penetration of the unit by through traffic; and all of the community and commercial facilities necessary to meet the day-to-day living requirements of the family within the immediate vicinity of its dwelling unit.

3. Suburban and rural density residential development should be located in areas where onsite soil absorption sewage disposal systems and private wells can be accommodated and access to other services and facilities can be provided through appropriate components of the transportation system at the community or regional level, thereby properly relating such development to a rural environment.

To meet the foregoing standards, land should be allocated in each urban and rural development category as follows:

Land Use Category	Percent of Area in Land Development Category					
	Urban High-Density (7.0 - 17.9 Dwelling Units/Net Residential Acre)	Urban Medium-Density (2.3 - 6.9 Dwelling Units/Net Residential Acre)	Urban Low-Density (0.7 - 2.2 Dwelling Units/Net Residential Acre)	Suburban Density (0.2 - 0.6 Dwelling Units/Net Residential Acre)	Rural Density (0.1 - 0.2 Dwelling Units/Net Residential Acre)	Agricultural (<0.2 Dwelling Units/Net Residential Acre)
Residential	66.0	71.0	76.5	82.0	85.0	6.0
Streets and Utilities	25.0	23.0	20.0	18.0	15.0	4.0
Parks and Playgrounds . .	3.5	2.5	1.5	--	--	--
Public Elementary Schools	2.5	1.5	0.5	--	--	--
Other Governmental and Institutional	1.5	1.0	1.0	--	--	--
Retail and Service	1.5	1.0	0.5	--	--	--
Nonurban	--	–	--	--	--	90.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

OBJECTIVE NO. 6

The preservation, development, and redevelopment of a variety of suitable industrial and commercial sites both in terms of physical characteristics and location.

PRINCIPLE

The production and sale of goods and services are among the principal determinants of the level of economic vitality in any society, and the important activities related to these functions require areas and locations suitable to their purpose.

STANDARDS

1. Regional industrial development should be located in planned industrial districts which meet the following standards:

   a. Minimum gross site area of 320 acres or a minimum employment of 3,500 persons.

   b. Direct access to the arterial street and highway system and access within two miles to the freeway system.

   c. Direct access to railroad facilities.

   d. Direct access to primary, secondary, and tertiary mass transit service.

   e. Access to a basic transport airport within a maximum travel time of 30 minutes and access to seaport facilities within a maximum travel time of 60 minutes.

   f. Available adequate water supply.

   g. Available adequate public sanitary sewer service.

   h. Available adequate storm water drainage facilities.

   i. Available adequate power supply.

   j. Site should be covered by soils identified in the regional soils survey as having very slight, slight, or moderate limitations for industrial development.

2. Regional commercial development, which would include activities primarily associated with the sale of shopper's goods, should be concentrated in regional commercial centers which meet the following minimum standards:

a. Accessibility to a population of between 75,000 and 150,000 persons located within either a 20-minute one-way travel period or a 10-mile radius.

b. A minimum gross site area of 60 acres.

c. At least two general sales and service department stores offering a full range of commodities and price levels.

d. Direct access to the arterial street system.

e. Direct access to the primary, secondary, and tertiary mass transit service.

f. Available adequate water supply.

g. Available adequate sanitary sewer service.

h. Available adequate storm water drainage facilities.

i. Available adequate power supply.

j. The site should be covered by soils identified in the regional soils survey as having very slight, slight, or moderate limitations for commercial development.

In addition to the above minimum standards, the following site development standards are desirable:

k. Provision of off-street parking for at least 5,000 cars.

l. Provision of adequate off-street loading facilities.

m. Provision of well-located points of ingress and egress which are controlled to prevent traffic congestion on adjacent arterial streets.

n. Provision of adequate screening to serve as a buffer between the commercial use and adjacent noncommercial uses.

o. Provision of adequate building setbacks from major streets.

3. Local industrial development should be located in planned industrial districts which meet the following standards:

a. Direct access to the arterial street and highway system.

b. Direct access to mass transit facilities.

c. Available adequate water supply.

d. Available adequate public sanitary sewer service.

e. Available adequate storm water drainage facilities.

f. Available adequate power supply.

g. Site should be covered by soils identified in the regional soils survey as having very slight, slight, or moderate limitations for industrial development.

4. Local commercial development, which includes activities primarily associated with the sale of convenience goods and services, should be contained within the residential planning units, the total area devoted to the commercial use varying with the residential density:

a. In urban low-density areas, land devoted to local commercial centers should comprise at least 0.5 percent of the total gross neighborhood area, or about 3.2 acres per square mile of gross neighborhood area.

b. In urban medium-density areas, land devoted to local commercial centers should comprise at least 1.0 percent of the total gross neighborhood area, or about 6.4 acres per square mile of gross neighborhood area.

c. In urban high-density areas, land devoted to local commercial centers should comprise at least 1.5 percent of the total gross neighborhood area, or about 9.6 acres per square mile of gross neighborhood area.

OBJECTIVE NO. 7

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

PRINCIPLE

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

STANDARDS[s]

1. Major or regional park and recreation sites should be provided within a 10-mile service radius of every dwelling unit in the Region and should have a minimum gross site area of 250 acres.

2. Local park and recreation sites should be provided within a maximum service radius of one mile of every dwelling unit in an urban area and should have a minimum gross site area of 5 acres.

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

OBJECTIVE NO. 8

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

PRINCIPLE

Agricultural areas, in addition to providing food and fiber, can supply significant wildlife habitat; contribute to maintaining an ecological balance between plants and animals; offer locations proximal to urban centers for the production of certain food commodities which may require nearby population concentrations for an efficient production-distribution relationship; support the agricultural and agricultural-related economy of the Region; and provide open spaces which give form and structure to urban development.

STANDARDS

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

2. All agricultural lands surrounding adjacent high-value scientific, educational, or recreational resources should be preserved.

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

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

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

[c] *Areas served, proposed to be served, or required to be served by public sanitary sewerage and water supply facilities require neighborhood facilities.*

[d] *Areas not served, not proposed to be served, nor required to be served by public sanitary sewerage and water supply facilities do not require neighborhood facilities.*

[e] *These categories do not include large open space areas not developed for active recreation use or school playgrounds.*

[f] *Gross public park and recreation area is defined as the net area devoted to active or intensive recreation use plus the adjacent "backup" lands and lands devoted to other supporting land uses such as roads and parking areas.*

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

[h] *Gross governmental and institutional area is defined as the net area devoted to governmental and institutional uses plus the area devoted to supporting land uses, including streets and onsite parking.*

[i] *Direct access implies adjacency or immediate proximity.*

[j] *Floodlands are herein defined as those lands inundated by a flood having a recurrence interval of 100 years where hydrologic and hydraulic engineering data are available, and as those lands inundated by the maximum flood of record where such data are not available.*

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

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

[m] *Floodway lands are herein defined as those designated portions of the floodlands that will safely convey the 100-year recurrence interval flood discharge with small, acceptable upstream and downstream stage increases.*

[n] *Wetland areas, as used herein, are defined as those lands which are partially covered by marshland flora and generally covered with shallow standing water, open lands intermittently covered with water, or lands which are wet and spongy due to a high water table or character of the soil and encompassing an area of one acre or more.*

[o] *The term woodland, as used herein, is defined as a dense, concentrated stand of trees and underbrush encompassing an area of one acre or more.*

[p] *A watershed, as used herein, is defined as a portion of the surface of the earth occupied by a surface drainage system discharging all surface water runoff to a common outlet and an area 25 square miles or larger in size.*

[q] *Includes all fish and game.*

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

[s] *It was deemed impractical to establish spatial distribution standards for open space, per se. Open spaces which are not included in the spatial distribution standards are: forest preserves and arboreta; major river valleys; lakes; zoological and botanical gardens; stadia; woodland, wetland, and wildlife areas; scientific areas; and agricultural lands whose location must be related to, and determined by, the natural resource base. It is intended that the park and open space standards set forth herein be supplemented by the more detailed park and open space standards set forth in SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin.*

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

Source: SEWRPC.

Table 65

SANITARY SEWERAGE SYSTEM PLANNING OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE KINNICKINNIC RIVER WATERSHED

OBJECTIVE NO. 1

The development of sanitary sewerage systems which will effectively serve the existing regional urban development pattern and promote implementation of the regional land use plan, meeting the anticipated sanitary waste disposal demand generated by the existing and proposed land uses.

PRINCIPLE

Sanitary sewerage systems are essential to the development and maintenance of a safe, healthy, and attractive urban environment, and the extension of existing sanitary sewerage 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. 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.

4. Lands designated as primary environmental corridors on the regional land use plan should not be served by sanitary sewers. However, 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 may be provided with sanitary sewer service. Engineering analyses relating to the sizing of sanitary sewerage facilities should assume the permanent preservation of all undeveloped primary environmental corridor lands in natural open space uses.

5. Floodlands[d] should not be served by sanitary sewers. However, 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 watershed plans may be provided with sanitary sewer service. Engineering analyses relating to the sizing of sewerage facilities should not assume ultimate development of floodlands for urban use.

6. Significant concentrations[e] 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 facilities should not assume ultimate urban development of such lands for urban use.

7. The timing of the extension of sanitary sewerage facilities should, insofar as possible, seek to promote urban development in a series of complete neighborhood planning 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.

8. The sizing of sewerage facility components should be based upon an assumption that future land use development will occur in general accordance with the land use pattern recommended in the regional land use plan.

9. 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.

OBJECTIVE NO. 2

The development of sanitary sewerage systems so as to meet established water use objectives and supporting water quality standards.

PRINCIPLE

Sewage treatment plant effluent is a major pollutant of the streams and lakes of the Region; the location, design, construction, operation, and maintenance of sewage treatment plants and the quality and quantity of the effluent of such plants have a major effect on stream and lake water quality and the ability of that water quality to support the established water uses.

STANDARDS

1. The level of treatment to be provided at each sewage treatment plant 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 will aid in achieving the water quality standards supporting each major water use objective as set forth in Table 27 of this report.

2. 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.

3. The specific standards for sewage treatment at all sewage treatment plants discharging effluent to surface waters in the Lake Michigan drainage basin shall be those established by the Federal Lake Michigan Enforcement Conference.

4. 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.

5. Interim sewage treatment plants deemed necessary to be constructed prior to implementation of the long-range plan should also 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.

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

7. 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.

8. Sewage treatment plants should be designed to perform their intended function 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.

OBJECTIVE NO. 3

The development of sanitary sewerage systems that are properly related to, and that will enhance the overall quality of, the natural and man-made environments.

PRINCIPLE

The improper location, design, construction, operation, and maintenance of sewerage system 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 0.5 foot.

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 sewage treatment plants should be properly related to the existing and proposed future urban development pattern, as reflected in the regional land use plan and 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.

OBJECTIVE NO. 4

The development of sanitary sewerage systems that are both economical and efficient, meeting all other objectives at the lowest cost possible.

PRINCIPLE

The total resources of the Region are limited, and any undue investment in sanitary sewerage systems must occur at the expense of other public and private investment; total sewerage system 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 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 sewerage systems is uneconomical, administrative and operational consolidation should be considered in order to obtain economies in manpower utilization and minimize duplication of administrative, laboratory, storage, sludge disposal, and other necessary appurtenant facilities and equipment.

3. Maximum feasible use should be made of all existing and committed sanitary sewerage facilities. Such facilities should be supplemented with additional facilities only as necessary to serve the anticipated sanitary waste demand generated by substantial implementation of the regional land use plan, while meeting pertinent water quality use objectives and standards.

4. 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 cost, or if by their superior performance lead to the achievement of water quality objectives at lesser costs.

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

6. 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.

7. Clear water inflows to the sanitary sewerage system should be eliminated and infiltration should be minimized.

8. Sanitary sewerage systems and storm water drainage systems should be designed and developed concurrently in order 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 pollution abatement and drainage benefits of the integrated design; and to minimize disruption to the natural resource base and existing urban development.

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[a] *Medium-density residential development is defined as that development having an average gross population density of 10.2 persons per acre and a net lot ranging from 6,333 to 19,819 square feet.*

[b] *High-density residential development is defined as that development having an average gross population density of 26.1 persons per acre and a net lot area per dwelling unit ranging from 6,333 to 2,430 square feet.*

[c] Low-density residential development is defined as that development having an average gross population density of 3.2 persons per acre and a net lot area per dwelling unit ranging from 19,820 to 209,090 square feet.

[d] Floodlands are defined as those lands, including the 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.

[e] Areas over 160 acres in extent.

Source: SEWRPC.

studies indicate that the national water use objectives cannot be attained because of natural background conditions or irretrievable man-induced conditions, or because the imposition of required controls would result in a substantial and widespread adverse economic and social impact.[4] In recognition of this qualification, the comparative analyses set forth in Chapters VII and XIII of this report are intended to provide the information needed to determine if the "fishable-swimmable" water use objectives are practically achieveable and, if not, to recommend establishment of a reasonable lower set of water use objectives and supporting 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 not only as aids in the development, test, and evaluation of watershed land use and water control facility plans but also in the development, test, and evaluation of local land use and community facility plans and in the development of plan implementation policies and programs as well.

Overriding Considerations

When applying the watershed development objectives, principles, and standards to the watershed 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 the objectives and standards alone, however, to assure such a 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, thereby permitting adjustment of the spatial distribution and capacities of the facilities and system to the existing and future runoff and waste loadings as derived from the adopted regional land use plan. 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 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 require resolution through compromise, such compromise being an essential part of any design effort. The degree to which the recommended Kinnickinnic River watershed plan meets the adopted objectives and standards is discussed in Chapter XIV of this report.

[4] *See U. S. Environmental Protection Agency, Guidelines for State and Areawide Water Quality Management Program Development, November 1976.*

ENGINEERING DESIGN CRITERIA AND ANALYTIC PROCEDURE

As noted earlier in this chapter, certain engineering design criteria and analytic procedures were utilized in the preparation of the watershed plan. More specifically, these criteria and procedures were used in the design of alternative plan subelements, in the test of the technical feasibility of those subelements, and in the making of the necessary economic comparisons. While these engineering criteria and procedures are widely accepted and firmly based in current engineering practice, it is, nevertheless, believed useful to document these here.

Rainfall Intensity-Duration-Frequency Relationships

If local storm water control as well as river flood control measures are to be compatible and function in a coordinated manner, plans for both must be based on consistent engineering design criteria. A fundamental criterion for both local and watershed drainage planning is the rainfall intensity-duration-frequency relationship representative of the watershed area.

The Commission has developed rainfall intensity-duration-frequency relationships based on a 64-year precipitation record at the Milwaukee National Weather Service station. These relationships are shown graphically and in equation form in Appendix B. The curves in Figure B-1 and the equations in Table B-1 are directly applicable to urban storm water control system design using the rational

Table 66

OUTDOOR RECREATION AND OPEN SPACE PLANNING OBJECTIVES, PRINCIPLES, AND STANDARDS FOR THE KINNICKINNIC RIVER WATERSHED

OBJECTIVE NO. 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.

PRINCIPLE

Attainment and maintenance of good physical and mental health is an inherent right of all residents of the Region. The provision of public general use outdoor recreation sites and related open space areas contributes to the attainment and maintenance of physical and mental health by providing opportunities to participate in a wide range of both intensive and extensive outdoor recreation activities. Moreover, an integrated park and related open space system properly related to the natural resource base, such as the existing surface water network, can generate the dual benefits of satisfying recreational demands in an appropriate setting while protecting and preserving valuable natural resource amenities. Finally, an integrated system of public general use outdoor recreation sites and related open space areas can contribute to the orderly growth of the Region by lending form and structure to urban development patterns.

A. PUBLIC GENERAL USE OUTDOOR RECREATION SITES

PRINCIPLE

Public general use outdoor recreation sites promote the maintenance of proper physical and mental health by providing opportunities to participate in such athletic recreational activities as baseball, swimming, tennis, and ice-skating—activities that facilitate the maintenance of proper physical health because of the exercise involved—as well as opportunities to participate in such less athletic activities as pleasure walking, picnicking, or just rest and reflection. These activities tend to reduce everyday tensions and anxieties and thereby help maintain proper physical and mental well being. Well-designed and properly located public general use outdoor recreation sites also provide a sense of community, bring people together for social and cultural as well as recreational activities, and thus contribute to the desirability and stability of residential neighborhoods and therefore the communities in which such facilities are provided.

STANDARDS

1. The public sector should provide general use outdoor recreation sites sufficient in size and number to meet the recreation demands of the resident population. Such sites should contain the natural resource or man-made amenities appropriate to the recreational activities to be accommodated therein and be spatially distributed in a manner which provides ready access by the resident population. To achieve this standard, the following public general use outdoor recreation site requirements should be met:

		Publicly Owned General Use Sites							
		Parks				Schools[a]			
		Minimum Per Capita Public Requirements		Maximum Service Radius (miles)[b]		Minimum Per Capita Public Requirements		Maximum Service Radius (miles)[c]	
Site Type	Size (gross acres)	(acres per 1,000 persons)[d]	Typical Facilities	Urban[e]	Rural	(acres per 1,000 persons)[f]	Typical Facilities	Urban[e]	Rural
I[g] Regional	250 or more	5.3	Camp sites, swimming beach, picnic areas, golf course, ski hill, ski touring trail, boat launch, nature study area, playfield, softball diamond, passive activity area[h]	10.0	10.0	–	--	–	--
II[i] Multicommunity	100-249	2.6	Camp sites, swimming pool or beach, picnic areas, golf course, ski hill, ski touring trail, boat launch, nature study area, playfield, softball and/or baseball diamond, passive activity area[h]	4.0[j]	10.0[j]	--	--	–	–
III[k] Community	25-99	2.2	Swimming pool or beach, picnic areas, boat launch, nature study area, playfield, softball and/or baseball diamond, tennis court, passive activity area[h]	2.0[l]	--	0.9	Playfield, baseball diamond, softball diamond, tennis court	0.5-1.0[m]	--
IV[n] Neighborhood	Less than 25	1.7	Wading pool, picnic areas, playfield, softball and/or baseball diamond, tennis court, playground, basketball goal, ice-skating rink, passive activity area[h]	0.5-1.0[o]	–	1.6	Playfield, playground, baseball diamond, softball diamond, tennis court, basketball goal	0.5-1.0[m]	--

2. Public general use outdoor recreation sites should, as much as possible, be located within the designated primary environmental corridors of the Region.

B. RECREATION-RELATED OPEN SPACE

PRINCIPLE

Effective satisfaction of recreation demands within the Region cannot be accomplished solely by providing public general use outdoor recreation sites. Certain recreational pursuits such as hiking, biking, pleasure driving, and ski touring are best provided for through a system of recreation corridors located on or adjacent to linear resource-oriented open space lands. A well-designed system of recreation corridors offered as an integral part of linear open space lands also can serve to physically connect existing and proposed public parks, thus forming a truly integrated park and recreation related open space system. Such open space lands, in addition, satisfy the human need for natural surroundings, serve to protect the natural resource base, and ensure that many scenic areas and areas of natural, cultural, or historic interest assume their proper place as form determinants for both existing and future land use patterns.

STANDARDS

The public sector should provide sufficient open space lands to accommodate a system of resource-oriented recreation corridors to meet the resident demand for extensive trail-oriented recreation activities. To fulfill these requirements the following recreation-related open space standards should be met:

1. A minimum of 0.16 linear mile of recreation related open space consisting of linear recreation corridors[p] should be provided for each 1,000 persons in the Region.

2. Recreation corridors should have a minimum length of 15 miles and a minimum width of 200 feet.

3. The maximum travel distance to recreation corridors should be five miles in urban areas and 10 miles in rural areas.

4. Resource-oriented recreation corridors should maximize use of:

   a. Primary environmental corridor as location for extensive trail-oriented recreation activities.

   b. Outdoor recreation facilities provided at existing public park sites.

   c. Existing recreation trail-type facilities within the Region.

OBJECTIVE NO. 2

The preservation of sufficient high-quality open space lands for protection of the underlying and sustaining natural resource base and enhancement of the social and economic well being and environmental quality of the Region.

PRINCIPLE

Ecological balance and natural beauty within the Region are primary determinants of the ability to provide a pleasant and habitable environment for all forms of life and to maintain the social and economic well being of the Region. Preservation of the most significant aspects of the natural resource base, that is, primary environmental corridors and prime agricultural lands, contributes to the maintenance of the ecological balance, natural beauty, and economic well being of the Region.

A. PRIMARY ENVIRONMENTAL CORRIDORS

PRINCIPLE

The primary environmental corridors are a composite of the best individual elements of the natural resource base including surface water, streams, and rivers and their associated floodlands and shorelands; woodlands, wetlands, and wildlife habitat; areas of groundwater discharge and recharge; organic soils, rugged terrain, and high relief topography; and significant geological formations and physiographic features. By protecting these elements of the natural resource base, flood damage can be reduced, soil erosion abated, water supplies protected, air cleansed, wildlife population enhanced, and continued opportunities provided for scientific, educational, and recreational pursuits.

STANDARDS

All remaining nonurban lands within the designated primary environmental corridors in the Region should be preserved in their natural state.

B. PRIME AGRICULTURAL LANDS

PRINCIPLE

Prime agricultural lands constitute the most productive farm lands in the Region and, in addition to providing food and fibre, contribute significantly to maintaining the ecological balance between plants and animals; provide locations close to urban centers for the production of certain food commodities which may require nearby population concentrations for an efficient production-distribution relationship; provide open spaces which give form and structure to urban development; and serve to maintain the natural beauty and unique cultural heritage of southeastern Wisconsin.

STANDARDS

1. All prime agricultural lands should be preserved.

2. All agricultural lands should be preserved that surround adjacent high-value scientific, educational, or recreational sites and are covered by soils rated in the regional detailed operational soil surveys as having very slight, slight, or moderate limitations for agricultural use.

OBJECTIVE NO. 3

The efficient and economical satisfaction of outdoor recreation and related open space needs meeting all other objectives at the lowest possible cost.

PRINCIPLE

The total resources of the Region are limited, and any undue investment in park and open space lands must occur at the expense of other public investment.

STANDARD

The sum total of all expenditures required to meet park demands and open space needs should be minimized.

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[a] *In urban areas the facilities commonly located in Type III or Type IV school outdoor recreation areas often provide a substitute for facilities usually located in parks by providing opportunities for participation in intensive nonresource-oriented activities.*

[b] *The identification of a maximum service radius for each park type is intended to provide another guideline to assist in the determination of park requirements and to assure that each resident of the Region has ready access to the variety of outdoor recreation facilities commonly located in parks.*

[c] *The identification of a maximum service radius for each school site is intended to assist in the determination of outdoor recreation facilities requirements and to assure that each urban resident has ready access to the types of facilities commonly located in school recreation areas.*

[d] *For Type I and Type II parks, which generally provide facilities for resource-oriented outdoor recreation activities for the total population of the Region, the minimum per capita acreage requirements apply to the total resident population of the Region. For Type III and Type IV sites, which generally provide facilities for intensive nonresource-oriented outdoor recreation activities primarily in urban areas, the minimum per capita acreage requirements apply to the resident population of the Region residing in urban areas.*

[e] *Urban areas are defined as areas containing a closely spaced network of minor streets which include concentrations of residential, commercial, industrial, governmental, or institutional land uses having a minimum total area of 160 acres and a minimum population of 500 persons. Such areas usually are incorporated and are served by sanitary sewerage systems. These areas have been further classified into the following densities: low-density urban areas or areas with 0.70 to 2.29 dwelling units per net residential acre, medium-density urban areas or areas with 2.30 to 6.99 dwelling units per net residential acre, and high-density urban areas or areas with 7.00 to 17.99 dwelling units per net residential acre.*

[f] *For public school sites, which generally provide facilities for intensive nonresource-oriented outdoor recreation activities, the minimum per capita acreage requirements apply to the resident population of the Region residing in urban areas.*

[g] *Type I sites are defined as large outdoor recreation sites having a multicounty service area. Such sites rely heavily for their recreational value and character on natural resource amenities. Type I parks provide opportunities for participation in a wide variety of resource-oriented outdoor recreation pursuits. There were three publicly owned nonschool Type I parks acquired and developed for outdoor recreation use in Ozaukee County in 1977. The combined acreage contained within these sites was 1,152 acres.*

[h] *A passive activity area is defined as an area within an outdoor recreation site which provides an opportunity for such less athletic recreational pursuits as pleasure walking, rest and relaxation, and informal picnicking. Such areas generally are located in all parks or in urban open space sites, and usually consist of a landscaped area with mowed lawn, shade trees, and benches.*

[i] *Type II sites are defined as intermediate size sites having a countywide or multicommunity service area. Like Type I sites, such sites rely for their recreational value and character on natural resource amenities. Type II parks, however, usually provide a smaller variety of recreation facilities and have smaller areas devoted to any given activity. There were no existing publicly owned nonschool Type II parks in Ozaukee County in 1977.*

[j] *In general, each resident of the Region should reside within 10 miles of a Type I or Type II park. It should be noted, however, that within urban areas having a population of 40,000 or greater, each urban resident should reside within four miles of a Type I or Type II park.*

[k] *Type III sites are defined as intermediate size sites having a multineighborhood service area. Such sites rely more on the development characteristics of the area to be served than on natural resource amenities for location. In Ozaukee County in 1977 there were six publicly owned nonschool Type III parks in urban areas, the combined acreage of which was 260 acres. There were five publicly owned Type III school sites located in urban areas, the combined total acreage with outdoor facilities of which was 171 acres.*

[l] *In urban areas the need for a Type III site is met by the presence of a Type II or Type I site. Thus, within urban areas having a population of 7,500 or greater, each urban resident should be within two miles of a Type III, II, or I park site.*

[m] *The typical service radius of school outdoor recreation facilities is governed by individual facilities within the school site and by population densities in the vicinity of the site. In high-density urban areas each urban resident should reside within 0.5 mile of the facilities commonly located in a Type III or Type IV school outdoor recreation area; in medium-density urban areas each resident should reside within 0.75 mile of facilities commonly located in Type III or Type IV school outdoor recreation areas; and in low-density urban areas each urban resident should reside within one mile of the facilities commonly located in a Type III or Type IV school outdoor recreation area.*

[n] *Type IV sites are defined as small sites which have a neighborhood as the service area. Such sites usually provide facilities for intensive nonresource-oriented outdoor recreation activities and are generally provided in urban areas. In Ozaukee County in 1977 there were 39 publicly owned nonschool Type IV parks located in urban areas, the combined acreage of which was 218 acres. In Ozaukee County in 1977 there were also 19 publicly owned Type IV school sites with outdoor recreation facilities located in urban areas, the combined total acreage of which was 157 acres. Recreation lands at the neighborhood level should most desirably be provided through a joint community-school district venture, with the facilities and recreational land area required to be provided on one site available to serve the recreation demands of both the school student and resident neighborhood population. Using the Type IV park standard of 1.7 acres per thousand residents and the school standard of 1.6 acres per thousand residents, a total of 3.3 acres per thousand residents or approximately 21 acres of recreation lands in a typical medium-density neighborhood would be provided. These acreage standards relate to lands required to provide for recreation facilities typically located in a neighborhood and are exclusive of the school building site and associated parking area and any additional natural areas which may be incorporated into the design of the park site such as drainageways and associated storm water retention basins, areas of poor soils, and floodland areas.*

[o] *The maximum service radius of Type IV parks is governed primarily by the population densities in the vicinity of the park. In high-density urban areas, each urban resident should reside within 0.5 mile of a Type IV park; in medium-density urban areas, each resident should reside within 0.75 mile of a Type IV park; and in low-density urban areas, each urban resident should reside within one mile of a Type IV park. It should be noted that the requirement for a Type IV park also is met by a Type I, II, or III park within 0.5-1.0 mile service radii in high-, medium-, and low-density urban areas, respectively. Further, it should be noted that in the application of the service radius criterion for Type IV sites, only multiuse parks five acres or greater in area should be considered as satisfying the maximum service radius requirement.*

[p] *A recreation corridor is defined as a publicly owned continuous linear expanse of land which is generally located within scenic areas or areas of natural, cultural, or historical interest and which provides opportunities for participation in trail-oriented outdoor recreation activities especially through the provision of trails designated for such activities as biking, hiking, horseback riding, nature study, and ski touring. In the Region in 1973 only Milwaukee County, with an extensive parkway system, and the Wisconsin Department of Natural Resources, with the Kettle Moraine State Forest—Southern Unit, possessed the continuous linear lands required to develop such a recreation corridor.*

Source: SEWRPC.

Table 67

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

OBJECTIVE NO. 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 watershed land use plan, meeting the anticipated runoff loadings generated by the existing and proposed land uses.

PRINCIPLE

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

STANDARDS

1. All new and replacement bridges and culverts over 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

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[a] foot in any unprotected upstream or downstream stream reaches. Increases in flood stages in excess of 0.1[a] 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.[b]

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[a] 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

An integrated system of land management and water quality control facilities and pollution abatement devices adequate to assure a quality of surface water necessary to support limited recreational uses and a marginal fish and aquatic life community.

PRINCIPLE

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

STANDARDS

1. All waters shall meet those water quality standards set forth in Table 27 of this report commensurate with the adopted water use objectives.

2. Water quality standards commensurate with adopted water use objectives are applicable at all times except during periods when streamflows are less than the average minimum seven-day low flow expected to occur on the average of once every 10 years.

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[a] *Although previous Commission watershed studies have used a standard of 0.5 foot—a standard that is interpreted by the Commission staff to mean no significant stage increase—that standard has been reduced in the Kinnickinnic River watershed report in order to be consistent with recent revisions to the Wisconsin Administrative Code. Chapter NR 116 of the Code, "Wisconsin's Floodplain Management Program," was revised by the Wisconsin Department of Natural Resources in July 1977 so as to specify a maximum computed stage increase of only 0.1 foot. This Department standard, which is numerically more stringent than the standard adopted earlier by the Commission and previously used by the Wisconsin Department of Natural Resources, may be waived by the Department only if "appropriate legal arrangements have been made with all affected local units of government and all property owners for any increased flood elevations on those properties.*

Although the Commission has adopted the numerically more stringent allowable stage increase in order to be consistent with the Wisconsin Administrative Code, the Commission staff has expressed concern with the use of 0.1 foot and, more particularly, with the accuracy of hydraulic computations that is implied by that standard. The Commission staff, in an April 18, 1977 letter to Mr. Thomas P. Fox, Chairman, Wisconsin Natural Resources Board, stated that "while it is true that the output from a computer backwater program may be stated with a precision of 0.1 foot—given the state of the art—no one can presently claim an accuracy of such work within 0.1 foot. It would appear to us that an accuracy level of 0.5 foot would be more reasonable."

[b] *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.*

Source: SEWRPC.

formula,[5] with the equations being intended primarily for incorporation into digital computer programs used in storm water control system analysis and design.

The curves in Figure B-2, which relate total rainfall to duration and frequency, are more convenient for use in basinwide hydrologic analysis. The variation of rainfall depth with tributary area and the seasonal variation of rainfall probability are shown in Figures B-3 and B-4, respectively. The relationships presented in Figure B-4 indicate that severe rainfall events as defined by their duration and recurrence interval are most likely to occur during the months of July, August, and September. All these rainfall relationships are directly applicable to the Kinnickinnic River watershed as well as to the Southeastern Wisconsin Planning Region.

Storm Sewer Design Criteria

Rainfall intensity-duration-frequency relationships and soil survey data make possible a detailed consideration of rainfall-runoff relationships in the design of storm sewers for urban areas in the Southeastern Wisconsin Region and in the watershed. Recommended values for the coefficient of runoff = C, which are based on land use, land slope, and soil type, are presented in Appendix B, Figure B-5, and Table B-2.[6] Soils which occur in the watershed and in the Southeastern Wisconsin Region are categorized in hydrologic groups according to their infiltration capabilities as presented in Appendix C of SEWRPC Planning Guide No. 6, Soils Development Guide.

Flood Discharge-Frequency Analyses

Each point on a watershed stream system has, for a given combination of floodland and nonfloodland development, a unique discharge-frequency-relationship which is normally presented graphically and relates possible annual peak discharges in cubic feet per second to the average frequency or recurrence interval in years at which the indicated discharge will be reached or exceeded. Discharge-frequency analyses of annual flood peaks were conducted under the Kinnickinnic River watershed study according to the log-Pearson Type III method of analyses as recommended by the U. S. Water Resources Council [7]

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[5] *For a detailed description of the rational method with emphasis on the use of soils, mapping land use, and hydrologic data available for the seven-county planning Region, refer to "Determination of Runoff for Urban Storm Water Drainage System Design" by K. W. Bauer, SEWRPC Technical Record, Volume 2, No. 4, April-May 1965. The procedures used to obtain equations for intensity-duration-frequency relationships are described in "Development of Equations for Intensity-Duration-Frequency Relationships" by S. G. Walesh, SEWRPC Technical Record, Volume 3, No. 5, March 1973.*

[6] *Ibid.*

[7] *United States Water Resources Council, Guidelines for Determining Flood Flow Frequency, Bulletin No. 17 of the Hydrology Committee, Washington, D. C., March 1976.*

and as specified by the Wisconsin Department of Natural Resources.[8] In the absence of suitable, long-term flow records, the discharge-frequency analysis was applied to simulated annual peak discharges at points of interest scattered throughout the watershed stream system so as to produce, in effect, watershedwide simulated discharge-frequency relationships. The simulated annual peak discharges were obtained for various combinations of floodland and nonfloodland development using a calibrated hydrologic-hydraulic model as described in Chapter VIII. The resulting discharge-frequency relationships were used to determine the magnitude of the 100-year recurrence interval regulatory flood, and were also used to compute monetary flood damages and to calculate economic benefits associated with alternative floodland management measures.

Design Flood

The design flood adopted for the Kinnickinnic River watershed is that event having a 100-year recurrence interval peak discharge under year 2000 recommended watershed land use and floodland development conditions. This discharge was determined for locations distributed throughout the watershed stream system and was used to delineate the 100-year recurrence interval floodlands, which in turn served as the basis for development and testing of alternative plans and selections of the recommended plan. For example, the 100-year recurrence interval flood hazard line was used to define those structures included in the synthesis of annual flood damages.

The selection of the design flood should be dictated by careful consideration of factors such as available hydrologic data, watershed flood characteristics, and costs attributable to flooding relative to benefits accruing to various floodplain management alternatives, but in the final analysis, it is as much a matter of public policy as it is of engineering practice and economic analysis. Sound engineering practice, however, dictates that the flood used to delineate floodlands for land use regulation purposes have a specific recurrence interval so that economic analyses of the costs and benefits of alternative flood control plans can be made, and the advantages and disadvantages of various levels and combinations of police power regulations, public acquisition, and public construction for flood damage abatement and prevention can be analyzed on a comparable basis.

The Commission has selected the 100-year recurrence interval flood as the design flood for all of its watershed planning efforts for the following reasons:

1. A 100-year recurrence interval flood approximates, with respect to the amount of land inundated, the largest known floods that have actually occurred in the Region since its settlement by Europeans, although not all streams within the Region have experienced floods as large as the 100-year recurrence interval flood. For example, the largest flood of record for the Menomonee River watershed as recorded near the watershed outlet at Wauwatosa was estimated to have had a recurrence interval of approximately 100 years; the two largest floods of record for the Milwaukee River watershed as measured near the watershed outlet at Milwaukee were estimated to have had a recurrence interval of 77 years; the largest flood of record for the Fox River watershed, as observed near the watershed outlet at Wilmot near the Wisconsin-Illinois border, was estimated to have had a recurrence interval of 37 years; and the largest flood of record for the Root River watershed as determined in Racine at the watershed outlet was estimated to have had a recurrence interval of 100 years. For regulatory purposes, the use of a flood event that is similar in terms of peak flood stages and corresponding area of inundation to the most severe flood which has actually occurred within the Region provides a means by which engineers, planners, and community leaders can meaningfully relate the seriousness of the flood problem to the public, and thereby obtain understanding of the need for floodland management.

2. The 100-year recurrence interval flood is judged to be a reasonably conservative choice when viewed in the context of the full range of possible regulatory flood events which could be used. A primary function of the regulatory flood is to define, by means of a floodplain and associated floodway, those riverine areas in which urbanization should be prohibited or strictly controlled. The regulatory flood should be at least as severe as the 10-year recurrence interval flood, since it would not be in the best interest of either the public in general or potential riverine property owners in particular to allow or encourage urban development in areas that are subject to inundation as frequently or more frequently than an average of once every 10 years. This is particularly true where the flooding may endanger the health or safety of floodplain inhabitants and require that costly rescue, cleanup, and repair work be undertaken by local units of government.

   The inadequacy of the 10-year flood event as the regulatory flood thus requires selection of a more severe event, such as the recurrence interval floods of 25, 50, and 100 years. Hydrologic and hydraulic analyses completed as part of comprehensive Commission watershed studies indicate that the streams and rivers of southeastern Wisconsin generally exhibit relatively small incremental differences in stage and areas of inundation as floods increase in severity from the 10- to the 100-year event. Flood discharges in this range exceed channel capacity so that the river occupies and flows on its floodplain.

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[8] *"Wisconsin's Floodplain Management Program," Wisconsin Administrative Code, Chapter NR 116, Register, July 1977, No. 259.*

Because of the large cross-sectional area of flow made available on the relatively broad floodplains characteristic of the streams of the planning Region, a situation is produced in which large increments of additional discharge are accommodated with relatively small stage increases. Therefore, the stage of a 100-year recurrence interval flood will normally be only a few feet above the 10-year stages, although discharges of the former are usually almost twice that of the latter. The differences between the stages of a 25- or 50-year recurrence interval flood event and the 100-year recurrence interval flood event are generally even smaller. The floodplains, moreover, are normally bounded on the outer fringes by relatively steep slopes leading to higher topography, and as a consequence of this lateral confinement, the area subject to inundation increases relatively little as floods increase in severity from the 10- to 100-year events.

Use of the 100-year recurrence interval flood event thus provides a greatly reduced probability of occurrence, yet entails only a relatively small incremental increase in stage and, therefore, in the area subject to regulation. Thus, the 100-year event, as opposed to the 25- or 50-year event, is recommended as the basis for floodland regulation.

3. Use of the 100-year recurrence interval flood for floodplain management purposes was recommended for use by federal agencies in 1969 [9] by the U. S. Water Resources Council, an organization composed of representatives of federal offices and agencies concerned with water resources problems. This U. S. Water Resource Council recommendation, in effect, formalizes a generally accepted practice followed by federal agencies, such as the U. S. Army Corps of Engineers and the U. S. Soil Conservation Service, of using the 100-year recurrence interval flood as the design flood for water resources planning purposes. The Commission's use of the 100-year recurrence interval flood as the design flood results in watershed plans that have floodland management recommendations which are in accord with federal water resources planning procedures. This is particularly important with respect to any plan recommendations that may require federal participation for implementation.

4. Subsequent to the Commission recommendation that the 100-year recurrence interval flood serve as the basis for floodland regulations in southeastern Wisconsin, the Wisconsin Legislature, in August 1966, enacted the State Water Resources Act. The Act authorizes and directs the Wisconsin Department of Natural Resources to carry out a statewide program leading to the adoption of reasonable and effective floodland regulations by all counties, cities, and villages. One of the requirements of the resulting state floodplain management program is that floodland regulations be based on the regional flood, which is defined by the Department as being the 100-year recurrence interval flood. Therefore, the use of the 100-year flood for land use regulatory purposes as orginally recommended by the Commission is now mandatory within Wisconsin.

Digital Computer Utilization

Extensive use was made of digital computers in the conduct of the Kinnickinnic River watershed study as in other Commission watershed studies. Computer utilization minimized manual data handling and facilitated the incorporation of more sophisticated analytical procedures into the planning process. The Commission staff was thus able to direct more of its efforts toward, and to be more effective in, the study design, objective formulation, analysis and forecast, plan synthesis, and plan testing phases of the watershed planning program. More specifically, extensive use was made of the digital computer in the Kinnickinnic River watershed planning program for the three reasons discussed below.

First, use of the digital computer encourages, and in fact demands, a systematic disciplined approach to the planning process on behalf of participating engineers, planners, and technicians. Because successful computer operation requires that all desired operations be completely and correctly programmed, each watershed study work element intended for computer utilization must be examined in its entirety and designed in detail prior to actually acquiring, collating, and preparing input data and writing computer instructions.

Second, the digital computer can store large amounts of alphanumerical information, facilitate the retrieval and processing of such information, and accurately perform large numbers of repetitive computations in a very small fraction of the time required for manual calculation. Because of the staff time requirements and associated monetary costs, it would, for example, have been impossible to manually perform the computations executed by the digital computer hydrologic-hydraulic-water quality model used in the watershed study. The principal value of the digital computer's speed, therefore, is that it facilitates the application of state-of-the-art analysis methods on a watershedwide basis.

Third, computer usage results in the basic watershed study data and information being stored in a form that is readily manageable and usable during plan implementation. Computer files and computer program input data are, relative to other forms of data and information storage, readily amended or revised as new or more accurate data become available subsequent to completion of the watershed plan.

[9] *U. S. Water Resources Council, Proposed Flood Hazard Evaluation Guidelines for Federal Executive Agencies, Washington, D. C., September 1969.*

Economic Evaluation

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

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

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

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

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

Benefit-Cost Analysis

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

In order to assure that public funds are committed and expended wisely, alternative plan elements should be formulated, developed, and analyzed, and the recommended plan should be selected from those alternatives which meet watershed development objectives only after consideration of the following hierarchy of economic considerations:

1. Benefits, including intangible values, must exceed costs in order for a project to be economically justified.

2. An excess of benefits over costs, however, is not a sufficient criterion on which to base a watershed plan recommendation; and, therefore, among those alternative plan elements exhibiting benefit-cost ratios greater than one, the alternative with the greatest difference between benefits and costs, not the greatest benefit-cost ratio, will produce the largest absolute return on the investment.

3. Maximization of benefits minus costs is not, however, in and of itself a sufficient criterion for selection among alternative plan elements, since the amount of public funds available or potentially available, and public attitudes toward and understanding of a particular plan element, must be considered in selecting among various plan elements. It may be politically and financially impossible to obtain support and funding for a plan element even though it, among all the available alternatives, would produce the greatest return on the investment.

Implementation of a comprehensive plan for the Kinnickinnic River watershed could include benefits of floodland management; recreation; efficient community utilities and facilities; enhancement of property values; and preservation of recreational, scenic, cultural, and ecological values. Costs which could be incurred in implementation of watershed plans include construction and land acquisition costs, and income foregone as a result of regulation of land use.

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

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

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

Use of an interest rate automatically incorporates consideration of the ever-present possibility of private investment as an alternative. Low interest rates tend to yield favorable benefit-cost analyses, whereas high interest rates tend to render projects uneconomical, particularly those alternatives that involve immediate capital expenditures to achieve a stream of benefits extended over a long period of time.

To be economical, a project should return to the public a benefit approximating that which might be obtained through private investment. Money invested privately is currently expected to return generally from 4 to 8 percent interest after taxes. Since implementation of the watershed plan should return benefits to the public similar to those which could be attained through private investment, an interest rate of 6 percent is recommended for use in the economic evaluation of plans. The 6 percent interest rate also approximates the current cost of money for public works projects.

The benefit-cost analysis for a project must be based on a specified number of years, usually equal to the physical or economic life of the project. Most of the improvements proposed in the Kinnickinnic River watershed plan, however, will continue to furnish benefits for an indefinite time, particularly in the land use control and park reservation elements. In indefinite situations such as this, government agencies have generally selected 50 years for the period of economic analysis and this period is recommended for the Kinnickinnic River watershed alternative plans.

Using a 6 percent interest, benefits accrued after 50 years, when discounted to the present, are very small. For example, given a uniform annual benefit of one dollar, the total present worth of the entire 50-year period, from year 51 through year 100, would be only one dollar. The total present worth of the benefits for the 50-year period, from year one through 50, however, would be almost $16.

A final reason for using a 50-year period as a basis for benefit-cost analysis is the inability to anticipate the social, economic, and technological changes which may occur in the more distant future and which may influence project benefits and costs.

Project Benefits: The benefits from a project can be classified as tangible, or measurable in monetary terms, and intangible. Intangible benefits either are of such a nature that no monetary value can be assigned to them, or are so obscure that calculation of the monetary value is impracticable. In the Kinnickinnic River watershed planning studies, tangible benefits might include flood damage reduction, enhancement of property values, and those parts of recreation and water quality management to which a monetary value can be assigned. Intangible benefits include aesthetic factors deriving from natural beauty and a pleasant environment. Intangibles also include benefits, such as improved efficiencies in community utilities and facilities, that have monetary values but which are impracticable to calculate. The exact procedures used to compute benefits commensurate with alternative plans are discussed later in this report in conjunction with the description of alternative plan synthesis and testing.

Project Costs: The direct costs of water resource development include the construction costs of physical elements of the plan; the cost of acquiring land; plus expenditures for engineering, legal work, and project administration. Costs of structural facilities were calculated using 1977 unit prices, which reflect the magnitude of work, the location in the urban region, and regional labor costs. The cost of land acquisition was based on 1977 market prices for land in the Kinnickinnic River watershed.

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

On the other hand, and as described above, an economic analysis determines if the project benefits to whomsoever they accrue exceed the costs to whomsoever they accrue. Since one of the legitimate objectives of government is to promote the general welfare, it is necessary to consider the effect of a proposed project on all of the people who may be affected, not just on the income and expenditures of a particular agency. The economic valuation of the benefits and costs may differ considerably from the actual income and expenditures of a government agency.

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

SUMMARY

The process of formulating objectives and standards to be used in plan design and evaluation is a difficult but necessary part of the planning process. It is readily conceded that regional and watershed development plans must advance development proposals which are physically feasible, economically sound, aesthetically pleasing, and conducive to the promotion of public health and safety. Agreement on development objectives beyond such generalities, however, becomes more difficult to achieve because the definition of specific development objectives and supporting standards inevitably involves value judgments. Nevertheless, it is essential to state such objectives for watershed planning purposes and to quantify them insofar as possible through standards in order to provide the framework within which watershed plans can be prepared.

Moreover, so that the watershed plans will form an integral part of the overall long-range plans for the physical development of the Region, the watershed development objectives must be compatible with, and dependent upon, regional development objectives while meeting the primary watershed development objectives. Therefore, the watershed development objectives and supporting principles and standards set forth herein are based upon, and incorporated in, previously adopted regional development objectives, supplementing these only as required to meet the specific needs of the Kinnickinnic River watershed planning program. The adopted development objectives for the watershed plan consist essentially of seven of eight previously adopted specific regional land use planning objectives, all of the four adopted regional sanitary sewerage system planning objectives, three of the seven recently adopted regional park and open space planning objectives, and two of four water control facility objectives adopted under earlier Commission comprehensive watershed planning studies.

In addition to presenting and discussing the objectives, principles, and standards adopted for the Kinnickinnic River watershed, this chapter also presents the engineering design criteria and analytic procedures used in the watershed study. These criteria and procedures were used to synthesize a Kinnickinnic River watershed plan capable of meeting the study objectives, and were applied in the inventory and analysis of data, in the synthesis and testing of alternative plan subelements, and in the making of economic comparisons between those subelements.

The selected design criteria and analytic procedures include watershed rainfall intensity-duration-frequency relationships, recommended storm sewer design procedures, a flood discharge-frequency analysis technique, and selection of the design flood for the floodland management element of the watershed study. Digital computer utilization and economic evaluation are also discussed in this chapter inasmuch as they relate to important analytic procedures utilized in the preparation of the watershed plan.

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Chapter XI

LAND USE BASE AND PARK AND OPEN SPACE PROTECTION MEASURES

INTRODUCTION

The economic and demographic base and the existing land use pattern of the Kinnickinnic River watershed were described in Chapter III of this report. Forecasts of probable future population and economic activity levels within the watershed were set forth in Chaper IV. The resident population of the watershed was forecast to decrease from the year 1975 level of about 165,000 persons to a year 2000 level of about 160,000 persons, a decrease of about 3 percent over the plan design period. This net decrease in population reflects the effects of high rates of outmigration and declining birthrates. Employment within the watershed was forecast to increase from the year 1972 total of about 77,000 jobs to a year 2000 total of about 84,000 jobs, an increase of about 9 percent.

The Kinnickinnic River watershed is the most highly urbanized watershed studied to date by the Commission. As of 1975, the amount of land devoted to urban use within the watershed was about 24 square miles, or about 92 percent of the total area of the watershed. The forecast population of 160,000 persons in the plan design year will reflect some migratory movement into as well as within the watershed, and will thereby require the conversion of some additional land from rural to urban use within the watershed. The increases occurring in the urban land use categories will have to be satisfied primarily through the conversion of the remaining "unused" open lands within the watershed to urban use. Therefore, these open lands totaling about 2.14 square miles in 1975 may be expected to be virtually developed by the year 2000. It is extremely important that the new urban development be related sensibly to soil capabilities, to long-established utility systems, and to the watercourses and associated floodlands of the watershed. If such new urban development is not so related, the already severe developmental and environmental problems of the watershed may be expected to continue to intensify. A land use plan must, therefore, constitute a major element of any comprehensive plan for the development of the Kinnickinnic River watershed. This land use plan must provide the basis for the design of any structural water control facility plan elements concerning flood control and pollution abatement which may be required to resolve the existing water resource-related problems of the watershed. This chapter presents a brief description of the necessary basic land use plan.

LAND USE PLANNING IN A HIGHLY URBANIZED WATERSHED

With respect to the potential for significant additional urban development, the Kinnickinnic River watershed is fundamentally different from the other four watersheds for which comprehensive plans have been prepared to date by the Commission. As noted in Chapter III of this report, only 8 percent of the watershed land surface is available for new urban land use development and, therefore, there is little potential for significant additional urban development in the Kinnickinnic River watershed. This absence of potential for significant additional urban development in the watershed does not mean, however, that land use planning is unimportant in this basin. Land use planning is important in the Kinnickinnic River watershed, but the focus of the land use concern is different from that in previously studied watersheds, which had the potential for significant additional urbanization. More specifically, land use planning in the Kinnickinnic River watershed should focus on the preservation of the positive aspects of the existing land uses and land use patterns in the watershed. Such planning should seek to enhance the urban areas of the watershed and resolve the environmental problems that detract from the overall quality of life in this urban basin.

Several of the adopted regional and watershed land use development objectives set forth in Chapter X of this report make explicit reference to preservation and enhancement of existing urbanized areas and are therefore particularly applicable to a heavily urbanized basin such as the Kinnickinnic River watershed. Objective No. 4 calls for maintenance of the spatial distribution of land uses properly related to the supporting transportation, utility, and public facility systems in order to ensure the economical provision of transportation, utility, and public facility services to urban residents. Objective No. 5 calls for the development and conservation of residential areas within a physical environment that is healthy, safe, convenient, and attractive. According to the principle supporting Objective No. 5, residential areas that are developed and designed as neighborhood units can assist in stabilizing community property values, preserving residential amenities, providing a desirable environment for family life, and supplying the resident population with improved levels of safety and convenience. Objective No. 7 calls for the preservation and provision of open space to enhance the total quality of the environment and give form and structure to urban development.

The watershed planning effort can contribute significantly to the preservation of the positive aspects of the urban areas in the watershed and to the enhancement of other urban areas in the watershed in conformance with the above objectives. This effort may be accomplished by identifying the positive features of the watershed, particularly sound residential neighborhoods that should be preserved and protected, and by recommending structural and nonstructural measures intended to mitigate flood problems and enhance surface water quality as it affects these neighborhoods, as is done in Chapters XII and XIII of this report.

LAND USE BASE

Design Methodology

A land use plan for a watershed located within an urbanizing region must be set within the framework of an areawide—or regional—land use plan. Accordingly, the watershed land use plan recommended herein is set within the context of, and reflects the concepts contained in, the regional land use plan for the year 2000. This regional land use plan is fully documented in SEWRPC Planning Report No. 25, A Regional Land Use Plan and A Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans. The regional land use development objectives which this regional land use plan is designed to meet are also set forth in SEWRPC Planning Report No. 25, Volume Two, and remain valid and attainable within the context of the more detailed watershed development plan. Therefore, these regional development objectives and the supporting principles and standards were made the basis of the watershed land use development objectives, principles, and standards set forth in Chapter X of this volume. The regional land use plan sets forth broad recommendations for areawide land use development designed to meet the social, physical, and economic needs of the Region while protecting and enhancing the natural resource base. This chapter describes the regional land use plan as it applies to the Kinnickinnic River watershed.

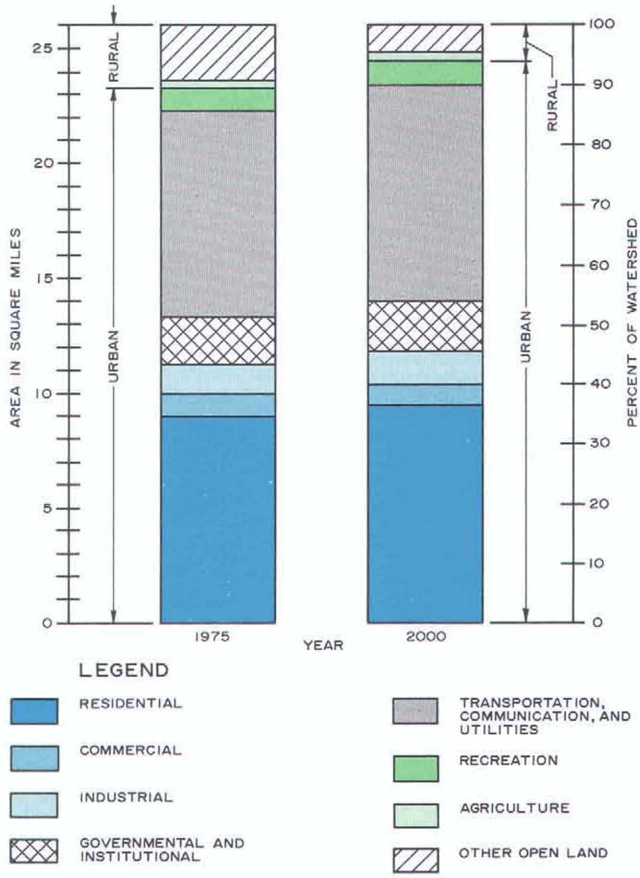
Land Use Base Description

As already noted, the regional land use plan for the year 2000 forms the recommended land use base for the Kinnickinnic River watershed plan. This recommended land use base is intended to meet the social, physical, and economic needs of the future resident population of the watershed by allocating sufficient land to each of the various major land use categories to satisfy the known and anticipated demand for each use. The land use base should meet both the demands of the urban land market and the adopted regional land use plan design standards. Under the recommended regional land use plan, the future land uses within each county of the Region have been allocated so as to meet the anticipated demand for land within each county through the plan design year 2000. To the extent possible, the proposals contained in existing community development plans and ordinances are accommodated in the land use plan. The land use plan seeks to protect and enhance the natural resource base of the Region and the watershed and allocates new urban development only to those areas of Region and watershed that are covered by soils well suited to such development. It further seeks to encourage urban development in those areas of the watershed that can be readily provided with gravity drainage sanitary sewer service and public water supply.

The land use base emphasizes continued reliance on the urban land market to determine the location, intensity, and character of future residential, commercial, and industrial development within the Region and the watershed. It does, however, propose to regulate in the public interest the effect of this market on development in order to provide for a more orderly and economical land use pattern and in order to avoid intensification of developmental and environmental problems within the Region and the watershed. This land use base is shown in graphic summary form on Map 44 and Figure 58. It is important to note that the recommended land use base would accommodate the anticipated demand for urban land uses through the conversion of about one square mile of land to urban use by the year 2000.

Figure 58

EXISTING AND PLANNED LAND USE IN THE KINNICKINNIC RIVER WATERSHED 1975 AND 2000

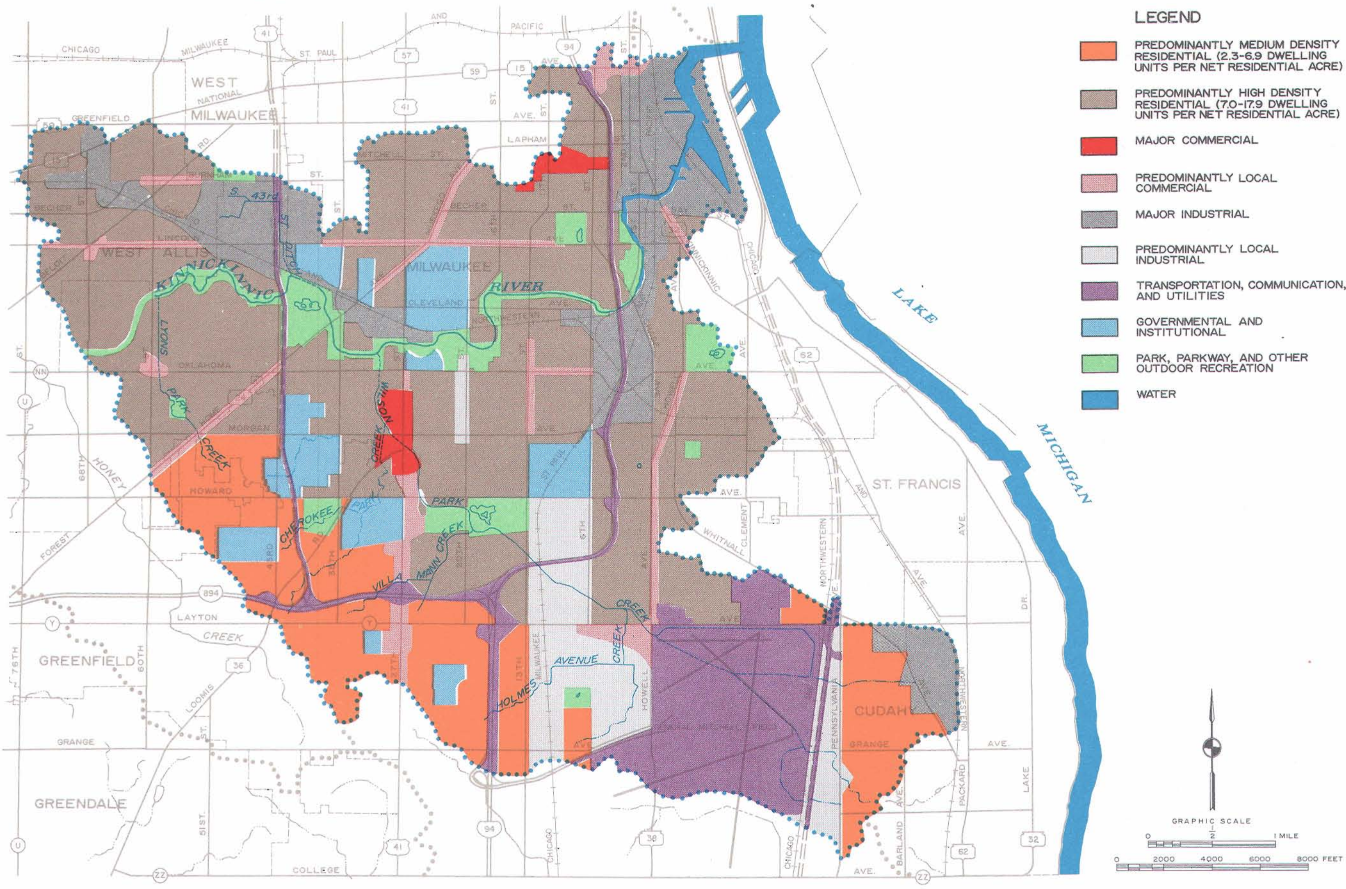


Source: SEWRPC.

Residential Land Use: As indicated in Table 68, about 92 percent of the total area of the watershed is presently devoted to urban use. About 0.7 square mile is proposed to be added to the existing stock of residential land in the watershed between the years 1975 and 2000. This new urban development is proposed to occur at medium population densities, with gross residential population densities ranging from about 2,900 to about 8,000 persons per square mile. Any new development would be located within essential public utility service areas, since the entire watershed is already served by public sanitary sewerage facilities and by public water supply facilities, as well as by electric power and gas facilities.

Map 44

RECOMMENDED LAND USE PLAN FOR THE KINNICKINNIC RIVER WATERSHED: 2000



The regional land use plan for the year 2000 forms the recommended land use base for the Kinnickinnic River watershed. This land use base would meet the social, physical, and economic needs of the future watershed population by allocating sufficient land to each of the various major land use categories to satisfy the known and anticipated demand for each use. About 24 square miles, or 92 percent of the watershed, are presently devoted to urban land uses. The recommended land use base would accommodate the anticipated demand for urban land uses through conversion of about one square mile of land to urban use by the year 2000.

Source: SEWRPC.

Retail and Service Land Use: In addition to scattered neighborhood, community, and highway-oriented commercial areas, two regional commercial centers exist wholly or partly within the watershed—Mitchell Street and Southgate-Point Loomis, both in the City of Milwaukee. Consequently, commercial land development within the watershed is proposed to be minimal and no new major commercial centers are proposed.

Industrial Land Use: The number of industrial employment opportunities—jobs in manufacturing, wholesaling, and construction industries—within the watershed are expected to increase from about 40,000 jobs in 1972 to about 41,000 jobs in the year 2000, an increase of about 3 percent. Industrial activity in the watershed is proposed to continue to be concentrated in the five existing major industrial centers located wholly or partly within the watershed: the Milwaukee Harbor area and Milwaukee South, both within the City of Milwaukee, and West Milwaukee, West Allis East, and Cudahy. No new major industrial centers would be provided in the watershed. A small increase in industrial land use of about 0.05 square mile, however, is provided in the watershed land use plan (an increase of about 3 percent) over the existing 1.50 square miles of land in manufacturing, wholesale, and storage use within the watershed.

Transportation, Communication, and Utility Facility Land Use: Transportation and related activities are inherently large consumers of land and represent the most extensive type of urban development in the watershed. As indicated in Table 68, transportation, communication, and utility facility land uses in the watershed may be expected to increase by about 0.28 square mile, or about 3 percent, over the plan design period. The Commission's recommended regional freeway system plan[1] within the Kinnickinnic River watershed recom-

[1] *See SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans, May 1978.*

Table 68

EXISTING AND PLANNED LAND USE IN THE KINNICKINNIC RIVER WATERSHED: 1975 AND 2000

Land Use Category	Existing 1975			Planned Increment		Total 2000		
	Square Miles	Percent of Major Category	Percent of Watershed	Square Miles	Percent Change	Square Miles	Percent of Major Category	Percent of Watershed
Urban Land Use								
Residential								
Urban High-Density	6.62	28.16	25.81	- 0.06	- 0.91	6.56	26.66	25.58
Urban Medium-Density	1.84	7.83	7.18	0.88	47.83	2.72	11.05	10.60
Suburban and Low-Density	0.46	1.95	1.79	- 0.10	- 21.74	0.36	1.46	1.40
Subtotal	8.92	37.94	34.78	0.72	8.07	9.64	39.17	37.58
Commercial	0.83	3.53	3.24	0.00[c]	0.00	0.83[c]	3.37	3.24
Industrial[a]	1.50	6.38	5.85	0.05	3.33	1.55	6.30	6.04
Governmental and Institutional	1.88	8.00	7.33	0.03	1.60	1.91	7.76	7.45
Transportation, Communication, and Utilities	9.12	38.79	35.55	0.28	3.07	9.40	38.20	36.65
Recreation	1.26	5.36	4.91	0.02	1.59	1.28	5.20	4.99
Urban Land Use Subtotal	23.51	100.00	91.66	1.10	4.68	24.61	100.00	95.95
Rural Land Use								
Agriculture	0.23	10.75	0.90	- 0.19	- 82.61	0.04	3.85	0.15
Other Open Lands	1.91	89.25	7.44	- 0.91	- 47.64	1.00	96.15	3.90
Rural Land Use Subtotal	2.14	100.00	8.34	- 1.10	- 51.40	1.04	100.00	4.05
Total	25.65[b]	--	100.00	--	--	25.65[b]	--	100.00

[a] *Includes manufacturing, wholesaling, and storage.*

[b] *This figure represents the total area of the watershed as determined by approximating the watershed boundary by U. S. Public Land Survey quarter sections and summing the quarter section totals.*

[c] *A slight increase of 2.34 acres, or 0.004 square mile, may be expected by the year 2000.*

Source: SEWRPC.

mends the completion of the Airport Spur Freeway, currently under construction; the design and construction of about one mile of an extension of the existing Stadium Freeway-South to W. Lincoln Avenue on the right-of-way already acquired for this purpose; and the design and construction of about three miles of an extension of the Lake Freeway (IH 794) to E. Layton Avenue. The completion of the Stadium Freeway-South to the Airport Freeway, and the Lake Freeway corridor in Kenosha and Racine Counties, would remain on the long-term plan, but for an indeterminate period of at least a decade.

Government and Institutional Land Use: As also indicated in Table 68, the land use plan envisions an increase of approximately 0.03 square mile for governmental and institutional land uses, an increase of about 2 percent over the plan design period.

Agricultural and Other Open Land Uses: The previously described increases in urban land uses in the watershed by the year 2000 would result in a corresponding decrease in agricultural and other rural and related open land uses. The existing stock of such land within the watershed could, therefore, be expected to decrease from 2.14 square miles in 1975 to 1.04 square miles in the year 2000, a decrease of more than 51 percent. Thus by the year 2000, less than 4 percent of the total area of the watershed would remain in agricultural and other open land uses.

RECOMMENDED REGIONAL PARK AND OPEN SPACE PLAN FOR THE KINNICKINNIC RIVER WATERSHED

Coincident with the plan preparation phase of the Kinnickinnic River watershed planning program, the Regional Planning Commission was completing work on a regional park and open space plan.[2] The park and open space plan contains recommendations for the Kinnickinnic River watershed which are related to and represent refinements of the land use plan for the watershed. The most significant recommendations of the regional park and open space plan as they apply to the Kinnickinnic River watershed are summarized below.

[2] *See SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000, November 1977.*

The regional park and open space plan is composed of two principal subelements—an open space preservation plan subelement and an outdoor recreation plan subelement. The open space preservation plan subelement contains recommendations intended to guide the preservation through public acquisition and land use regulation of the remaining primary environmental corridors and prime agricultural lands of the Region. The outdoor recreation plan subelement is composed of: 1) a resource-oriented outdoor recreation component containing recommendations as to the number and locations of large parks, proposed recreation corridors to accommodate trail-oriented activities, and water access facilities; and, 2) an urban-oriented outdoor recreation component containing recommendations to guide the public provision of needed local parks and nonresource-oriented recreation facilities within urban areas.

Open Space Preservation Plan Subelement

The open space preservation plan subelement recommends the continued maintenance and preservation in essentially natural open uses of all remaining primary environmental corridor lands within the Region and the watershed. As shown on Map 45, these corridor lands consist of about 327 gross acres located along that reach of the Kinnickinnic River from S. 16th Street to S. 69th Street. This corridor is composed of Jackson Park (116 acres), Kinnickinnic Parkway Recreation area (50 acres), Pulaski Park (18 acres), Manitoba School (6 acres), and a small nonpublicly owned section south of the Chicago & North Western Railway to W. Dakota Street (about 2 acres), as well as 135 acres of the 170 acres of publicly owned Kinnickinnic Parkway lands. In addition, a very narrow environmental corridor consisting of lake, beach, and bluff area exists along

Map 45

RECOMMENDED PARK AND OPEN SPACE PLAN FOR THE KINNICKINNIC RIVER WATERSHED: 2000

The recently completed regional park and open space plan for southeastern Wisconsin includes recommendations for the Kinnickinnic River watershed. Recommendations for the acquisition, development, and maintenance of park and open space land and facilities in the watershed are related to and represent refinements of the land use plan for the watershed. Included in the recommendations for the Kinnickinnic River watershed are: protection of primary environmental corridors; development of recreation corridors; continued maintenance of Jackson Park—a large, general use, outdoor recreation site; continued use of 16 existing community and neighborhood parks partially or wholly within the watershed; completion of the development of two neighborhood parks; acquisition and development of three new neighborhood parks; development of urban outdoor recreation facilities for community and neighborhood parks, the type and quantity of which would be based on a more detailed study of neighborhood needs; and detailed engineering and environmental studies possibly leading to the location of boat launching ramps and mooring facilities in the estuary portion of the watershed.

Source: SEWRPC.

the entire length of the Lake Michigan shoreline in the Region and a portion of that corridor crosses the Kinnickinnic River watershed near its outlet as shown on Map 45. Although certainly not a "natural area," this eastern extremity of the watershed is considered a part of the lakeshore corridor because of a combination of existing conditions or factors including its function as a potential link in a continuous lakeshore corridor, the scenic vistas to the east, places of historic significance, public lake access, and the boating and fishing opportunities available on and along the Lake Michigan shoreline and in the inner and outer harbor areas. The open space preservation plan subelement of the regional park and open space plan recommends that this primary environmental corridor along the Lake Michigan shoreline within and adjacent to the Kinnickinnic River watershed be protected through public land use regulation. The open space preservation plan subelement does not contain any recommendations for the protection of prime agricultural lands in the Kinnickinnic River watershed because there are no such lands remaining in the basin.

Outdoor Recreation Plan Subelement

Recreation Corridor: A recreation corridor is defined by the Commission as a publicly owned ribbon of land at least 15 miles in length located through areas of scenic, scientific, historic, or other cultural interest which contains trails marked and maintained for such activities as hiking and biking. Within urban areas, recreation corridors rely on the use of existing streets as well as of public open space lands. As shown on Map 45, a four-mile segment of a recommended recreation corridor passes across the eastern edge of the watershed in a generally north-south direction. This corridor is based upon the Milwaukee County Park Commission's Bike Tour Route and the portion lying within the Kinnickinnic River watershed passes, from north to south, along S. First Street, S. Kinnickinnic Avenue, and E. Bay Street. There are no development or acquisition costs associated with the portion of the recreation corridor lying within the Kinnickinnic River watershed since the corridor would rely exclusively on the use of existing streets.

Large Parks: Type I and Type II parks are defined by the Commission as large, public, general use, outdoor recreation sites which generally provide opportunities for such activities as camping, golfing, picnicking, and swimming and have a large area containing significant natural resource amenities. Type II parks, by definition, range in area from 100 to 249 acres, while Type I parks are 250 acres or more in area. Type I and Type II parks generally attract users from relatively long distances and serve persons of all age groups residing in both urban and rural areas. Type II parks typically provide a smaller variety of recreational facilities than Type I parks and have a smaller area devoted to any given activity.

There are no existing or proposed Type I parks within the Kinnickinnic River watershed. As shown on Map 45, Jackson Park is the only existing Type II park in the watershed, and the regional park and open space plan recommends the continued maintenance of this facility. There are no recommendations for additional Type II parks in the Kinnickinnic River watershed.

Small Parks: In contrast to Type I and Type II parks, Type III and Type IV general use outdoor recreation sites depend more upon the developmental characteristics of the area to be served than on the underlying natural resource base and amenities. Type III general use sites by definition range in size from 25 to 99 acres while Type IV general use sites are generally under 25 acres in area. Type III and Type IV general use sites, which typically provide opportunities for intensive nonresource-oriented outdoor recreation activities such as baseball, basketball, ice-skating, softball, and tennis, generally attract users from a relatively small service area and are provided primarily to meet the outdoor recreation demand of residents of urban areas.

As shown on Map 45, the following seven developed Type III general use outdoor recreation sites, all of which are Milwaukee County Parks, are located wholly or partly within the Kinnickinnic River watershed: Wilson Park (78 acres), Wilson Park Recreation Complex (52 acres), Humboldt Park (70 acres), Cherokee Park (42 acres), Kosciuszko Park (33 acres), Baran Park (32 acres), and Kinnickinnic Parkway Recreation area (50 acres). The regional park and open space plan does not recommend the acquisition and development of any additional Type III general use outdoor recreation sites in the Kinnickinnic River watershed.

As shown on Map 45, the following nine developed Type IV general use outdoor recreation sites are located wholly or partly within the Kinnickinnic River watershed: Pulaski Park (18 acres), Airport Park (18 acres county-leased land), Holler Park (15 acres), Lyons Park (12 acres), Adams Playfield (12 acres), West Milwaukee Park (10 acres),[3] Washington Playground (6 acres), Cudahy Park (3 acres),[4] and Tippecanoe Park (1 acre).[5]

[3] *Of the total 19 acres comprising West Milwaukee Park, about 10 acres are located within the Kinnickinnic River watershed. The remainder are located in the Menomonee River watershed.*

[4] *Of the total 18 acres comprising Cudahy Park, about 3 acres are located within the Kinnickinnic River watershed. The remainder are located in the area which has minor tributaries to Lake Michigan.*

[5] *Of the total 18 acres comprising Tippecanoe Park, about 1 acre is located within the Kinnickinnic River watershed. The remainder are located in the area which has minor tributaries to Lake Michigan.*

In addition, the Kinnickinnic River watershed contains two undeveloped Type IV general use outdoor recreation sites. One of these is a playlot located at S. 30th Street and W. Fordale Avenue in the City of Milwaukee and the other consists of the Barnard site located near W. Layton Avenue and S. 35th Street in the City of Greenfield.[6] In accordance with the recreation plan subelement of the regional park and open space plan, the development of Type IV general use outdoor recreation sites requires the detailed analysis of the needs of the neighborhood within each urban area. These analyses are the responsibility of the implementing agency—the Milwaukee County Park Commission.

The regional plan does recommend the acquisition of three additional Type IV general use outdoor recreation sites in the Kinnickinnic River watershed and indicates, as shown on Map 45, the general desired location of these sites. One site would be located on the extreme northwest corner of the watershed in the City of West Allis, the second site would be located in the center of the watershed in the City of Milwaukee, and the third site would be located in the southeastern corner of the watershed in the City of Cudahy. The three sites would have a total combined area of about 20 acres, and the total acquisition cost is estimated at $4.8 million[7]—a cost that is reflected in the total cost of the regional park and open space plan and is not included in the implementation of the Kinnickinnic River watershed plan.

Nonresource-Oriented Recreation Facilities: The regional plan also consists of recommendations concerning the quantity of urban outdoor recreation facilities which should be provided to meet existing and probable future recreation needs within urban areas. In comparison to the resource-oriented recreation sites and facilities, nonresource-oriented outdoor recreation sites and facilities—including baseball diamonds, basketball courts, ice-skating rinks, playfields, playgrounds, softball diamonds, and tennis courts—rely less heavily on natural resources amenities, generally have greater need in urban rather than rural areas, and have a relatively smaller service radius.

All of the new intensive nonresource-oriented outdoor recreation facilities proposed under this plan element for the Kinnickinnic River watershed would be developed on existing or proposed Type III and Type IV park lands. Although the type and quantity of these facilities proposed for the watershed would be determined through a joint effort by the County, school districts, and local community recreation agencies, based on a more detailed study of neighborhood needs, facility development costs have been estimated for the watershed.

The total urban park facility development costs for the watershed are estimated at $618,800. This estimate includes the development costs of intensive nonresource-oriented facilities—for example, softball diamonds, tennis courts, and playfields, as well as the support facilities, primarily parking spaces, directly related to the recommended facilities—for the three Type IV recreation sites proposed for acquisition, the two acquired and proposed to be developed Type IV sites, and any existing Type III or Type IV park lands within the watershed. This cost is reflected in the total cost of the regional park and open space plan and is not included in the implementation costs of the Kinnickinnic River watershed plan.

Water Access Facilities: The regional park and open space plan identifies the need for additional water access facilities within the Region such as boat launching ramps and boat mooring slips on navigable waters. Five general sites are identified for development of additional water access facilities along Lake Michigan. One of the five sites could be located within the watershed based on completion of more detailed engineering and environmental studies which would be needed before recommending specific locations for boat launching ramps and mooring slips. The regional park and open space plan notes that the County Executive of Milwaukee County has recommended a study concerning the feasibility of providing recreational boat launching ramps and mooring slips in the Kinnickinnic River estuary.

SUMMARY

The Kinnickinnic River watershed is the most highly urbanized watershed studied to date by the Commission. As of 1975, the amount of land devoted to urban use within the watershed was about 24 square miles, or about 92 percent of the total area of the watershed. The amount of land devoted to urban use within the watershed is forecast to increase to about 25 square miles, or about 96 percent of the total area of the watershed, by the year 2000. This increase will have to be satisfied primarily through the conversion of existing "unused" open lands to urban use. It is extremely important that the new urban development be related sensibly to soil capabilities; to long-established utility systems; and to the floodlands and surface water resources of the watershed. If such new urban development is not so related, the already severe developmental and environmental problems of the watershed may be expected to continue to intensify and the quality of life for existing and future watershed residents will be lessened.

The recommended land use plan element thus constitutes a major element of the comprehensive plan for the development of the Kinnickinnic River watershed. The recommended watershed land use plan is set within the context of, and reflects the concepts and recommendations contained in, the regional land use plan

[6] *As of November 1977, Barnard Park has been partially developed as a neighborhood park by the Milwaukee County Park Commission. The land has been graded and seeded, and an all-purpose play area has been developed.*

[7] *Since these sites are located within densely populated areas of the central portion of the County of Milwaukee, this amount reflects high acquisition, clearing, and relocation assistance costs.*

for the year 2000. The regional and watershed land use development objectives and standards on which the land use plan is based are intended to guide and shape the spatial distribution of land uses within the watershed in order to achieve a safer and a more healthful, pleasant, and efficient land use pattern while meeting the forecast net land use demand requirements. The land use plan element emphasizes efficient utility services, cohesive urban development, preservation of unique resource areas, and protection of remaining undeveloped floodland areas from urban encroachment.

Coincident with the plan preparation phase of the Kinnickinnic River watershed planning program, the Regional Planning Commission was completing work on a regional park and open space plan. The park and open space plan contains recommendations for the Kinnickinnic River watershed and those recommendations are related to and are refinements of the land use plan for the basin. Included in the recommendations for the Kinnickinnic River watershed are: continued maintenance and preservation of existing primary environmental corridors along the Kinnickinnic River; protection through public land use regulation of that portion of the Lake Michigan shoreline primary environmental corridor crossing the eastern limits of the watershed; continued maintenance of Jackson Park—a large, general use, outdoor recreation site; continued use of 16 existing community and neighborhood parks partially or wholly within the watershed; completion of two acquired but not fully developed neighborhood parks; acquisition and development of three new neighborhood parks; development of urban outdoor recreation facilities for community and neighborhood parks, the type and quantity of which would be based on a more detailed study of neighborhood needs; and detailed engineering and environmental studies possibly leading to the location of boat launching ramps and mooring facilities in the estuary portion of the watershed.

Chapter XII

ALTERNATIVE FLOODLAND MANAGEMENT MEASURES

INTRODUCTION

The inventory and analysis phases of the Kinnickinnic River watershed planning program have identified certain water resource and water resource-related problems, including flooding and water pollution. As stated in Chapter I, the overriding objective of the Kinnickinnic River watershed planning program is to assist in the abatement of these water resource and water resource-related problems by developing a workable plan which can be used to preserve and protect sound existing development within the watershed and to guide development and redevelopment within the watershed into a safer, more healthful, and more economic pattern, a pattern which is properly related to the sustaining ability of the underlying natural resource base without intensifying existing or creating new socioeconomic and environmental problems.

The purpose of this chapter is to present floodland management alternatives from which an integrated water resource management plan for the watershed can be synthesized. The structural and nonstructural floodland management alternatives described herein were designed for, and should be considered as adjuncts to, the basic land use development proposals advanced in Chapter XI to facilitate the attainment of regional and watershed development objectives. The alternative floodland management measures are thus subordinate to the basinwide land use plan element, and the incremental benefits and costs of these alternatives can be separated from those of the basinwide land use plan element.

The evaluation of a particular alternative relative to other alternatives intended to resolve an identified problem is a sequential process during which the plan subelement is subjected to several levels of review and evaluation including technical, economic, financial, legal, and administrative feasibility and political acceptability. In anticipation of making a comparative evaluation of the various floodland management alternatives and to facilitate selection of a recommended comprehensive watershed plan, the technical, economic, and environmental aspects of each floodland management alternative are presented in this chapter.

Concerning organization of the material presented in this chapter, structural and nonstructural floodland management measures available for resolution or prevention of flood problems are described, followed by a discussion of the hydrologic, hydraulic, and economic consequences of committed channel modifications and planned land use changes. Floodwater storage and diversion alternatives are then described, followed by a comparison of structural flood control measures for selected flood-prone communities. Bridge and culvert alteration is discussed, followed by a description of nonstructural floodland management measures recommended for application throughout the watershed. The chapter concludes with a discussion of accessory floodland management measures.

AVAILABLE FLOODLAND MANAGEMENT MEASURES

Floodland management may be defined as the planning and implementation of a combination of measures intended to reconcile the floodwater conveyance and storage function of floodlands with the space and related socioeconomic needs of a resident population. Specific purposes of floodland management include elimination of loss of life, lessening of danger to human health and safety, minimization of monetary damage to private and public property, reduction in the cost of utilities and services, and minimization of disruption in community affairs. A broader goal is the enhancement of the overall quality of life of the watershed residents by protection of those environmental values—recreational, aesthetic, ecological, and cultural—normally associated with, and concentrated in, riverine areas.

Preparation of a floodland management plan for a watershed involves the development of alternative plan elements, a comparative evaluation of those elements, and the synthesis of the most effective elements into an integrated plan. The floodland management plan for the Kinnickinnic River watershed is specifically intended to achieve the land use development objectives, sanitary sewerage system development objectives, and water control facility development objectives and supporting standards set forth in Chapter X.

The techniques of floodland management may be broadly subdivided into two categories: structural measures and nonstructural measures. Structural measures include floodwater storage facilities such as reservoirs and impoundments, diversions, floodwater containment facilities such as earthen dikes and concrete floodwalls, floodwater conveyance facilities such as major channel modifications, and bridge and culvert modifications or replacements. Nonstructural measures include reservation of floodlands for recreational and open space uses, floodland use regulations, land use controls outside of the floodlands, structure floodproofing, structure removal, channel maintenance, flood insurance, lending institution policies, realtor policies, community utility policies, and emergency programs. Table 69 lists structural and nonstructural measures of floodland management that may apply, individually or in combinations, to portions of the Kinnickinnic River watershed, and summarizes the

Table 69

ALTERNATIVE FLOODLAND MANAGEMENT MEASURES CONSIDERED IN THE KINNICKINNIC RIVER WATERSHED PLANNING PROGRAM

Alternative: Major Category	Alternative: Name	Function	Comment
Structural	Storage	To detain floodwaters upstream of flood-prone reaches for subsequent gradual release	May be accomplished by on-channel reservoirs or by off-channel or underground storage
	Diversion	To divert waters from a point upstream of the flood-prone reaches and discharge to an acceptable receiving watercourse outside of the watershed, or to divert floodwaters around a flood-prone area on a completely new alignment	--
	Dikes and floodwalls	To prevent the occurrence of overland flow from the channel to floodland structures and facilities	
	Channel modification and enclosure	To convey flood flows through a river reach at significantly lower stages	May be accomplished by straightening, lowering, widening, lining, and otherwise modifying a channel or by enclosing a major stream, includes construction of a new length of channel for the purpose of bypassing a reach of a natural stream
	Bridge and culvert alteration or replacement	To reduce the backwater effect of bridges and culverts	May be accomplished by increasing the waterway opening or otherwise substantially altering the crossing or by replacing it
Nonstructural	Reservation of floodlands for recreational and related open space use	To minimize flood damage by using floodlands for compatible recreational and related open space uses and also to retain floodwater storage and conveyance	May be accomplished through private development, such as a golf course, or by public acquisition of the land or of an easement
	Floodland regulations	To control the manner in which new urban development is carried out in the floodlands so as to assure that it does not aggravate upstream and downstream flood problems	May be accomplished through zoning, land subdivision control, sanitary and building ordinances
	Control of land use outside of the floodlands	To control the manner in which urban development occurs outside of the floodlands so as to minimize the hydrologic impact on downstream floodlands	--
	Flood insurance	To minimize monetary loss or reduce monetary impact on structure owner	Premiums may be subsidized or actuarially determined
	Lending institution policies	To discourage acquisition or construction of flood-prone structures by means of mortgage granting procedures	--
	Realtor policies	To discourage acquisition or construction of floodprone structures by providing flood hazard information to prospective buyers	--
	Community utility policies	To discourage construction in flood-prone areas by controlling the extension of utilities and services	--
	Emergency programs	To minimize the danger, damage, and disruption from impending flood events	Such a program may include installation of remote stage sensors and alarms, road closures, and evacuation of residents
	Structure floodproofing	To minimize damage to structures by applying a combination of protective measures and procedures on a structure-by-structure basis	--
	Structure removal	To eliminate damage to existing structures by removing them from flood-prone areas	--
	Channel maintenance	To maintain integrity of flood stage profiles; to permit unobstructed flow from storm sewers, drainage ditches, and drainage tile; and to remove potentially troublesome buoyant material	Will not significantly reduce stages of major floods except as those stages might be influenced by accumulation of buoyant material on the upstream side of bridge waterway openings

Source: SEWRPC.

function of each. Structural measures tend to be more effective in achieving the objectives of floodland management in riverine areas that have already been urbanized, while nonstructural measures are preventative in that they are generally more effective in riverine areas that have not yet been converted to flood-damage-prone rural and urban development but have the potential for such development.

Structural Measures

Each of the five structural floodland management measures set forth in Table 69 is discussed briefly below. Emphasis is placed on the function of each measure; on the key factors, or basic requirements, used to determine if the given alternative applies to a particular riverine area or portion of the watershed; and on some of the more significant positive and negative features of each measure.

Storage: From the perspective of floodland management, the function of floodwater storage facilities is to detain floodwaters upstream of flood-prone areas for subsequent gradual release, thereby substantially decreasing downstream discharges and stages and, consequently, flood damage. A key factor in the potential application of this alternative is the existence of sites of sufficient volume that are positioned upstream of all, or a significant portion of, the flood-prone riverine areas and are located so as to control the runoff from a significant portion of the total watershed area tributary to the flood-prone areas. In addition, the site must be "available" in the sense that it does not contain significant urban development.

Floodwater storage facilities may be directly located on the stream system, such as is the case with a conventional reservoir, or may be located off the channel system, as in an abandoned quarry or in excavated chambers in the underlying bedrock. In the latter case the floodwaters are diverted to the storage area during a flood event and later returned to the stream by pumping.

A positive feature of reservoirs in the context of a comprehensive floodland management plan element is their potential for mitigating flooding in several downstream reaches or communities, in contrast with most other structural floodland management measures which provide only more local flood relief. Another favorable aspect of reservoirs is their potential for serving several water resource-related uses—in addition to flood mitigation—such as recreation, low flow augmentation, and water supply. Negative aspects of reservoirs include the large capital cost, large land area required, potential adverse water quality conditions both within and downstream of the impoundment, and the false sense of security with respect to the flood dangers that may be engendered in downstream reaches, leading to the possible influx of urban development into the remaining flood-prone areas.

Diversion: The function of a diversion is to intercept potentially damaging floodwaters at a point upstream of the flood-prone reaches and to route those floodwaters along a completely new alignment in order to bypass the flood-prone reach. Diverted flood flows are sometimes discharged to receiving watercourses outside of the subwatershed or watershed in which flood mitigation is desired. Two structural elements are entailed in a diversion alternative: (1) the control structure itself located on the stream channel that establishes the river stage at which the diversion process will begin and the rate at which it will occur; and (2) the open channel or closed conduit that conveys the diverted floodwaters from the stream channel to the point of discharge. A key factor in assessing the application of this alternative is the availability of a suitable diversion route or alignment and an adequate receiving watercourse or other point of discharge.

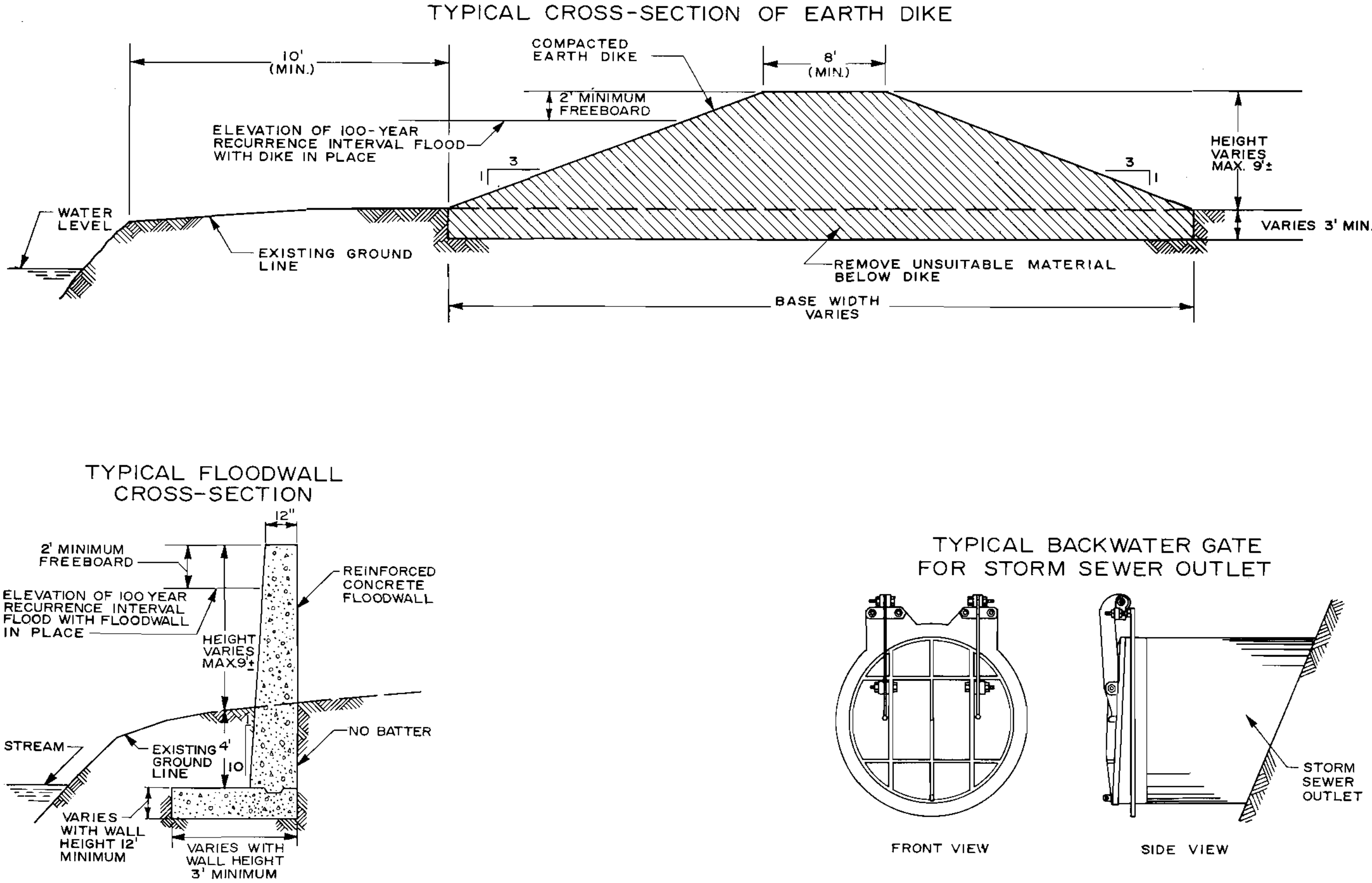
A favorable feature of the diversion technique, shared with the reservoir alternative, is the potential which a single major upstream facility may have to mitigate flood problems in several downstream reaches and communities. A negative aspect, also shared with impoundments, is the false sense of security with respect to downstream flood dangers that may develop as a result of the construction of a diversion facility. Another negative feature of diversions for flood control purposes is the potential legal restrictions on the transfer of water between watersheds as discussed in Chapter IX of this report.

Dikes and Floodwalls: Earthen dikes and concrete or sheet steel floodwalls, like those shown in Figure 59, are technically feasible means of providing flood control in certain flood-prone riverine areas. The principal function of dikes and floodwalls is to contain the floodwaters; that is, to prevent the occurrence of overland flow laterally from the channel to adjacent floodland areas containing flood-damage-prone structures and facilities. A key physical factor in the potential application of this structural alternative is the availability of sufficient space between the stream channel and the land uses that are to be protected to permit the construction of the dikes or floodwalls, the latter having the advantage of requiring a narrower strip of land.

In order to be effective in reducing flooding, dikes and floodwalls must normally be supplemented by the installation of backwater gates on those storm sewer outfalls and other drainage outlets penetrating the dikes and floodwalls that have street inlets or other entry points in the area to be protected at elevations approximating the 100-year recurrence interval river flood stage. A storm water drainage system, which typically includes the aforementioned street storm water inlets and storm sewer outfalls, normally provides for the conveyance of storm water runoff from developed urban areas to the river. During major flood events, however, high river levels can reverse the operation of the storm water drainage system, thus negating its function and resulting in the movement of floodwaters from the river into developed riverine areas, thereby producing unwanted inundation and attendant monetary damages and inconvenience. Backwater gates prevent such flow reversal by

Figure 59

TYPICAL EARTH DIKE, CONCRETE FLOODWALL, AND BACKWATER GATE



Source: SEWRPC.

functioning as valves that normally pass the storm water to the river but close when the hydraulic head on the river side of the hinged gate exceeds the head on the opposite side of the gate.

While backwater gates, operating as described above, will prevent the movement of floodwaters from the river, they may, depending on topographic conditions, create local flood problems attributable to the accumulation of storm water runoff which does not have access to the river because of the closed storm sewer outfall. Areas susceptible to this problem may be protected by making provision for temporary or permanent pumping facilities to convey the impounded storm water over the dikes and floodwalls to the river during major flood events.

An important factor which must be considered in the design of dikes and floodwalls is the stage which the design flood may be expected to reach in passing through the reach to be protected. This design-condition flood stage may be several feet higher than the "natural" condition stage as a result of the lateral constriction imposed on the stream by the dikes and floodwalls, and is used with an appropriate freeboard to establish the crest elevation of the dikes and floodwalls.

A favorable feature of dikes and floodwalls is that they are a means whereby a given community can readily and by unilateral action protect existing development within its own corporate boundaries. It must be recognized, however, that serious negative aspects of dikes and floodwalls are their potential for increasing upstream flood stages as a result of the hydraulic constriction imposed on the river, and the possibility that a series of successive dike-floodwall projects along a stream could substantially reduce the natural floodwater storage capability of the river reach so as to increase downstream dischargers and associated stages. Other significant negative characteristics of dikes and floodwalls include the potentially high aesthetic cost, or penalty, normally associated with the placement of these high, long structures in the riverine areas, particularly if those areas are devoted primarily to residential land use, and the false sense of security that may develop with respect to flood dangers through over-topping of the dikes or walls.

Channel Modification and Enclosure: Channel modifications—more commonly called channelization—may include one or more of the following major changes to the natural stream channel, all designed to increase the capacity of the stream system channel: straightening, deepening, and widening; placement of a concrete invert and partial sidewalls; and reconstruction of selected bridges and culverts as needed. In some instances, a portion of the channelized reach may be constructed so as to bypass a segment—such as a series of meander loops—of the existing channel. This has been done in the Menomonee River watershed for a portion of Underwood Creek in the City of Wauwatosa. However, such a bypass is not as extreme in terms of new alignment and total length as the diversion approach discussed above. This form of channel modification is particularly well suited to river reaches containing intense urban development. Upon completion of bypass construction, all or a portion of the original natural channel may be retained to provide for conveyance of local storm water runoff to the relocated channel.

In the context of structural floodland management measures, channel enclosure refers to the installation of large underground conduits along or close to the alignment of major stream reaches intended to convey floodwaters through an area so as to substantially reduce overland flooding and sanitary sewer backup. An example of major channel enclosure in the Kinnickinnic River watershed is the 0.90-mile-long reach of Wilson Park Creek in the City of Milwaukee that passes along the northern edge of Mitchell Field.

The function of channel modifications or enclosure is to yield a lower, hydraulically more efficient waterway, through which a given flood discharge can be conveyed at a much lower flood stage relative to that which would exist under natural or prechannelization conditions. Key factors in the potential application of this structural floodland management alternative to a flood-prone reach are the acquisition of a strip of land of sufficient width to accommodate the modified channel, and careful consideration of the length of upstream and downstream natural channel that must be modified to effect an acceptable transition from the natural channel and floodplain to the channelized or enclosed reach.

A key advantage of channelization or enclosure is that it—like dikes and floodwalls—provides a means whereby a community can take unilateral action to effectively provide local relief to a flood-prone area. Significant negative features of major channel modifications or enclosures include the potential high aesthetic cost, particularly of the former, and the possibility for aggravating downstream discharges and stages resulting from the loss of floodwater storage capacity in a long channelized or enclosed reach.

The Milwaukee-Metropolitan Sewerage Commissions, in cooperation with the Milwaukee County Park Commission, have used major channel modifications to achieve flood control in those riverine areas of Milwaukee County where urbanization has proceeded to the point where channel modifications are, in effect, the only remaining, technically feasible structural means of achieving flood relief. In recent years, some major channel modification proposals in Milwaukee County have met with citizen opposition on the grounds that the modifications would destroy, to varying degrees, the beauty and aesthetic quality of the natural riverine environment. A commonly cited example used by such opposition to illustrate the potential negative aesthetic aspects of major channel alterations is the reach of the Kinnickinnic River extending from S. 6th Street to S. 16th Street in the City of Milwaukee. In this reach, the natural channel has been replaced by a trapazoidal, concrete-lined channel with steep side slopes and has been converted, in effect, to no more than a large open storm drain. In contrast, there are riverine areas in Milwaukee County where major channel modifications have been accomplished while retaining some of the aesthetic attributes of the natural channel and its floodplain. This has generally been achieved by paving only the lower portions of the modified cross-section and then landscaping the remainder of the channel with grass, shrubbery, and trees. The Kinnickinnic River just upstream of the aforementioned reach serves as an example of such channel modification.

Bridge and Culvert Alteration or Replacement: Existing or new highway and railway bridges and culverts, or modifications to existing bridges and culverts, may significantly affect upstream and downstream flood stages and aggravate existing flood hazards or create new ones. Furthermore, increased regulatory flood stages are reflected in enlarged floodland regulatory zones, thereby creating difficult administrative, legal, and political problems for community officials. Flood events, on the other hand, can interfere with the proper functioning of the regional transportation system by inundating highways or railroad bridges or their approaches, thereby rendering them impassable during major floods.

The function of the bridge and culvert alteration or replacement alternative is to avoid or minimize the aforementioned adverse effects of existing bridges and culverts on flood flow characteristics and the adverse effects of flood flows on the functioning of the transportation system. Elimination of these adverse effects is accomplished by increasing the size of the waterway opening or by otherwise substantially altering the crossing or by replacing it. The potential usefulness of this structural alternative in a watershed is contingent upon identifying those existing bridges and culverts that produce major backwater effects as a result of their inadequate hydraulic capacity, and identifying those structures that are impassable during major flood events. Determination of bridge and culvert backwater effects is a routine procedure associated with the operation of Hydraulic Submodel 2 as described in Chapter VIII of this report.

Contemporary bridge design generally employs larger waterway openings that yield relatively small, and in effect insignificant, backwater effects. Therefore, this structural floodland management alternative is most likely to be applicable to older waterway crossings that will be replaced as a part of the normal transportation improvement process.

Nonstructural Measures

Each of the 11 nonstructural floodland management measures presented in Table 69 is discussed briefly below. The function of each measure is described and the key factors or basic requirements needed to determine if the given alternative applies to a riverine area or portion of the watershed are discussed. In addition, some of the more significant positive and negative features of the various measures are identified.[1]

Reservation of Floodlands for Recreational and Related Open Space Uses: Comprehensive land use planning recognizes that there is, and will continue to be, a need for active and passive recreational and open space lands readily accessible to residents of the metropolitan area. Floodlands provide an ideal location for such lands and supporting facilities because the floodlands and the environmental corridors of which they are a part provide sufficient space, assure the presence of water and other key recreation elements, improve the accessibility of the recreation areas to the urban population, and are compatible with recreation use and supporting facilities.

Recreational and related open space uses of floodlands may be accomplished by several mechanisms, including public or private acquisition of the land or acquisition of an easement followed by development for recreational use such as a golf course. The principal advantage of this floodland management alternative is its definitiveness and legal incontestability, whereas the key disadvantage of public acquisition of the lands is the public cost. Public acquisition of floodland areas for recreational and related open space use can sometimes be accomplished at no major direct cost to the municipalities by encouraging developers of large tracts to dedicate the land in the environmental corridor portions of those tracts to a local government unit or agency for public maintenance and use. Since floodlands are not well suited for residential development not only because of flooding but also because of soils, utility, and other problems; since land subdivision regulations often require developers to provide a minimum amount of recreational and open space land; and since existing floodland regulations may limit the extent of floodland development, the land developer may be receptive to the idea of dedicating the floodlands and adjacent environmental corridors to a local government unit or agency.

In addition to preventing additional flood-prone development, minimizing aggravation of upstream and downstream flood problems, and providing prime and readily accessible outdoor recreational land, the reservation of floodlands for recreational and related open space uses also may be expected to have a significant and favorable impact on the value of residential property in close proximity to the riverine area parkways. A study was recently conducted by the Commission under its regional park and open space planning program[2] to investigate the effects of public open space land on residential values. The emphasis was upon the extent to which residential property values may be influenced by proximity to public open space areas. A variety of information sources and analysis procedures were used to carry out the study, including personal interviews of assessors, appraisers, and developers; collection and collation of census housing value data; analysis of residential land sales information; analysis of locally assessed property values; and a survey of occupants of riverine area residential property.

The study indicated that most public open space lands have a positive impact on the value of residential property situated adjacent to or with a view toward the public open space areas. Furthermore, this impact is directly related to the size of the open land as well as to the value of the natural resource amenities which it contains. Public open space areas, such as Jackson Parkway, that preserve and enhance high value elements of the natural resource base have the greatest impact on the value of adjacent developed residential property. The value of property situated adjacent to or with a view toward such parkways exceeds the value of property located away from the parkway land by an average of about 30 percent. The analysis also indicated that, within a given subdivision that is under development, the sale prices of lots situated adjacent to or with a view toward such parkways exceeds by an average of 12 percent the sale prices of lots situated away from parkway lands.

Floodland Regulations: Floodland regulations take the form of or are incorporated into zoning, land subdivision, sanitary, and building ordinances adopted by counties, cities, villages, and towns under police powers granted by state legislatures. Such regulations are ordinarily intended for the single purpose of flood damage mitigation by controlling the manner in which new urban development is carried out in the floodlands so as to assure that it is not flood-prone and, equally important, that it does not aggravate upstream and downstream flood problems. As discussed in Chapter IX of this report, the regulation

[1] *For additional information on nonstructural measures, see: James H. Owen, Annotations of Selected Literature on Nonstructural Floodplain Management Measures, Hydrologic Engineering Center, U. S. Army Corps of Engineers, Davis, California, March 1977, 95 pp.*

[2] *SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin, Chapter X, "Impact of Public Open Space Lands on Residential Property Values Based Upon an Analysis in Milwaukee County," November 1977.*

of floodlands in Wisconsin is governed primarily by the rules and regulations adopted by the Wisconsin Department of Natural Resources pursuant to Wisconsin Statutes. All counties, cities, and villages are expected to adopt reasonable and effective floodland regulations under the enabling Wisconsin Statutes. The principal advantage of floodland regulations is that they control the manner in which new development occurs in riverine areas. The principal disadvantage of floodland regulations is that they offer no relief to existing flood-prone structures other than to encourage their ultimate removal from floodland areas.

Floodland use regulations in Wisconsin generally employ the two-district floodway-floodplain fringe approach as incorporated in the State of Wisconsin Floodplain Management Program. That program was recently modified[3] to require that floodways be delineated so as to cause no increase in the regulatory or 100-year recurrence interval flood stage.

Although stipulation of a "no-stage increase" floodway eliminates or reduces some of the potential problems associated with the two-district floodway-floodplain fringe approach to floodland regulations, one significant negative aspect remains. The two-district floodway-floodplain fringe approach to floodland regulations may lead to the destruction of the environmental corridors of a watershed, since it encourages floodland fill and development outside of the floodway limits, but within environmentally critical areas. There is the possibility of making floodland and other land use recommendations more effective for environmental corridor protection as well as flood damage mitigation. Such more comprehensive floodland regulations typically incorporate a floodway, a developable floodplain fringe, and an undevelopable conservancy district.

Control of Land Use Outside of the Floodlands: In a watershed, it is important to regulate the manner in which urban development occurs outside of the floodlands, as well as within the floodlands, so as to minimize the hydrologic impact on floodland areas receiving direct runoff from tributary watershed areas. Although planning for land use outside of floodland areas has not traditionally been considered a floodland management alternative, recent studies of the hydrologic-hydraulic interdependence between the land surface and the streams of the watershed system suggest that land use planning may indeed be an effective floodland management measure.[4] It is vital that land use planning consider the hydrologic-hydraulic consequences of the location of future urban development, the amount of impervious surface in that development, and the manner in which storm water runoff from that new development is controlled.

[3] *Wisconsin Administrative Code, "Wisconsin's Flood Plain Management Program," Chapter NR 116, July 1977.*

Structure Floodproofing: As discussed in Chapter IV of this report, residential, commercial, and industrial structures located within or adjacent to floodlands are particularly vulnerable to flood damage because of the variety of ways in which floodwaters can enter such structures. It is possible and generally practicable for individual owners to make certain structural adjustments to their private properties and to employ certain measures or procedures, all of which are intended to significantly reduce potential flood damages. This approach is referred to as floodproofing, and may be more specifically defined as a combination of physical measures applied to existing structures in combination with selected emergency procedures, all of which are intended to eliminate or significantly reduce damage to the structure and its contents.

Floodproofing measures and techniques intended for application to existing structures generally can be divided into one of three categories:[5] 1) techniques for preventing entry of floodwaters; 2) techniques for insuring continuation of, or at least protection of, utilities and other services during flood events and for protecting structure contents in the event that the water does—by design or otherwise—enter the building; and 3) the techniques of

[4] *For a graphic demonstration of the potential impact of land use changes outside of floodland areas on flood discharges, stage, and damage, refer to SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume Two, Alternative Plans and Recommended Plan, pp. 72-97.*

[5] *For descriptions of floodproofing measures and estimates of costs see:*

- *John R. Sheaffer, et al., Introduction to Floodproofing: An Outline of Principles and Methods," University of Chicago Center for Urban Studies, April 1967, 61 pp.*
- *U. S. Army Corps of Engineers, Floodproofing Regulations, Washington, D.C., June 1972.*
- *Shelton R. McKeever, Floodproofing: An Example of Raising a Private Residence, U. S. Army Corps of Engineers, South Atlantic Division, Atlanta, Georgia, March 1977, 19 pp.*
- *William K. Johnson, Physical and Economic Feasibility of Nonstructural Flood Plain Management Measures, U. S. Army Corps of Engineers—Hydrologic Engineering Center and Institute for Water Resources, May 1977, 281 pp.*
- *William D. Carson, Estimating Costs and Benefits for Nonstructural Flood Control Measures, U. S. Army Corps of Engineers—Hydrologic Engineering Center, October 1975.*

raising—that is, elevating—the structure such that the first or othermost damage-prone floor is above the design flood stage, supplemented with measures to protect the basement and other portions of the structure below the design flood stage from damage.

The particular combination of floodproofing measures applied to a given structure must be tailored to the function of the structure, the nature of its construction, and the vertical and horizontal position of the structure within the floodplain. Extensive floodproofing should be applied only under the guidance of a registered professional engineer who has carefully inspected the building and contents, has analyzed its structural integrity, and has evaluated the flood threat. It is important to emphasize that, even if a successful floodproofing program is instituted in a flood-prone area, overland flooding and the inconvenience with it will continue to occur.

Prevention of Floodwater Entry: A variety of floodproofing measures and techniques are available to prevent the entry of floodwaters. Sanitary sewer backup through basement floor drains may be prevented by installation of backwater valves or the use of vertical standpipes screwed into a fitting in the floor drain, provided that the building sewer can withstand the attendant pressure that will be exerted. Sump pumps, preferably provided with standby gasoline powered electrical generators, can remove water that enters the basement of a structure through foundation drains or other openings, provided that the discharge point is above and not affected by flood stage. Waterproof seals can be installed at structural joints—such as the contact between basement walls and the basement floor—and impermeable materials can be applied to the outside of basement walls. Overland flood damage may be prevented by the construction of earthen berms or concrete or masonry walls around the perimeter of the structure or cluster of structures. Glass block[6] may be placed in basement window openings, and flood shields have been designed for quick installation over doorways, windows, and other structural openings.

It is important to reemphasize the critical need for a complete analysis of the ability of a given structure to withstand the external hydrostatic forces that would be applied to the walls and basement floor of a structure prior to implementing floodproofing procedures intended to prevent water from entering the basement of such structures. Generally speaking, the concrete block basements widely used in residential construction in southeastern Wisconsin are not capable of withstanding hydrostatic forces associated with complete saturation of the soil surrounding the buildings.[7] A possible alternative, therefore, to attempting to prevent floodwater from entering the basement of such structures is to intentionally flood the basement with clean water prior to the inflow of floodwater, thereby maintaining its structural integrity while minimizing the entry of sanitary sewage, sediment, and other objectionable materials normally associated with basement flooding and, as discussed below, incorporating measures to maintain utilities and services and protect structure contents.

Maintain Utilities and Services and Protect Contents: The second category of floodproofing measures applicable to existing residential, commercial, industrial, and other structures consists of techniques designed to ensure the maintenance of utilities and other services needed for the building to function possibly during, but certainly immediately after, a flood event. Also included in this category are procedures intended to protect structural contents. Because of the above structural problems, this second category of floodproofing measures should be considered for structures having concrete block basements.

Mechanical equipment such as heating and air conditioning units or manufacturing equipment may be placed on upper floors, elevated above the floor on which it is placed, surrounded by low walls to prevent intrusion of floodwaters, temporarily covered with impermeable sheet material, or altered so as to be mobile for removal from flood-prone areas prior to the occurrence of a flood event. Electrical circuits serving flood-prone sections of a structure should be altered so that they can be easily shut off, and consideration should be given to moving the electrical service box to the first floor of the structure above anticipated flood levels and to the use of waterproof electrical fixtures in flood-prone areas of the structure. Some mechanical and electrical equipment may be protected by removal of critical water-vulnerable components—for example, the blower motor on a forced air heating unit—prior to entry of the floodwaters.

If there is a high probability that water will enter portions of the structure and damage the contents, such as furnishings in a house or stock stored in a commercial building, an emergency evacuation program should be prepared for the contents of the buildings. Flood-vulnerable contents could be temporarily moved out of the buildings or to higher floors or temporarily elevated on supports or shelves.

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[6] *The Wisconsin Uniform Building Code states that basement windows must have a minimum openable area of 1 percent of the floor area unless ventilation is provided by other means such as mechanical ventilation units. Furthermore, the current policy of the interpretation committee of the Southeastern Wisconsin Building Inspectors Association is to require the use of glass block for basement windows in flood-prone areas and to require that this be supplemented with mechanical ventilation equipment.*

[7] *For example, see: Investigation of Basement Construction in Fargo, North Dakota and Moorhead, Minnesota Area, prepared for the Federal Insurance Administration by the National Association of Home Builders Research Foundation, Inc., Rockville, Maryland, June 1975.*

Some of the above floodproofing measures are contingent upon receiving adequate forewarning—at least several hours—of the impending occurrence of a flood event. It is important to recognize that such a warning, even if it were provided at the outset of a flood, would not be very effective in the Kinnickinnic River watershed since this is a small, heavily urbanized basin characterized by a rapid response of peak flood flows to a major rainfall event.

Elevating the Structure: The third category of floodproofing measures is raising the structure—that is, elevating it—on its present site such that the first floor or othermost damage-prone floor is above the design flood stage. Structure raising is supplemented with basic floodproofing measures like those described above to protect the basement and other portions of the elevated structure that remain below the design flood stage.

While basic floodproofing measures like those discussed above are generally considered feasible for most nonresidential structures—such as business and commercial buildings and schools—even if the design flood stage is above the first floor elevation, such measures are not generally technically feasible or practical for single-family residences when the design flood stage is above the elevation of the first floor. This is the condition for which structure elevation is often the most appropriate floodproofing measure.

A typical structure raising procedure applied for floodproofing purposes is as follows: remove shrubs and other landscaping materials, concrete porches, walks and driveways, and other objects attached to or located close to the building; excavate as needed near the structure and place beams or other supports beneath the structure; disconnect utilities and services; use jacks to raise the structure; extend the basement walls upward and use the jacks to lower the structure down onto the extended walls; reconnect utilities and services; apply basic floodproofing measures to the basement as described above, possibly including raising the basement floor approximately the same distance that the structure was raised; fill and grade the yard around the structure to match the structure's new elevated position; replace shrubs, porches, walks, and driveway and restore landscaping; and paint and redecorate the exterior of the house as needed.

The total capital cost of elevating a structure is composed of costs that are directly dependent on and increase with the extent to which the structure is elevated, and fixed costs that are independent of the height to which the structure is raised. Examples of the latter, or fixed, costs include placing beams or other supports beneath the structure, disconnecting utilities, and replacing shrubs, whereas examples of the former, or variable, costs include vertical extensions to the basement walls, and the fill required to raise the yard grade. While the average cost of applying basic floodproofing techniques to a single family residential structure—that is, floodproofing the structure without elevating it—so as to prevent the entry of floodwaters or to at least maintain utilities and services and protect contents is estimated at $2,500, the cost of elevating the residential structure—which would probably be required if the design flood stage were above the first floor elevation—is estimated at about $22,000, assuming that the building is raised four feet, and increases about $2,000 for each additional foot that the structure is raised. While the costs of floodproofing structure elevation may be expected to greatly exceed the cost of basic floodproofing, the structure elevation alternative may be expected to be considerably less costly than the structure acquisition and removal alternative described below.

Principal Advantages and Disadvantages of Floodproofing: The principal advantage of floodproofing is that it provides a means whereby individual homeowners or property owners unilaterally can take definitive action to protect their flood-prone structures against future flood damage. A significant negative effect of floodproofing is the very real possibility that it will be applied without adequate professional engineering guidance, thereby leading to possible major damage to the structure as well as posing a threat to the owners, tenants, and users of the structure.

Another negative attribute of floodproofing individual structures is the very real possibility that the technique will not be applied in a coordinated way throughout the entire flood-prone portion of a given community, thereby leaving a significant residual demand for flood relief—a demand that will be focused on community officials and will be intensified during and immediately after each flood event. In such a situation, and in spite of the fact that numerous individual property owners have implemented floodproofing and have incurred the necessary costs, community officials still will be faced with the problem of reducing the flood threat to those structures that have not been floodproofed.

Structure Removal: As discussed above, it is generally technically and economically feasible to apply basic floodproofing measures to well-constructed brick and masonry structures used for commercial or industrial purposes and to floodproof private residences, sometimes by elevating them. There are, however, situations in which structure floodproofing is not technically practicable or economically sound, such as when the structures are dilapidated and do not meet building code standards or when the cost of elevating them would be prohibitively high because of a large difference between the first floor elevation and the design flood stage.

Therefore, floodproofing measures considered in the design of alternative flood damage abatement plans are sometimes supplemented with proposals to remove those structures, usually private residences, having first floor elevations below the 100-year recurrence interval flood stage—the stage used to design floodproofing and removal alternatives. The cost of removing a residential structure from a flood-prone area is computed as the sum of the structure and site acquisition cost, structure demolition or moving cost, site restoration costs, and occupant relocation cost, the last of which is provided to the displaced homeowner or tenant in compensation for expenses incurred as a result of moving.

A positive aspect of structure removal, in addition to flood damage reduction, is that it enhances the opportunity to develop the aesthetic and recreation potential or riverine lands. Structure removal can assist in restoring river floodlands to an open, near natural state, thereby enhancing the aesthetic value of the riverine area and, in effect, recreating environmental corridors. Such restored environmental corridor lands could be used for outdoor recreation and related open space purposes.

A negative aspect of structure removal is the opposition which is likely to be encountered from some property owners even if they are offered an equitable price for the flood damage-prone property. Although some of the value placed on a home may be intangible, and therefore cannot be expressed in monetary terms, it is nevertheless real and must be considered when structure removal alternatives are proposed.

Another potentially negative aspect of structure removal is a loss in tax base to a community as a result of removing taxable property from within the corporate limits. It should be noted, however, that while there may be a loss in tax base to a community, the net cost to the community may be considerably smaller than the lost taxes because of the likely compensating effect of several factors, including: the reduced cost of municipal services such as schools, water supply, and sewerage; the reduced cost of flood-related emergency services; and the likelihood that some of the evacuated residents will construct new residences within the civil division on previously undeveloped land, thereby restoring some of the lost tax base.

Channel Maintenance: Channel maintenance consists of periodic removal of silt, sand, and gravel deposits; heavy vegetation; and the wide variety of debris found in all streams but most commonly in streams flowing through urban areas. Examples of debris commonly found in stream channels are: brush, tree limbs, scrap lumber, oil drums, wooden crates, cardboard boxes, rubble from demolition activities, tires, bicycles, shopping carts, and appliances.

Channel maintenance may be expected to yield three positive results with respect to flooding and related stormwater inundation problems. First, periodic stream channel cleaning and maintenance are important to maintain the integrity of the flood stage profiles developed under the watershed planning program. As noted in Chapter VIII of this report, hydraulic, hydrologic, and flood economic analyses completed under the watershed planning program assume that the stream channels and the hydraulic structure waterway openings will be periodically cleaned of debris, heavy vegetation, silt, and other deposits and properly maintained so as to provide at least the amount of conveyance capacity that existed at the time the hydraulic system inventory was conducted for the watershed planning program. The second reason for periodic cleaning and maintenance of the stream channels is the need to maintain the channel bottom profile at an elevation below the invert of existing or planned storm sewer and storm water channels outfalls in urban areas and drainage tile and drainage ditch outfalls in rural areas. Failure to provide such cleaning and maintenance may result in partial or full blockage of the outfalls by debris, vegetation, silt, and other deposits, in turn causing nuisance or serious flooding or storm water inundation of urban areas and of cropland. Finally, cleaning and maintenance of the watershed channel system are important to reduce the probability that buoyant objects and debris such as tree limbs, fence posts, scrap lumber, and brush will be carried downstream with the rising floodwaters and accumulate on the upstream side of bridge and culvert waterway openings, thereby partially blocking them and further increasing flood stages in areas of inundation.

While it is important for civil divisions and governmental agencies within the watershed affected by or having jurisdiction over the stream system to carry out channel maintenance, it is important to recognize that such maintenance will have no significant affect on the peak stage of major flood events as calculated and presented in this report. It should be noted, however, that if such maintenance is not performed, the probability of debris accumulating on the upstream side of bridge waterway openings is much greater and thus could result in flood stages higher than those calculated and presented in this report as a result of such accumulations. The intensive relationship of peak flood stages to minor channel cleaning and alteration has been quantified and documented in Commission studies of flood problems in the City of West Allis in the Root River watershed,[8] the Village of Elm Grove in the Menomonee River watershed,[9] and the Village of Pewaukee in the Fox River watershed.[10] These studies have all indicated that channel cleaning and maintenance will not in itself have any significant effect on reducing peak flood stages.

Flood Insurance: The overriding objective of the national flood insurance program is to encourage the purchase of flood insurance by individual land owners to reduce the

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[8]*January 23, 1974 letter report to Milwaukee County Executive and Milwaukee County Board of Supervisors from SEWRPC concerning reevaluation of Root River watershed plan as it relates to flood problems in the City of West Allis, p. 17.*

[9]*SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume Two, Alternative Plans and Recommended Plan, Chapter IV, "Alternative Floodland Management Measures," pp. 116-117, October 1976.*

[10]*SEWRPC Community Assistance Planning Report No. 14, A Floodland Management Plan for the Village of Pewaukee, Chaper III, "Alternative Floodland Management Measures and Recommended Floodland Management Plan," pp. 100-101, draft report, September 1977.*

need for periodic federal disaster assistance. From the perspective of the owner of the flood-prone residential, commercial, or industrial structure, federal flood insurance provides a means of distributing monetary flood losses in a relatively uniform manner in the form of an annual flood insurance premium, and also actually reduces the monetary flood losses in those situations where the insurance premiums are federally subsidized.

It is in the best interest of communities in the Kinnickinnic River watershed to participate in the federal flood insurance program, in accordance with the procedures described in Chapter IX of this report, so as to provide some relief to citizens of those communities in which flood-prone structures are located. Such participation will provide some relief in the event that a serious flood occurs prior to implementation of committed or planned flood control measures. It is important to note that one of the requirements that must be met by a community before citizens of that community can participate in the federal flood insurance program is that the community must enact land use controls which meet federal standards for floodland protection and development. A very close tie, therefore, exists between two of the nonstructural floodland measures—the flood insurance program and floodland regulations.

Lending Institution Policies: Lending institutions have gradually become more aware of the flood hazards associated with properties located in floodland areas. The interest of lending institutions in the possible flood-prone status of property has been intensified as a result of the Federal Flood Disaster Protection Act of 1973 which expanded the National Flood Insurance Program. This Act requires the purchase of flood insurance for a structure within a flood hazard area when the purchaser seeks a mortgage through a federally supervised lending institution. The private lending institutions in the southeastern Wisconsin area have largely assumed the responsibility for the determination of whether or not a property is in a flood-prone area. This information is obtained by the lending institution from the local units of government and the Regional Planning Commission. Indications are that the lending institutions are not reluctant to provide mortgages on flood-prone structures provided that federal flood insurance is secured by the owner of the property.

Realtor Policies: As a result of an executive order by former Governor Patrick Lucey of Wisconsin on November 26, 1973, real estate brokers, salesmen, or their agents are strongly urged to properly inform potential purchasers of property of any flood hazards which may exist at the site. The function of this floodland management measure is to reduce the unwitting acquisition or construction of flood-prone structures by providing flood hazard information to prospective buyers.

Community Utility Policies: Local communities may adopt policies relating to the extension of certain public utility services that discourage construction in flood-prone areas. Such policies should relate to the extension of streets as well as of such utilities as sanitary sewers and water mains. The location and size or capacity of utility facilities tend to influence the location of urban development. For example, selection of a sewer alignment that parallels and lies close to or within a floodplain or terminates at the edge of a floodplain may, in the absence of other land use controls, result in the construction of flood-prone residential, commercial, and industrial development. The sanitary sewerage system development objectives and standards which have been incorporated into the overall development objectives and standards for the Kinnickinnic River watershed specify that floodlands should not be served by sanitary sewers, and that analyses related to the sizing of sanitary sewer system components should not assume the ultimate urbanization of those floodlands. Similar objectives and standards can be established for water supply, transportation, and other facilities and services by the local units of government and other agencies having responsibilities for such services and utilities in the Kinnickinnic River watershed. In addition to contributing to sound floodland management, community utility policies that are restrictive in serving flood-prone areas may have a significant economic benefit in that the unit cost of utilities and services constructed in flood-prone areas is normally higher than the unit cost of such facilities and services constructed in nonflood-prone areas. The incremental costs associated with sanitary sewer construction in flood-prone areas will also include higher treatment cost as the result of potentially increased clear water infiltration and inflow problems that will probably develop in floodlands.

Emergency Programs: The function of an emergency program is to minimize the damage and disruption associated with flooding through a coordinated preplanned series of actions to be taken when a flood is impending or occurring. Such a program may include a variety of devices and techniques[11] such as installation of remote upstream stage sensors and alarms, patrolling of riverine areas to note when bankful conditions are imminent, monitoring of National Weather Service flash flood watch and warning bulletins during periods when rainfall or snowmelt are occurring or are anticipated, emergency messages broadcast to community residents over radio and television, use of police patrol cars or other vehicles equipped with public address systems, a siren warning system employing a special pattern to indicate that flooding is occurring, preplanned road closures and evacuation of residents, and mobilization of portable pumping equipment to relieve the surcharge of sanitary sewers.

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[11] *William K. Johnson, Physical and Economic Feasibility of Nonstructural Flood Plain Management Measures, U. S. Army Corps of Engineers—Hydrologic Engineering Center and Institute for Water Resources, May 1977, 281 pp.*

HYDROLOGIC-HYDRAULIC CONSEQUENCES OF COMMITTED CHANNEL MODIFICATIONS AND PLANNED LAND USE

The principal purpose of developing and calibrating the water resource simulation model under the Kinnickinnic River watershed planning program, as described in Chapter VIII of this report, was to provide a tool for quantifying watershed hydrologic, hydraulic, and water quality characteristics under existing and future development conditions within the watershed. The results of applying the hydrologic and hydraulic submodels to the entire watershed for three watershed land use-floodland development conditions are described immediately below. Additional model applications to portions of the watershed and its stream system for plan design and evaluation purposes are discussed in Chapter VIII and in subsequent sections of this chapter.

Procedure

Watershedwide applications of the simulation model were made for three combinations of floodland and nonfloodland development conditions in order to quantify the probable impact of future urban development in the Kinnickinnic River watershed. The three development conditions are schematically illustrated in Figure 60 and consist of:

- Existing (1975) Land Use and Floodland Development and Channel Conditions—90 percent of the total area of the watershed in urban land use and 10 percent in rural land use outside of the floodlands in combination with 13.6 miles of existing major channel modifications.

- Existing (1975) Land Use and Floodland Development Conditions with Committed Channel Modifications—same as Condition 1 plus the following additional major channel modifications: lowering, widening, and lining with concrete along the 2.71-mile reach of Wilson Park Creek bounded on the downstream end by W. Euclid Avenue (River Mile 0.32) and at the upstream end by S. 6th Street (River Mile 3.03); channel modification and removal of bridges and bridge abutments along the 0.62-mile-long reach of the Kinnickinnic River bounded at the downstream end by S. 5th Street extended (River Mile 2.70) and at the upstream end by S. 13th Street (River Mile 3.32).

- Year 2000 Plan Land Use and Floodland Conditions Including Committed Channel Modifications—94 percent of the total area of the watershed in urban land use and 6 percent in agriculture and other open areas such as streams and unused lands with no additional floodland development relative to 1977 conditions, with the exception of the committed channel modifications identified above. The 6 percent of the watershed area expected to be in nonurban uses in the year 2000 will be distributed throughout the watershed.

The hydrologic and hydraulic submodels were applied to each of the three combinations of floodland and nonfloodland development conditions using the full available meteorologic data base consisting of 37 years of data. Each of these model applications yielded corresponding flood flows for the 37-year period at 15 selected points in the watershed—six on the Kinnickinnic River, seven on Wilson Park Creek, and two on Lyons Park Creek—as shown on Map 46. The 15 locations selected for comparison of flood flows under the three watershed development conditions were chosen so as to include the Kinnickinnic River and its major tributaries.

The series of simulated flood flows at each of the 15 sites was used to develop log-Pearson Type III discharge-frequency relationships to each selected location. Inasmuch as discharge-frequency relationships are concise representations of the watershed or subwatershed flood flow characteristics, these discharge-frequency relationships were selected as an effective means for comparing and contrasting the hydrologic-hydraulic response of the watershed to the three combinations of development in floodland and nonfloodland areas.

The hydraulic response of the watershed to the three combinations of floodland and nonfloodland development was determined by computing and contrasting the 100-year recurrence interval flood stages for each of the floodland and nonfloodland development conditions. The impact of the various combinations of floodland and nonfloodland development also was quantified by computing and comparing the average annual monetary flood risks for selected flood-prone reaches under existing (1975) and year 2000 plan development conditions.

Existing Land Use-Floodland Conditions

The watershed land surface and stream system were represented as shown on Map 40 of this report for the purpose of simulating 1977 conditions with the Hydrologic Submodel and Hydraulic Submodel 1. As shown on that map, seven land segment types and 29 land segments were required to represent the surface of the watershed outside of the floodland areas. The 15.5 lineal miles of floodland in the modeled portion of the watershed stream system were represented by 13 stream reaches which are also shown on Map 40 of this report.

Inasmuch as Hydraulic Submodel 2 also was applied in order to obtain flood stage profiles, the following types of channel data for 1977 conditions were prepared for the 15.5 miles of stream system: channel floodplain cross sections at an average spacing of about 500 feet, Manning roughness coefficient for each channel and floodplain at each cross section, and hydraulic structure data.

The hydrologic and hydraulic submodel applications yielded a flood flow discharge-frequency relationship at each of 15 locations in the watershed. Table 70 presents 5-, 10-, 50-, 100-, and 500-year recurrence interval flood flow discharges for each of the 15 selected sites. One hundred-year recurrence interval flood flows for up to three different conditions at each of the 15 selected sites are shown on Map 46.

Graphical discharge-frequency relationships for five selected locations are presented in Figures 61 to 65. The discharge-frequency relationship for the Kinnickinnic River at its confluence with the Milwaukee River (River Mile 0.00) is shown in Figure 61, whereas Figure 62 shows the discharge-frequency relationship for the Kinnickinnic River at S. 16th Street (River Mile 3.58), Figure 63 shows the discharge-frequency relationship for Wilson Park Creek at its confluence with the Kinnickinnic River (River Mile 0.00), Figure 64 shows the discharge-frequency relationship for Wilson Park Creek at W. Layton Avenue (River Mile 3.51), and Figure 65 shows the discharge-frequency relationship for Lyons Park Creek at its confluence with the Kinnickinnic River (River Mile 0.00).

The 10-, 50-, and 100-year recurrence interval discharges were used to generate flood stages for 15.5 miles of the watershed stream system with the computed stages being obtained at an average spacing of 500 feet. Resulting 10-, 50-, and 100-year recurrence flood stages are presented in Appendix D.

Existing Land Use with
Committed Channel Modifications

Committed Channel Modifications on the Kinnickinnic River: As described in Chapter VI of this report, prior to the July 1976 initiation of SEWRPC staff work on the preparation of the watershed plan, the Milwaukee-Metropolitan Sewerage Commissions and the City of Milwaukee took steps to solve the flood problem along the S. 6th to S. 16th Street reach of the Kinnickinnic River by means of implementation of bridge removal or alteration and channel modification. The sequential actions of the Milwaukee-Metropolitan Sewerage Commissions, City of Milwaukee, Kinnickinnic River Watershed Committee, the Corps of Engineers, and SEWRPC are described in Chapter VI. The preliminary plans for channel modification and bridge removal include:

- Removal of the restrictions caused by the abandoned North Shore Railroad crossing; removal of the bridges at S. 7th Street, S. 8th Street, S. 9th Street, S. 10th Street, S. 11th Street, S. 12th Street, S. 14th Street, S. 15th Street, and S. 15th Place; and removal and replacement of the bridges at S. 6th Street, S. 9th Place, S. 13th Street, and S. 16th Street. Therefore, the bridge removal and replacement portion of the preliminary design consists of the removal without replacement of 10 crossings along a 0.9-mile-long reach of the Kinnickinnic River and the removal and replacement of four crossings in that reach.

- Reconstruction of the channel through the reach bounded at the upstream end by S. 6th Street (River Mile 2.81) and at the downstream end by S. 5th Street extended (River Mile 2.70). This reconstruction would consist of changes in the alignment to form a smoother horizontal alignment and flow pattern, channel widening to increase hydraulic capacity, renewal of concrete bottom and sidewalls to decrease hydraulic resistance, and flattening of the channel slope near the lower end of the reach to decrease flow velocities so as to prevent the occurrence of supercritical or unstable flow in the reach.

- Removal of the vertical sidewalls located on the north side of the Kinnickinnic River in the vicinities of S. 8th Street and S. 12th Street.

- Construction of earthen berms or concrete floodwalls along the top of the existing channel banks so as to provide two feet of freeboard above the 100-year recurrence interval design flood stage.

The proposed alterations in this reach are shown on Map 47.

Committed Channel Modifications on Wilson Park Creek: As discussed in Chapter V of this report, major channelization has been applied to the entire 5.34-mile length of the Wilson Park Creek extending from its confluence with the Kinnickinnic River upstream to the City of Milwaukee-City of Cudahy boundary. About 2.5 miles of the major channelization consist of a constructed turf-lined channel generally having a trapezoidal shape. More specifically, the turf channel consists of a 0.36-mile-long reach bounded at the downstream end by W. Euclid Avenue (River Mile 0.32) and at the upstream end by W. Morgan Avenue (River Mile 0.68), and a 2.16-mile-long reach bounded at the downstream end by S. 27th Street (River Mile 0.87) and at the upstream end by S. 6th Street (River Mile 3.03).

The Milwaukee-Metropolitan Sewerage Commissions have prepared plans for additional channel modifications in this reach in order to increase its flood-carrying capacity.[12] These would consist of lowering the stream bed profile by from 2.5 to 6.0 feet through the reach, forming a trapezoidal section with a bottom width of about 20 feet, and lining the channel bottom portion of the sidewalls with concrete. All bridges in this reach have already been constructed in such a manner that their inverts match the lowered stream bed. The proposed stream bed profile for Wilson Park Creek is shown in Appendix C, as are typical proposed channel cross sections(also see Map 47A, p. 363).

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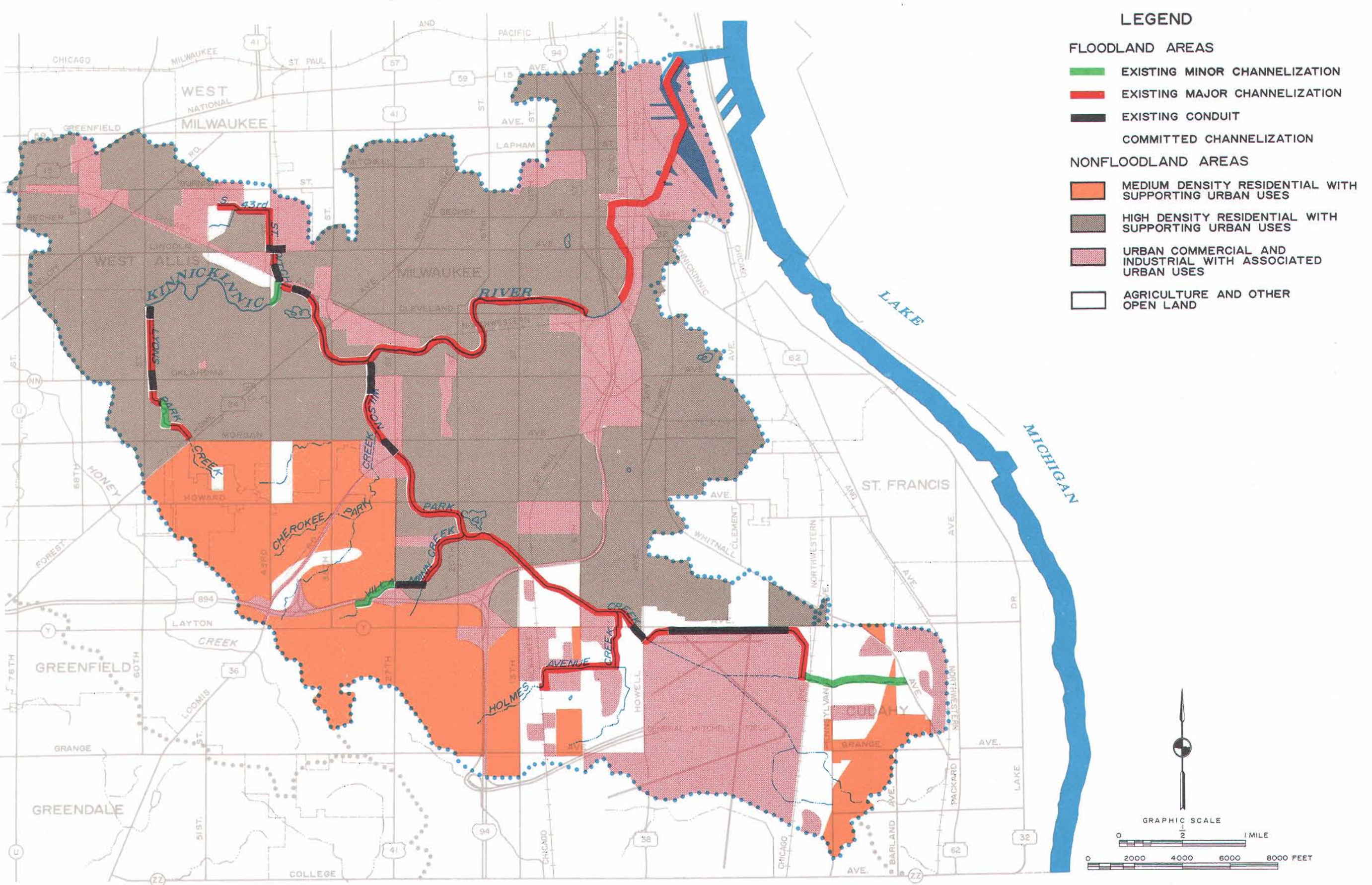
[12] *See Milwaukee-Metropolitan Sewerage Commissions channel bottom profiles sheet titled "S. 20th Street to Kinnickinnic River Parkway" (Contracts No. 520, 534, 562, 685, and 749) and the channel bottom profile sheet titled "S. Howell Avenue to S. 20th Street" (Contracts No. 598, 632, and 707).*

Figure 60

REPRESENTATION OF EXISTING AND FUTURE FLOODLAND AND NONFLOODLAND DEVELOPMENT CONDITIONS IN THE KINNICKINNIC RIVER WATERSHED

Existing (1975) Land Use and Floodland Development and Channel Conditions



Existing (1975) Land Use and Floodland Development Conditions with Committed Channel Modifications

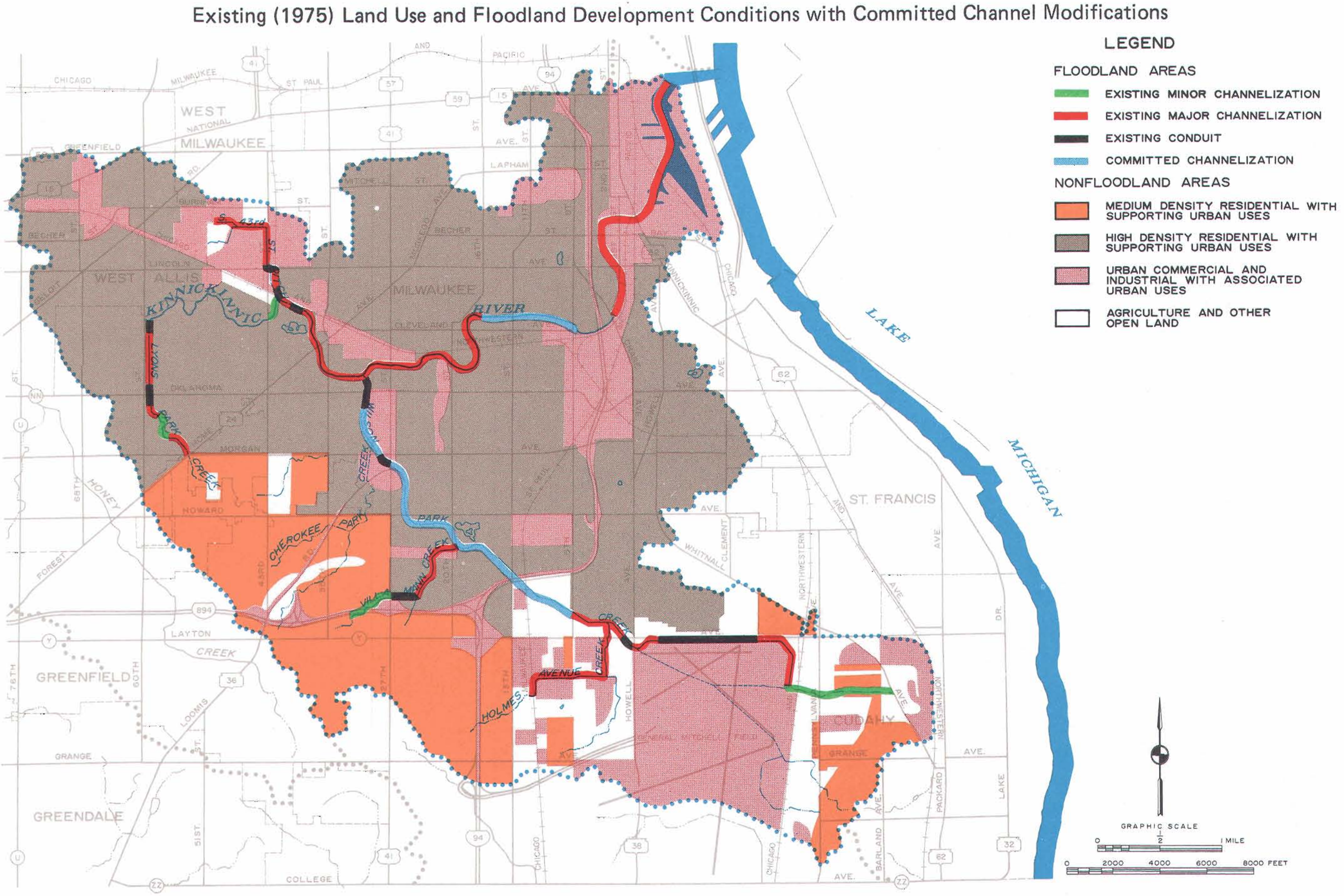
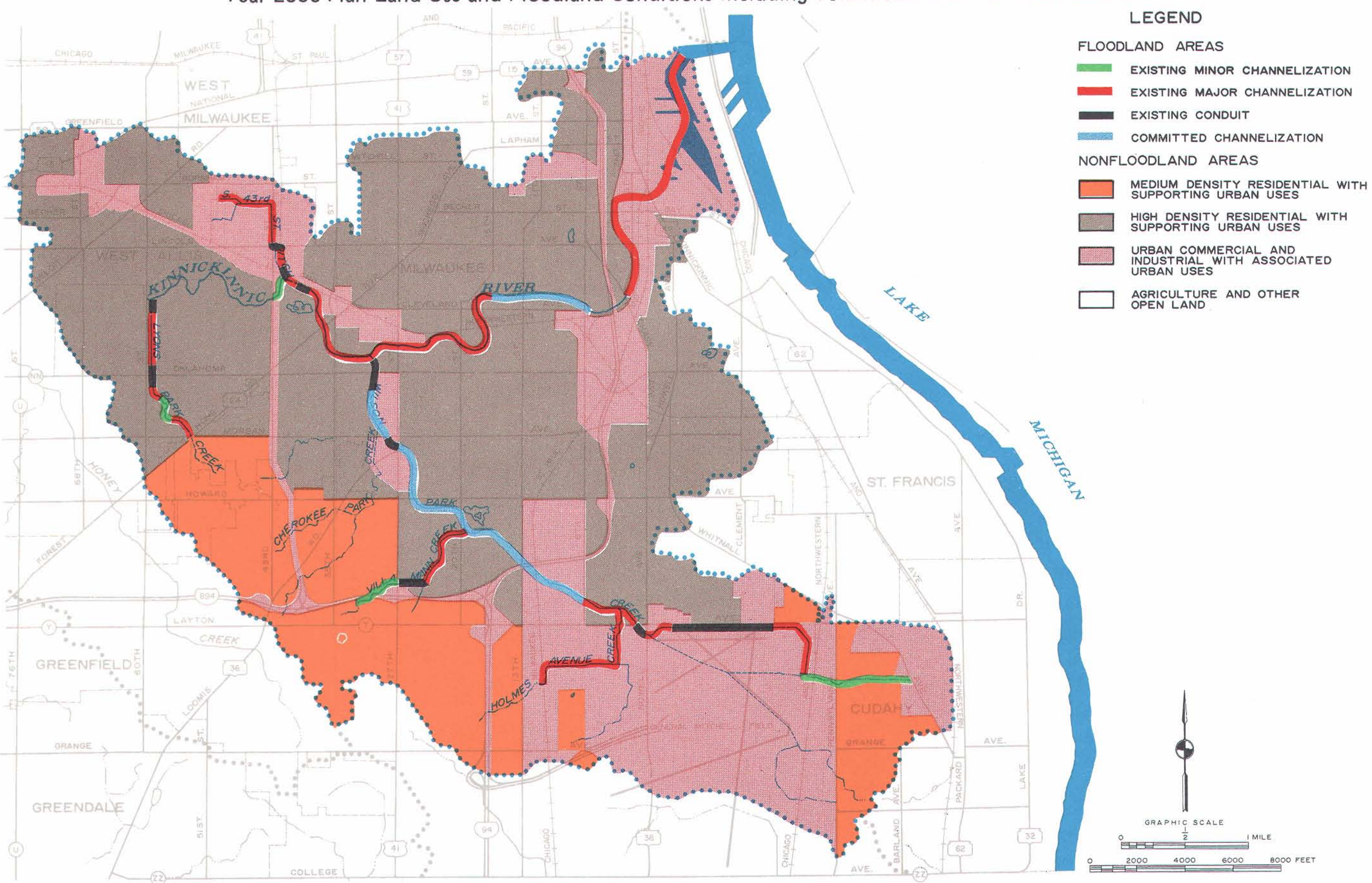


Figure 60 (continued)

Year 2000 Plan Land Use and Floodland Conditions Including Committed Channel Modifications



Source: SEWRPC.

Purpose of the Analysis: The above-committed channel modifications on the Kinnickinnic River and Wilson Park Creek are intended to achieve a substantial reduction in flood stages through the affected reaches. Such channel modifications also have the potential to alter downstream flood flows by reducing available channel-floodplain storage or by altering the response time of the watershed to major rainfall or rainfall-snowmelt events. Accordingly, a simulation analysis was conducted of the committed channel modifications in combination with the existing land use in order to quantify the probable impact of the committed channel modifications on both flood flows and flood stages in the watershed.

The watershed land surface and stream system were represented as shown on Map 40—with the exception of those portions of the Kinnickinnic River and Wilson Park Creek where the channel cross sections and stream bed profile were to be modified—for the purpose of simulating the hydrologic and hydraulic behavior of the watershed under existing land use with committed channel modifications.

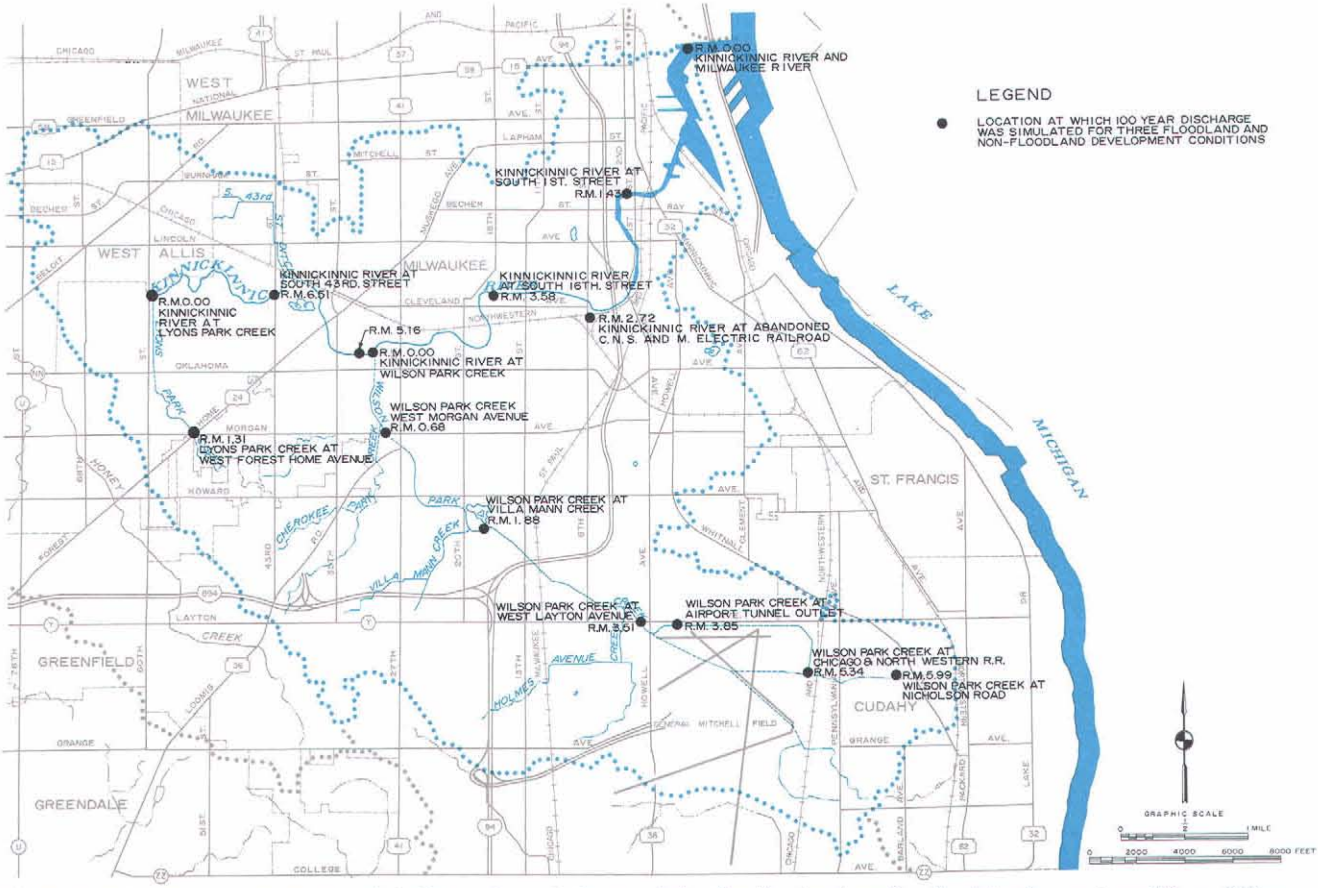
Results: Application of the hydrologic and hydraulic model using 37 years of meteorologic data yielded flood flow discharge-frequency information for each of the 15 selected locations in the basin. Table 70 presents 5-, 10-, 50-, 100-, and 500-year recurrence interval flood flows for each of the 15 sites. Supplemental computations yielded 10-, 50-, and 100-year recurrence interval flood stages for the simulated portion of the stream system which are shown in Appendix E. Graphical discharge-frequency relationships for five selected locations on the watershed stream system are presented in Figures 61 to Figure 65.

Year 2000 Plan Land Use-Floodland Conditions with Committed Channel Modifications

The recommended year 2000 land use plan for the Kinnickinnic River watershed is described in Chapter XI of this report. That plan calls for a conversion of about one square mile of land from rural to urban use by the year 2000. The planned conversion of land from rural to urban and changes within the urban use category toward increased impervious area use may produce changes in the flood flow characteristics of the watershed, particularly in those stream reaches immediately downstream of areas that will experience urbanization. Simulation of the year 2000 plan land use in combination with committed channel modifications was intended to quantify the changes in flood flow characteristics associated with the planned conversion from rural to urban uses. More specifically, the purpose of the simulation was to determine: where changes in flood flow characteristics may be expected, the magnitude of the changes, and the possible significance of the changes with respect to the aggravation of existing flood problems or to the development of new flood problems.

Map 46

EFFECTS OF FLOODLAND AND NONFLOODLAND DEVELOPMENT ON 100-YEAR FLOOD FLOWS IN THE KINNICKINNIC RIVER WATERSHED



Analysis conducted under the watershed study indicates that, relative to existing floodland and nonfloodland development conditions, 100-year flood flows in the watershed under the year 2000 plan on land use conditions with committed channel modifications may be expected to increase by up to 30 percent at 15 locations in the watershed, with an average increase of 7 percent.

Source: SEWRPC.

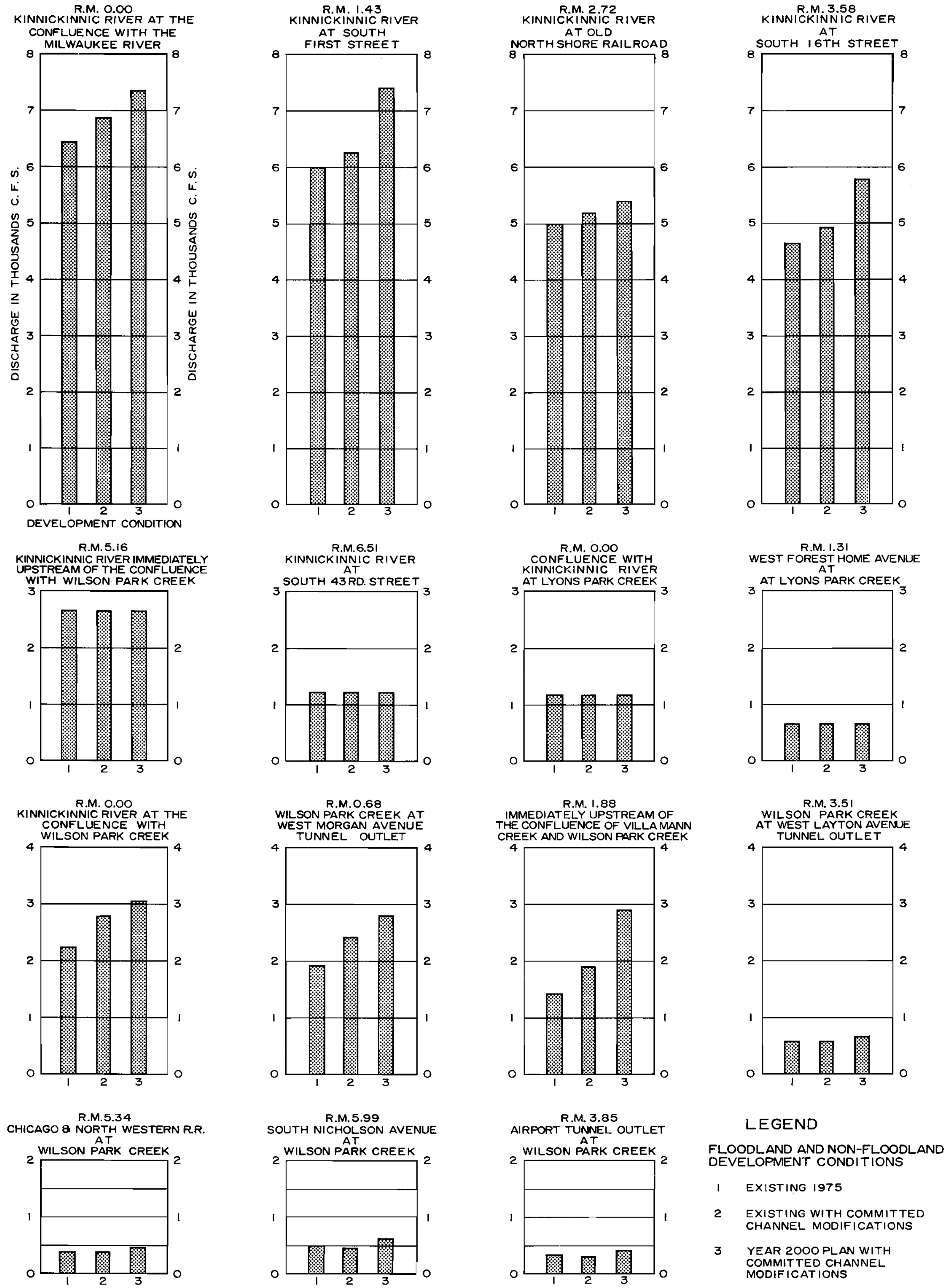
The watershed land surface and stream system were represented as shown on Map 48 for the purpose of simulating hydrologic and hydraulic behavior of the watershed under year 2000 plan land use with committed channel modifications. As shown on Map 48, seven different land segment types and 29 land segments were required to represent the surface of the watershed outside of the floodland areas. The 15.5-mile floodland in the modeled portion of the watershed stream system was represented for Hydraulic Submodel 1 by 13 stream reaches which are also shown on Map 48. Detailed channel-floodplain data were assembled for Hydraulic Submodel 2.

Application of the hydrologic and hydraulic model using 37 years of meteorological data yielded a flood flow discharge-frequency relationship for each of 15 selected locations on the watershed stream system. Table 70 presents the 5-, 10-, 50-, 100-, and 500-year recurrence interval food flow discharges for each of the 15 sites. One hundred-year recurrence interval flood flows for each of the 15 sites are shown on Map 46 for comparison to other floodland and nonfloodland development conditions. Graphical discharge-frequency relationships for five selected locations are presented in Figures 61 through 65 for comparison to other floodland and nonfloodland development conditions.

Discussion of the Hydrologic-Hydraulic Response of the Watershed to Committed Channel Modifications and Year 2000 Planned Land Use

The 5- through 50-year recurrence interval discharge-frequency data presented in Table 70 and the discharge-frequency relationships shown graphically in Figures 61 through 65 demonstrate and quantify the expected hydrologic-hydraulic impact of channel modifications and land use changes. The following discussion draws on the results of the watershedwide simulation modeling to identify the locations at which flood discharge and stage changes occur, and to indicate the magnitude and significance of those impacts.

Map 46 (continued)



Source: SEWRPC.

Table 70

HYDROLOGIC EFFECT OF FLOODLAND AND NONFLOODLAND CONDITIONS
IN THE KINNICKINNIC RIVER WATERSHED

Location			Recurrence Interval (years)	Existing (1975) Condition Discharge (cfs)	Existing with Committed Channel Modification Condition		Year 2000 Plan with Committed Channel Modification Condition	
Stream	River Mile	Description			Discharge (cfs)	Relative to Existing Conditions (ratio)	Discharge (cfs)	Relative to Existing Conditions (ratio)
Kinnickinnic River	0.00	Confluence with Milwaukee River	5	3,100	3,350	1.1	3,700	1.2
			10	3,800	4,100	1.1	4,550	1.2
			50	5,600	5,900	1.1	6,500	1.2
			100	6,400	6,800	1.1	7,400	1.2
			500	8,600	9,000	1.1	9,800	1.1
	1.43	S. First Street	5	2,900	3,200	1.1	3,600	1.2
			10	3,600	3,850	1.1	4,350	1.2
			50	5,200	5,500	1.1	6,200	1.2
			100	6,000	6,300	1.1	7,000	1.2
			500	8,000	8,300	1.0	9,200	1.2
	2.72	Old North Shore Railroad	5	2,450	2,700	1.1	3,100	1.3
			10	3,000	3,250	1.1	3,750	1.3
			50	4,350	4,600	1.1	5,300	1.2
			100	5,000	5,200	1.0	6,000	1.2
			500	6,700	6,800	1.0	7,900	1.2
	3.58	S. 16th Street	5	2,300	2,550	1.1	2,950	1.3
			10	2,800	3,050	1.1	3,550	1.3
			50	4,050	4,300	1.1	5,000	1.2
			100	4,650	4,850	1.0	5,700	1.2
			500	6,200	6,300	1.0	7,400	1.2
	5.16	Immediately upstream of the confluence with Wilson Park Creek	5	1,350	1,350	1.0	1,350	1.0
			10	1,600	1,600	1.0	1,600	1.0
			50	2,250	2,250	1.0	2,250	1.0
			100	2,550	2,550	1.0	2,550	1.0
			500	3,300	3,300	1.0	3,300	1.0
	6.51	S. 43rd Street	5	660	660	1.0	660	1.0
			10	790	790	1.0	790	1.0
			50	1,050	1,100	1.0	1,100	1.0
			100	1,200	1,200	1.0	1,200	1.0
			500	1,500	1,500	1.0	1,500	1.0
Wilson Park Creek	0.0	Confluence with Kinnickinnic River	5	1,200	1,500	1.2	1,850	1.5
			10	1,450	1,800	1.2	2,150	1.5
			50	2,000	2,450	1.2	2,800	1.4
			100	2,250	2,750	1.2	3,050	1.4
			500	2,850	3,500	1.2	3,600	1.3
	0.68	W. Morgan Avenue Tunnel Outlet	5	1,100	1,350	1.2	1,650	1.5
			10	1,300	1,600	1.2	1,950	1.5
			50	1,700	2,200	1.3	2,600	1.5
			100	1,900	2,450	1.3	2,850	1.5
			500	2,300	3,000	1.3	3,500	1.5
	1.88	Immediately upstream of the confluence with Villa Mann Creek	5	810	1,000	1.2	1,350	1.7
			10	970	1,250	1.3	1,600	1.6
			50	1,300	1,700	1.3	2,100	1.6
			100	1,450	1,900	1.3	2,350	1.6
			500	1,800	2,400	1.3	2,850	1.6
	3.51	W. Layton Avenue Tunnel Outlet	5	410	410	1.0	460	1.1
			10	460	460	1.0	520	1.1
			50	550	550	1.0	660	1.2
			100	590	590	1.0	710	1.2
			500	670	670	1.0	850	1.3

Table 70 (continued)

Stream	River Mile	Description	Recurrence Interval (years)	Existing (1975) Condition Discharge (cfs)	Existing with Committed Channel Modification Condition: Discharge (cfs)	Existing with Committed Channel Modification Condition: Relative to Existing Conditions (ratio)	Year 2000 Plan with Committed Channel Modification Condition: Discharge (cfs)	Year 2000 Plan with Committed Channel Modification Condition: Relative to Existing Conditions (ratio)
Wilson Park Creek (continued)	3.85	Airport Tunnel Outlet	5	165[a]	165	1.0	230	1.4
			10	200	200	1.0	275	1.4
			50	285	285	1.0	365	1.3
			100	320	320	1.0	405	1.3
			500	405	405	1.0	495	1.2
	5.34	Chicago & North Western Railway	5	210	210	1.0	335	1.6
			10	255	255	1.0	400	1.6
			50	360	360	1.0	550	1.5
			100	410	410	1.0	620	1.5
			500	530	530	1.0	800	1.5
	5.99	S. Nicholson Avenue	5	205	205	1.0	300	1.5
			10	245	245	1.0	350	1.4
			50	350	350	1.0	450	1.3
			100	380	380	1.0	510	1.3
			500	450	450	1.0	600	1.3
Lyons Park Creek	0.0	Confluence with Kinnickinnic River	5	550	550	1.0	550	1.0
			10	670	670	1.0	670	1.0
			50	980	980	1.0	980	1.0
			100	1,150	1,150	1.0	1,150	1.0
			500	1,500	1,500	1.0	1,500	1.0
	1.31	W. Forest Home Avenue	5	405	405	1.0	405	1.0
			10	475	475	1.0	475	1.0
			50	640	640	1.0	640	1.0
			100	710	710	1.0	710	1.0
			500	860	860	1.0	860	1.0
		Maximum ratio of 10-year discharges				1.3		1.6
		Minimum ratio of 10-year discharges				1.0		1.0
		Median ratio of 10-year discharges				1.0		1.2
		Maximum ratio of 100-year discharges				1.3		1.6
		Minimum ratio of 100-year discharges				1.0		1.0
		Median ratio of 100-year discharges				1.0		1.2

[a] *The decrease in flood flows downstream may be attributed to the attenuating effect produced by the moderate volume of storage available immediately upstream.*

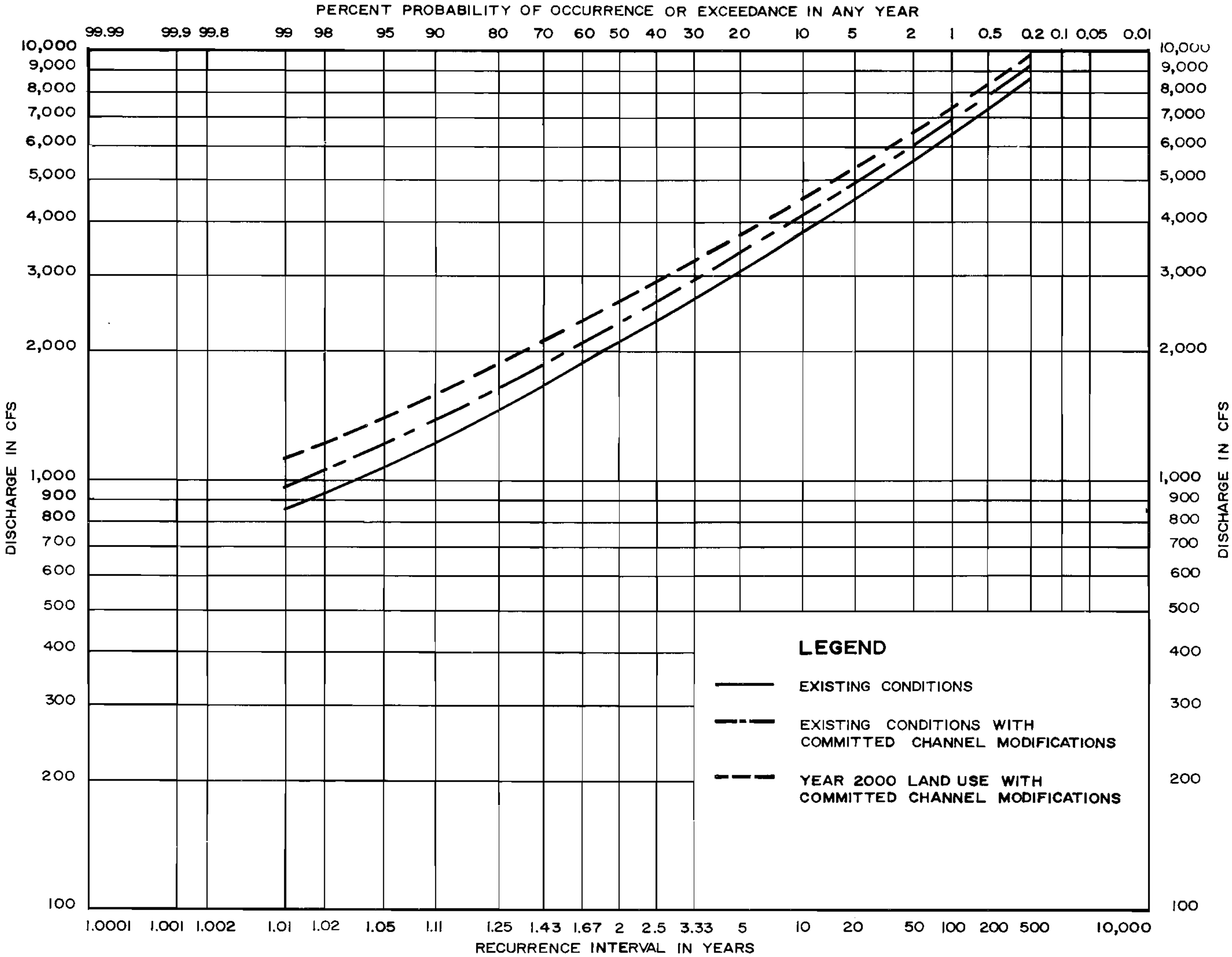
Source: SEWRPC.

Discharge-Frequency Relationships: Figures 61 through 65, which present discharge-frequency relationships for five watershed locations under each of the three land use-floodland conditions, are typical of the discharge-frequency relationships that exist or may be expected to exist within the watershed under various development conditions. It may be noted that the three discharge-frequency curves at each location are approximately parallel with a slight tendency to converge for the more severe flood events. If the discharge-frequency relationships for any two land use-floodland development conditions at a given location on the stream system were exactly parallel, then a constant ratio of flood flows would exist between the two conditions. A slight convergence of discharge-frequency relationships for increasing recurrence intervals indicates that the ratio of flood flows for the two conditions decreases slightly for more infrequent flood events.

Consider, for example, discharge-frequency relationships on the Kinnickinnic River at S. 16th Street (River Mile 3.58) for existing land use-floodland conditions, existing land use-floodland conditions but with committed channel modifications, and year 2000 plan land use-floodland conditions including committed channel modifications. The ratios of 10- and 100-year recurrence interval flood flows for existing land use with committed channel modifications conditions to the comparable flood flows for existing land use-floodland-channel conditions are, respectively, 1.1 and 1.0. The ratios of 10- and 100-year

Figure 61

SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR THE KINNICKINNIC RIVER AT ITS CONFLUENCE WITH THE MILWAUKEE RIVER (RIVER MILE 0.00) UNDER EXISTING AND FUTURE FLOODLAND AND NONFLOODLAND DEVELOPMENT CONDITIONS



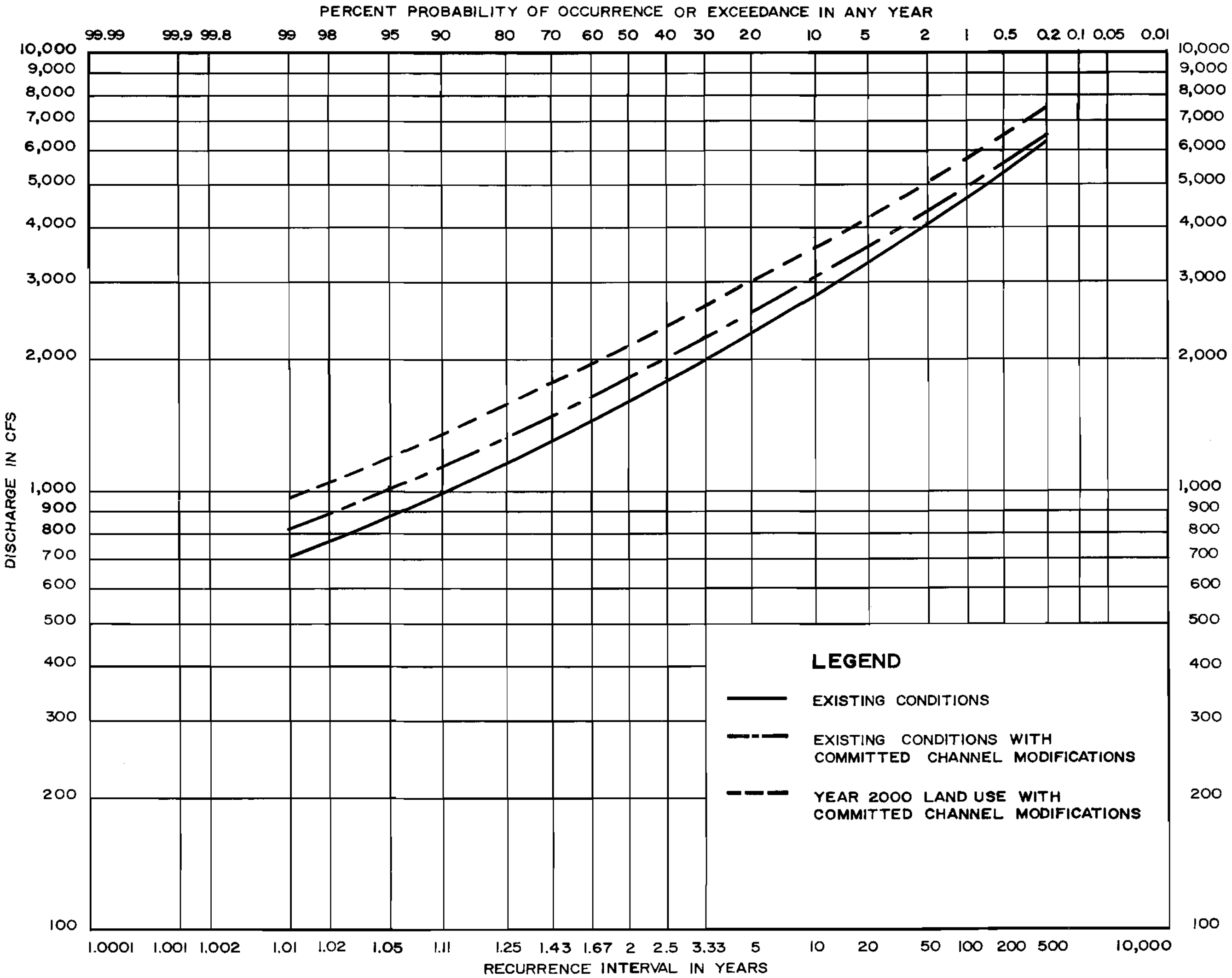
Source: SEWRPC.

recurrence interval flood flows for the year 2000 plan land use-floodland conditions including committed channel modifications to the comparable flood flows for existing land use-floodland-channel conditions are, respectively, 1.3 and 1.2. The relative impact of land use tends to be somewhat less for more rare flood events—as indicated by a slight decrease in the above ratios—because the volume and intensity of rainfall and rainfall-snowmelt associated with the more severe flood saturates the pervious portions of the watershed, causing those areas to behave in a manner similar to impervious areas.

Hydrologic-Hydraulic Impact of Committed Channel Modifications: A comparison of discharge-frequency values for the watershed under existing land use-floodland channel conditions to those that would exist under existing land use with committed channel modifications serves to illustrate the expected impact that the channel modifications have on flood flow characteristics of portions of the watershed. Inasmuch as committed channel modifications are, as discussed above and as shown in Figure 60, applicable to Wilson Park Creek and a portion of the Kinnickinnic River downstream of the Wilson Park Creek-Kinnickinnic River confluence, it follows that the impact of the committed channel modifications will be manifested only along Wilson Park Creek downstream of the committed channel modifications, and on the Kinnickinnic River downstream of the Wilson Park Creek-Kinnickinnic River confluence. That is, channel modifications will have no impact on flood flows along

Figure 62

SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR THE KINNICKINNIC RIVER AT S. 16TH STREET (RIVER MILE 3.58) UNDER EXISTING AND FUTURE FLOODLAND AND NONFLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

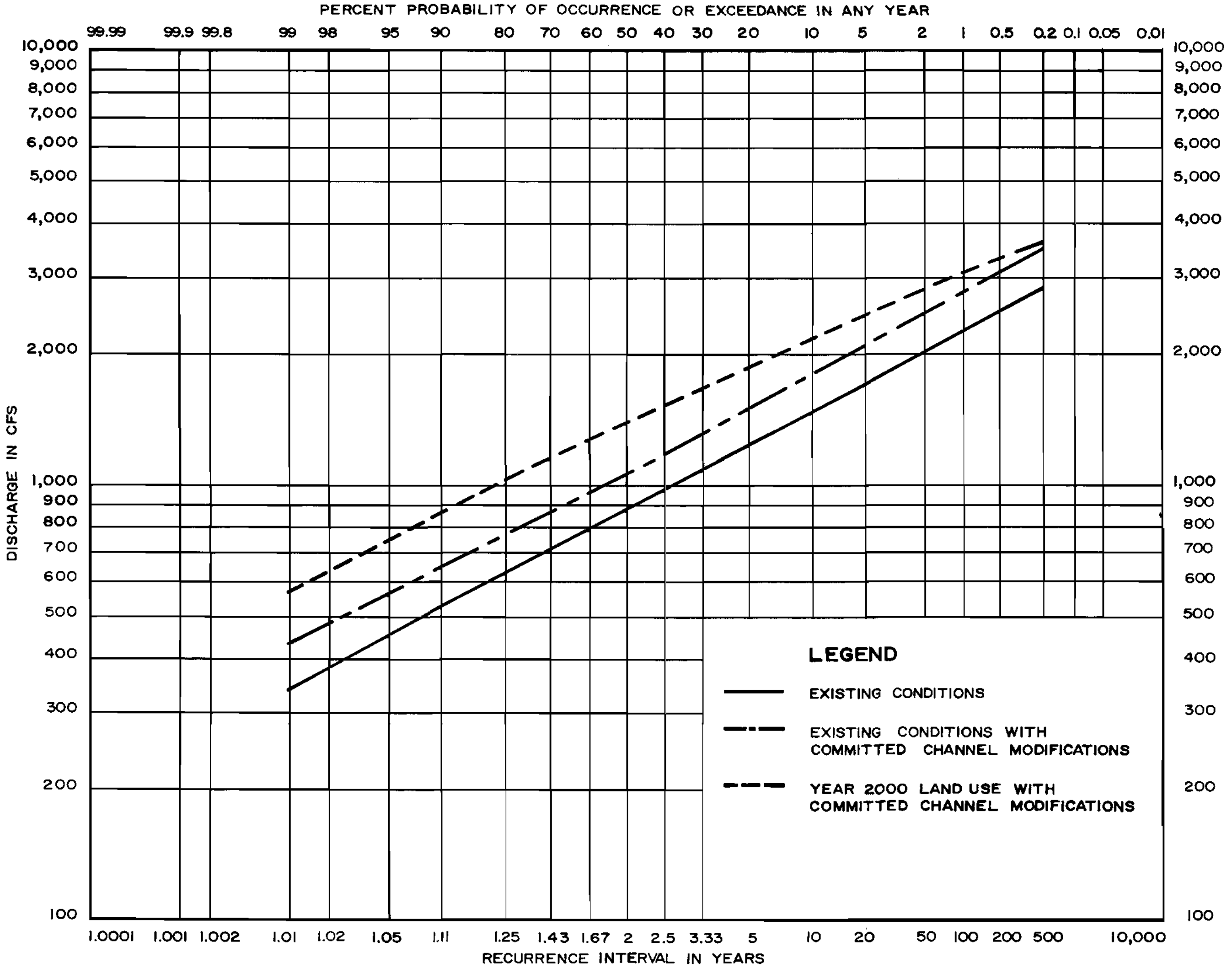
the Kinnickinnic River upstream of the Wilson Park Creek-Kinnickinnic River confluence or along Lyons Park Creek.

Considering the watershed as a whole, the existing land use-floodland-channel conditions' 10-year recurrence interval peak flood discharge at the watershed outlet is 3,800 cfs, whereas under existing land use with committed channel modifications this discharge is 4,100 cfs, or 8 percent greater than the existing condition value. The 100-year recurrence interval peak flood discharge for the watershed outlet under existing land use-floodland-channel conditions is 6,400 cfs, whereas under existing land use with committed channel modifications the discharge is 6,800 cfs, or 6 percent greater than the existing condition value. Therefore, the committed channel modifications may be expected to have only a slight impact on flood flow discharges at the watershed outlet. Similar results, that is, a minor impact of channel modifications on flood flows, were indicated by the simulation modeling for the entire length of the Kinnickinnic River downstream of its confluence with Wilson Park Creek.

Considering the hydrologic results at all of the seven selected sites on Wilson Park Creek and the Kinnickinnic River that are located downstream of committed channel modifications, the ratio of the 10-year recurrence interval peak flood discharge under existing land use with committed channel modifications to this discharge under

Figure 63

SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR WILSON PARK CREEK AT ITS CONFLUENCE WITH THE KINNICKINNIC RIVER (RIVER MILE 0.00) UNDER EXISTING AND FUTURE FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

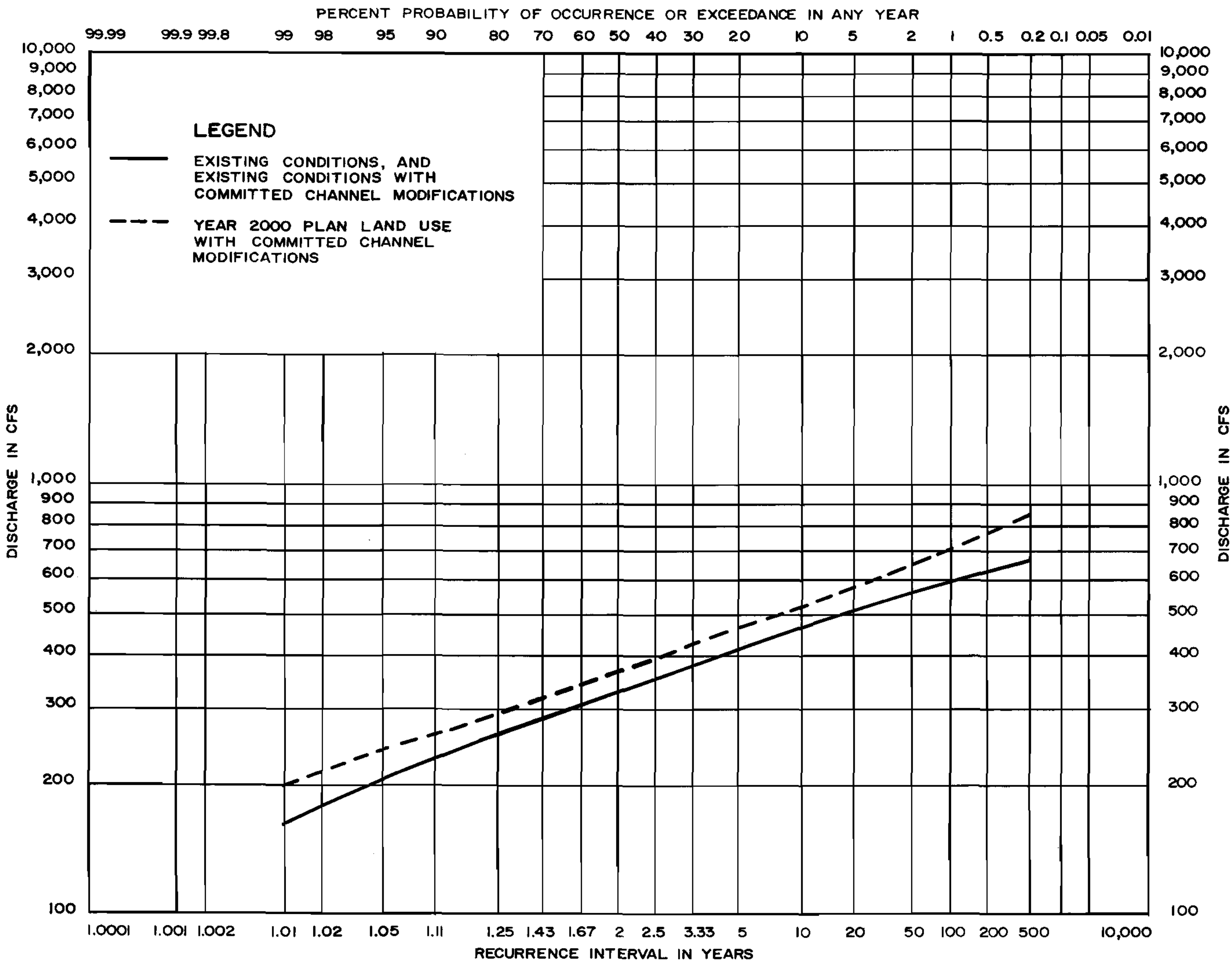
existing land use-floodland conditions ranges from 1.1 to 1.3, with a median value of only 1.2. The ratio of 100-year recurrence interval peak flood discharges under these two conditions ranges from 1.0 to 1.3, with a median value of only 1.1.

The impact of committed channel modifications is greatest along the downstream-most reaches of Wilson Park Creek; that is, within and immediately downstream of the 2.5-mile-long reach of Wilson Park Creek that would be subjected to channel modifications. For example, consider the peak flood discharges on Wilson Park Creek immediately upstream of its confluence with the Kinnickinnic River. The 10-year recurrence interval peak flood discharge under existing land use-floodland-channel conditions is 1,450 cfs compared to a value of 1,800 cfs—24 percent larger—under existing land use with committed channel modifications. The 100-year recurrence interval peak flood discharge at this location under existing land use-floodland-channel conditions is 2,250 cubic feet per second compared to a value of 2,750 cubic feet per second—22 percent greater—under existing land use with committed channel modifications.

The increase in flood flows along Wilson Park Creek as a result of committed channel modifications on Wilson Park Creek should not, however, result in increased flood hazards. The flood flows should be contained within the enlarged channel or within the existing channel.

Figure 64

SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR WILSON PARK CREEK AT W. LAYTON AVENUE TUNNEL OUTLET (RIVER MILE 3.51) UNDER EXISTING AND FUTURE FLOODLAND DEVELOPMENT CONDITIONS



Source: SEWRPC.

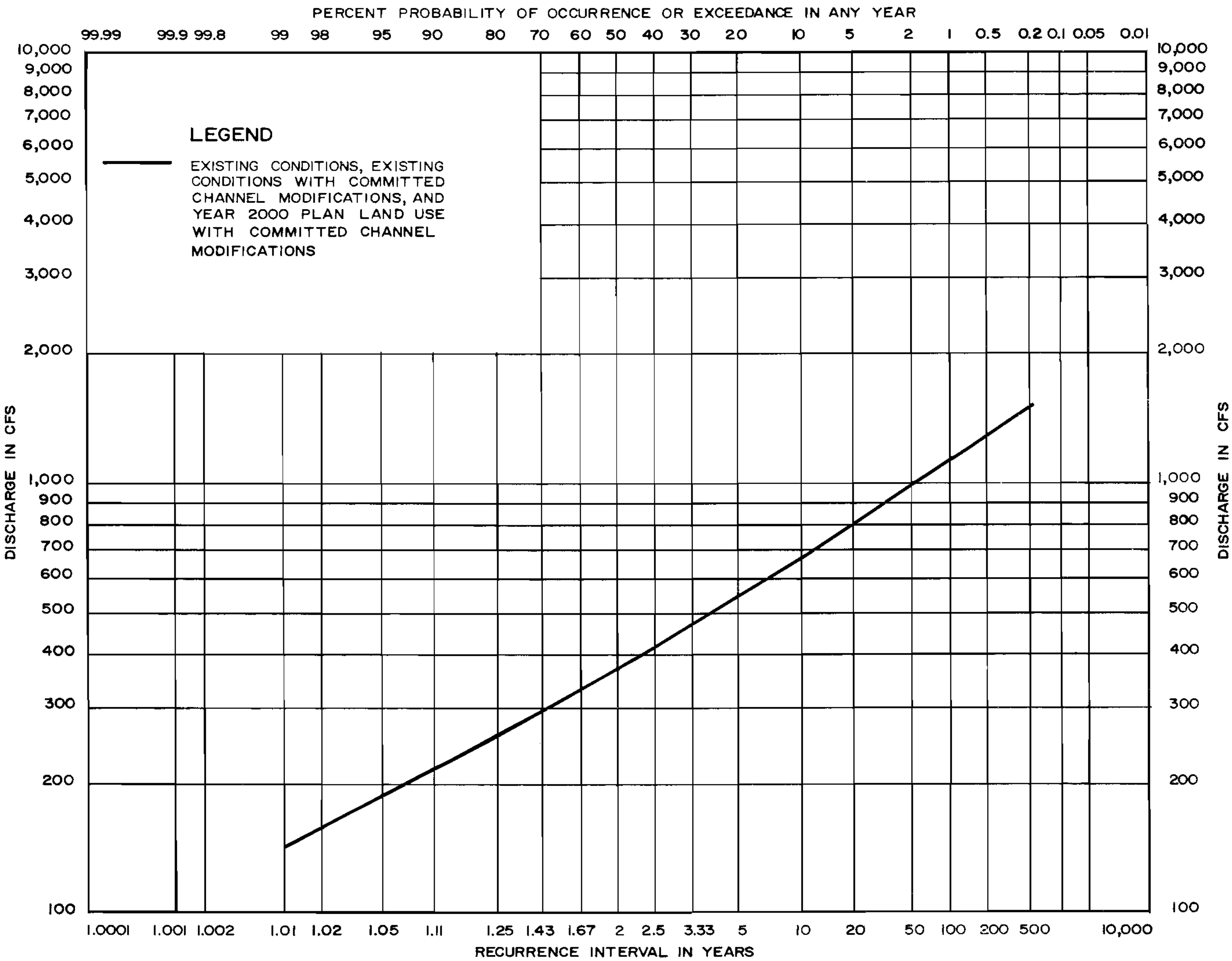
Hydrologic-Hydraulic Impact of Year 2000 Land Use Plan: With respect to existing and potential flood problems, there is concern over the possible hydrologic-hydraulic consequences of the incremental urban development associated with the year 2000 land use plan, particularly when combined with the increased flood flows expected as the result of committed channel modifications. More specifically, it is necessary to know how much larger flood flows and how much higher attendant flood stages may be under year 2000 plan land use and floodland development conditions throughout the watershed relative to the discharges and stages that exist under existing conditions. It is important to reiterate here that the year 2000 plan recommends no significant additional floodland fill and development.

As shown in Figure 60, incremental urban development in the Kinnickinnic River watershed is expected to occur almost entirely within the area tributary to Wilson Park Creek. Therefore, and as was the case with committed channel modifications, the hydrologic-hydraulic impact of incremental urbanization will be restricted to Wilson Park Creek and that reach of the Kinnickinnic River downstream of the confluence of Wilson Park Creek and the Kinnickinnic River.

Considering the watershed as a whole, the 10-year recurrence interval peak flood discharge for year 2000 plan land use-floodland conditions with committed channel modifications is 4,550 cfs, or 11 percent greater than the recurrence interval discharge of 4,100 cfs for existing

Figure 65

SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR LYONS PARK CREEK AT ITS CONFLUENCE WITH THE KINNICKINNIC RIVER (RIVER MILE 0.00) UNDER EXISTING AND FUTURE FLOODLAND DEVELOPMENT CONDITIONS



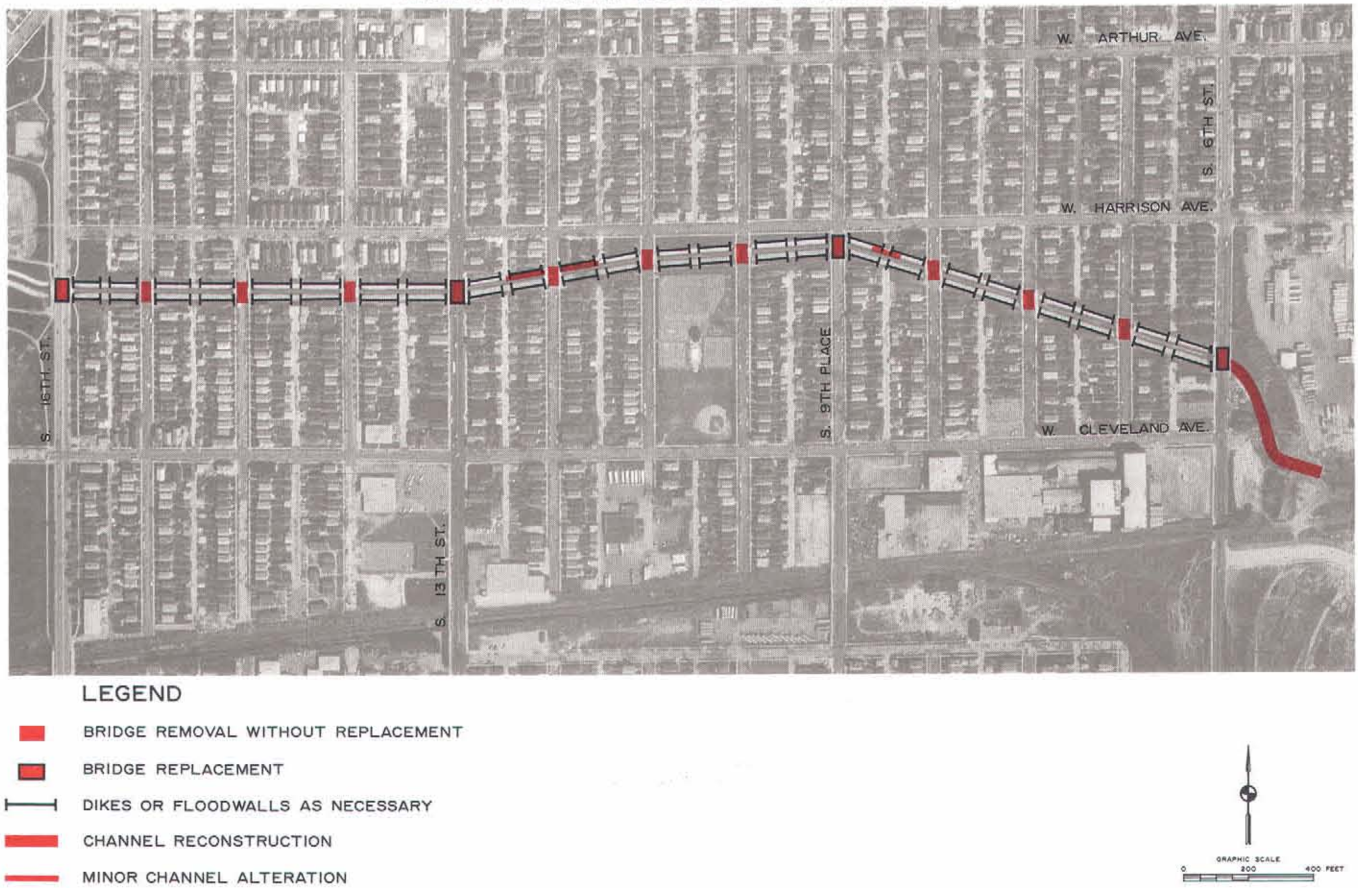
Source: SEWRPC.

land use conditions with committed channel modifications, and 20 percent larger than the recurrence interval discharge of 3,800 cfs for existing land use-floodland-channel conditions. Similarly, the 100-year recurrence interval discharge at the watershed outlet for year 2000 plan land use-floodland conditions with committed channel modifications is 7,400 cfs, or 9 percent greater than this recurrence interval discharge of 6,800 cfs for existing land use conditions with committed channel modifications, and 16 percent greater the recurrence interval discharge of 6,400 cfs for existing land use-floodland-channel conditions. Thus the simulation model studies indicate that the combination of committed channel modifications and additional urban development outside of the floodlands in accordance with year 2000 land use plan recommendations may be expected to cause up to a 20 percent increase in peak flood flows at the watershed outlet.

Considering the hydrologic results at all of the 11 selected sites on Wilson Park Creek and the Kinnickinnic River that are located downstream of committed channel modifications or incremental urban development, the ratio of the 10-year recurrence interval discharge under year 2000 plan land use-floodland development conditions with committed channel modifications to this recurrence interval discharge under existing land use-floodland-channel development conditions ranges from 1.1 to 1.4, with a median value of 1.3. The ratio of

Map 47

COMMITTED CHANNEL MODIFICATIONS ALONG THE KINNICKINNIC RIVER
FROM S. 5TH STREET EXTENDED TO S. 16TH STREET



Following initiation of the watershed study, the Milwaukee-Metropolitan Sewerage Commissions and the City of Milwaukee took steps to resolve the flood problem along the S. 6th to S. 16th Street reach of the Kinnickinnic River by bridge removal and channel modification. The preliminary plans for these actions were incorporated into the watershed plan, were evaluated, and were found to be adequate to carry the 100-year recurrence interval design flow of 6,000 cfs.

Source: SEWRPC.

100-year recurrence interval discharges under these two conditions ranges from 1.1 to 1.6, with a median value of 1.2.

In general, the impact of incremental urban development is the greatest along Wilson Park Creek inasmuch as essentially all the incremental urban development occurs in that tributary area. For example, consider peak flood discharges on Wilson Park Creek immediately above the confluence with the Kinnickinnic River. The 10-year recurrence interval discharge under year 2000 plan land use-floodland conditions with committed channel modifications is 2,150 cfs, or 19 percent greater than the recurrence interval discharge of 1,800 cfs under existing land use with committed channel modifications, and 48 percent more than the recurrence interval discharge of 1,450 cfs under existing land use-floodland-channel conditions. The 100-year recurrence interval peak flood discharge at this location under year 2000 plan land use-floodland conditions with committed channel modifications is 3,050 cfs, or 11 percent greater than the recurrence interval discharge of 2,750 cfs for existing land use with committed channel modifications; and 35 percent greater than the recurrence interval discharge of 2,250 cfs for existing land use-floodland-channel conditions.

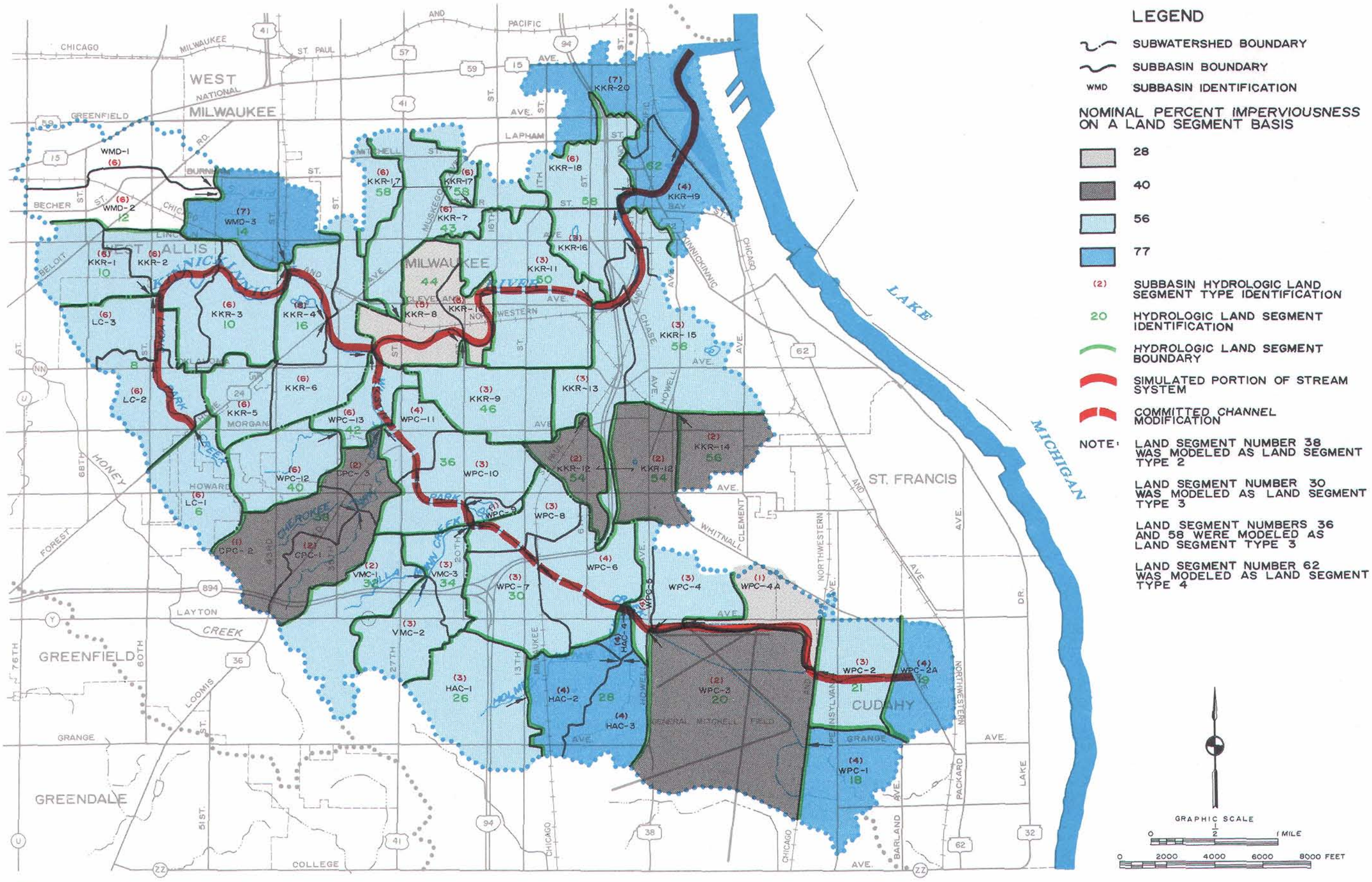
Thus the simulation model studies indicate that the combination of channel modifications plus incremental urban development may be expected to produce 10- and 100-year recurrence interval peak flood flows on Wilson Park Creek and the Kinnickinnic River that are up to 60 percent larger than existing land use-floodland channel condition discharges. The largest increase in peak flood flows may be expected to occur at River Mile 1.88 on Wilson Park Creek within a reach committed to be modified. The increased flood flows are not expected to significantly aggravate flood hazards inasmuch as the existing and committed channel modifications are generally of sufficient capacity to contain the increased 100-year recurrence interval peak flood flows as shown in Appendix C.

Concluding Statement: Hydrologic-Hydraulic Consequences of Committed Channel Modifications and Planned Land Use

The combination of committed channel modifications and incremental urbanization in the Kinnickinnic River watershed may be expected to produce 100-year recurrence interval peak flood flow increases of up to 60 percent. These relative increases are small compared to those obtained in the Menomonee River watershed planning program—up to a six-fold increase in 100-year flood

Map 48

REPRESENTATION OF THE KINNICKINNIC RIVER WATERSHED FOR HYDROLOGIC-HYDRAULIC SIMULATION: YEAR 2000 PLAN CONDITIONS WITH COMMITTED CHANNEL MODIFICATIONS



The watershed land surface and stream system were represented as shown for the purpose of simulating the hydrologic-hydraulic behavior of the watershed under the year 2000 plan land use conditions, including committed channel modifications. Simulation results indicate that year 2000 plan conditions will have a minimal impact on flood flow throughout the watershed. For 15 locations on the watershed stream system, the ratio of year 2000 and existing condition 100-year recurrence interval flood flows ranges from 1.0 to 1.6, with a median value of only 1.2.

Source: SEWRPC.

flows—for uncontrolled development in floodland and nonfloodland areas of the basin.[13] This is to be expected inasmuch as the Kinnickinnic River watershed is already highly urbanized. Urban land uses occupy 90 percent of the watershed area and 88 percent of the portion of stream system selected for hydrologic-hydraulic simulation that has been subjected to some form of channel modification. The existing high degree of floodland and nonfloodland development creates a situation in which additional disruptive hydrologic-hydraulic modifications are highly unlikely. The intensive urbanization that has occurred in the Kinnickinnic River watershed, however, has resulted in the generation of very high flood flows compared to those expected for rural or slightly urbanized watersheds similar in size, soil type, and topographic conditions. For example, the 100-year recurrence interval peak flood discharge of 3,050 cfs at the outlet to the 11.2-square-mile Wilson Park Creek subwatershed—270 cfs per square mile—under year 2000 plan land use with committed channel modifications is five times larger than the 590 cfs 100-year discharge for the 10.5-square-mile—56 cfs per square mile—rural headwater area of the Little Menomonee River in Ozaukee County. Inasmuch as these two areas are similar in size, soil type, topography, and meteorology, the large differences in 100-year flood flows are attributable to urbanization.

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[13] *SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume Two, Alternative Plans and Recommended Plan, Chapter IV, "Alternative Floodland Management Measures," October 1976.*

SELECTION OF FLOOD-PRONE REACHES

Development of a floodland management element of a comprehensive plan for the Kinnickinnic River watershed requires that the existing and probable future flood-prone reaches within the watershed be identified so that alternative floodland management measures may be developed for those reaches which have or may be expected to have severe flood problems. A multistep approach was used to determine the stream reaches for which alternative floodland management measures should be developed, recognizing in that approach the committed channel improvements agreed upon by the Watershed Committee during the course of the study and the year 2000 land use plan. The approach utilized hydrologic-hydraulic simulation of existing land use-floodland development conditions as well as the results of the historic flood surveys conducted in the watershed to identify existing flood-prone reaches and areas. The effects of the committed channel improvements on these reaches and areas were then analyzed using hydrologic-hydraulic simulation of existing land use with the committed channel improvements for identification of residual flood-prone areas. The effect of future development and redevelopment within the watershed in accordance with the year 2000 land use plan was then analyzed using hydrologic-hydraulic simulation of the year 2000 land use plan with the committed channel improvements to identify those areas in the watershed which may be expected to be flood-prone under year 2000 conditions without implementation of any further floodland management measures. This final identification of flood-prone reaches and areas indicated only one such reach—along Wilson Park Creek in the City of Cudahy—required further assessment of additional alternative floodland management measures.

ALTERNATIVE FLOODLAND MANAGEMENT PLAN ELEMENTS FOR THE CITY OF CUDAHY

The Flood Problem

The City of Cudahy contains one flood-prone reach of Wilson Park Creek, known locally as the Edgerton Channel, which extends from Whitnall Avenue, River Mile 6.12, to the Chicago & North Western Railway, River Mile 5.34, for a total length of 0.8 mile. For that part of the Kinnickinnic River watershed within the City average, annual monetary flood risks attributable to both primary and secondary flooding are estimated, by application of the economic submodel described in Chapter VIII, at $47,000 under existing conditions; $47,000 under existing and committed modified channel conditions; and $93,500 under year 2000 plan land use and committed modified channel conditions. The simulation model studies indicated that the committed channel modifications located downstream from the City from S. 6th Street on Wilson Park Creek to S. 5th Street extended on the Kinnickinnic River may be expected to have little effect with regard to reducing flood damages in the City, causing a reduction in average annual damages of less than 1 percent. Conversely, the studies indicated that further development in accordance with the year 2000 land use plan may be expected to cause average annual damages to increase by more than 90 percent. It should be emphasized that the increase in average annual monetary damages under year 2000 plan conditions is solely attributable to anticipated changes in upstream land use development in the subwatershed, inasmuch as the analysis presumes that no new flood-prone structures would be constructed in the City of Cudahy. If additional flood-prone development were permitted along Edgerton Channel, even higher monetary risks could be expected to be incurred. As a result of direct and indirect flood damages associated with Edgerton Channel flooding, the City may be expected to incur flood damages of about $240,000 during a 100-year recurrence interval flood event and about $80,000 during a 10-year recurrence flood event under existing conditions. Under year 2000 plan conditions, flood damages of $320,000 and $140,000 could be expected, respectively, during 100- and 10-year events.

Diversion of Lake Michigan

In the consideration of alternative structural flood control measures, it was recognized that Lake Michigan could provide a convenient discharge point for floodwaters diverted from Wilson Park Creek—Edgerton Channel—upstream of flood-prone reaches but that, while such a diversion may be technically feasible, it would probably not be economically sound. A preliminary examination of such a diversion alternative was conducted, as described below, and found this alternative to be technically feasible but economically unacceptable.

The diversion was assumed to consist of a gravity flow conduit extending from Wilson Park Creek immediately downstream of the Nicholson Avenue crossing to Lake Michigan through the City of Cudahy along the alignment of Edgerton Avenue. The diversion conduit would drop a total of 80 feet from its upstream invert elevation of about 660 feet above National Geodetic Vertical Datum (mean sea level datum) to its downstream invert elevation of about 580 feet above National Geodetic Vertical Datum. The concrete-lined conduit would have a total length of 7,500 feet. Based on a design flow of 510 cfs—approximately the 100-year recurrence interval flood discharge of Wilson Park Creek under year 2000 conditions at the diversion point—hydraulic calculations indicate a conduit approximately six feet in diameter would be required under gravity flow conditions using the available hydraulic head.

Assuming a unit cost of $500 per lineal foot of conduit, the total capital cost for the diversion conduit would be $3.75 million. The corresponding average annual cost at a 6 percent interest rate and a project life and amortization period of 50 years would be $238,000, excluding operation and maintenance costs. The maximum potential flood control benefits which could be anticipated from this alternative are estimated at an average of $93,500 per year under year 2000 plan conditions. The benefit-cost ratio for this diversion alternative would thus be 0.39, clearly indicating that this alternative would be economically unsound.

Floodproofing and Elevation of Structures

A structure floodproofing, elevation, and removal alternative was developed and analyzed to determine if such a structure-by-structure approach would be a technically, economically, and environmentally acceptable solution to the flood problem in the City. For the purpose of this analysis, the 100-year recurrence interval flood stage under year 2000 plan conditions was used to estimate the number of flood-prone structures to be floodproofed, elevated, or removed and the approximate costs involved.

In the case of residential structures in the primary flooding zone, floodproofing was assumed to be feasible if the design flood stage was below the first floor elevation. Structure elevation was considered feasible for residential structures with basements if the estimated cost of elevating the structure was less than the estimated structure removal cost. Structures to be elevated were assumed to be raised to an elevation two feet higher than the 100-year recurrence interval design flood stage to provide adequate freeboard. For aesthetic reasons, structure elevation was limited to four feet. Structures which would have to be elevated more than four feet were designated for removal.

Floodproofing was assumed to be feasible for all nonresidential structures within the primary flooding zone provided the flood stage was not more than seven feet above the first floor, with the floodproofing cost for stages above the first floor being a function of the depth of water on the first floor. With respect to structures located in the secondary flooding zone, that is, outside of but immediately adjacent to the 100-year recurrence interval floodlands, it was assumed that floodproofing would be applied to those structures with basement floors below the elevation of the design flood stage. The total floodproofing cost so computed for the secondary flooding zone was then reduced to 5 percent of the original total to reflect the fact that only a small proportion—estimated to be 5 percent of the buildings in that zone with basement floor grades below the design flood stage—would probably actually incur secondary flooding. Computation of flood damages, as described earlier, included a similar percent reduction for secondary flood damages. This value was determined using historical flood information obtained through field interview, knowledge of the type and extent of sanitary and storm sewers and the hydrologic-hydraulic characteristics of the stream reach, and experience gained through studies conducted previously.

As shown on Map 49, the analysis indicated that 169 structures located in the primary and secondary flooding zones may require some form of floodproofing, that 11 structures would have to be elevated, and that none would have to be removed from the 100-year recurrence interval floodlands under this alternative. Future flood damage to private residences and commercial structures within the City of Cudahy would be virtually eliminated by the floodproofing and elevation. Table 71 sets forth the number and type of structures to be floodproofed and elevated and also summarizes the estimated costs and benefits.

Assuming that these structure floodproofing and elevation measures would be fully implemented, and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the equivalent average annual cost is estimated at about $24,300 per year, consisting entirely of the amortization of the $383,000 capital cost—$195,500 for floodproofing and $187,500 for structure elevation. The average annual flood damage abatement benefit is estimated at $93,500 per year, yielding a benefit-cost ratio of 3.8 and an excess of $69,200 in annual benefits over costs. Therefore, the structure floodproofing, raising, and removal plan element, as described herein, would be both technically and economically feasible within the City of Cudahy.

Channel Modification

Major Channelization: A major channelization alternative for the flood-prone reach along the Edgerton Channel is shown on Map 50. The physical characteristics and attendant costs and benefits are set forth in Table 71. Under this alternative, major channel improvements would be carried out over a reach about 0.8 mile in length, and would be located along the alignment of the existing channel from the upstream limit of the existing airport channelization to Whitnall Avenue.

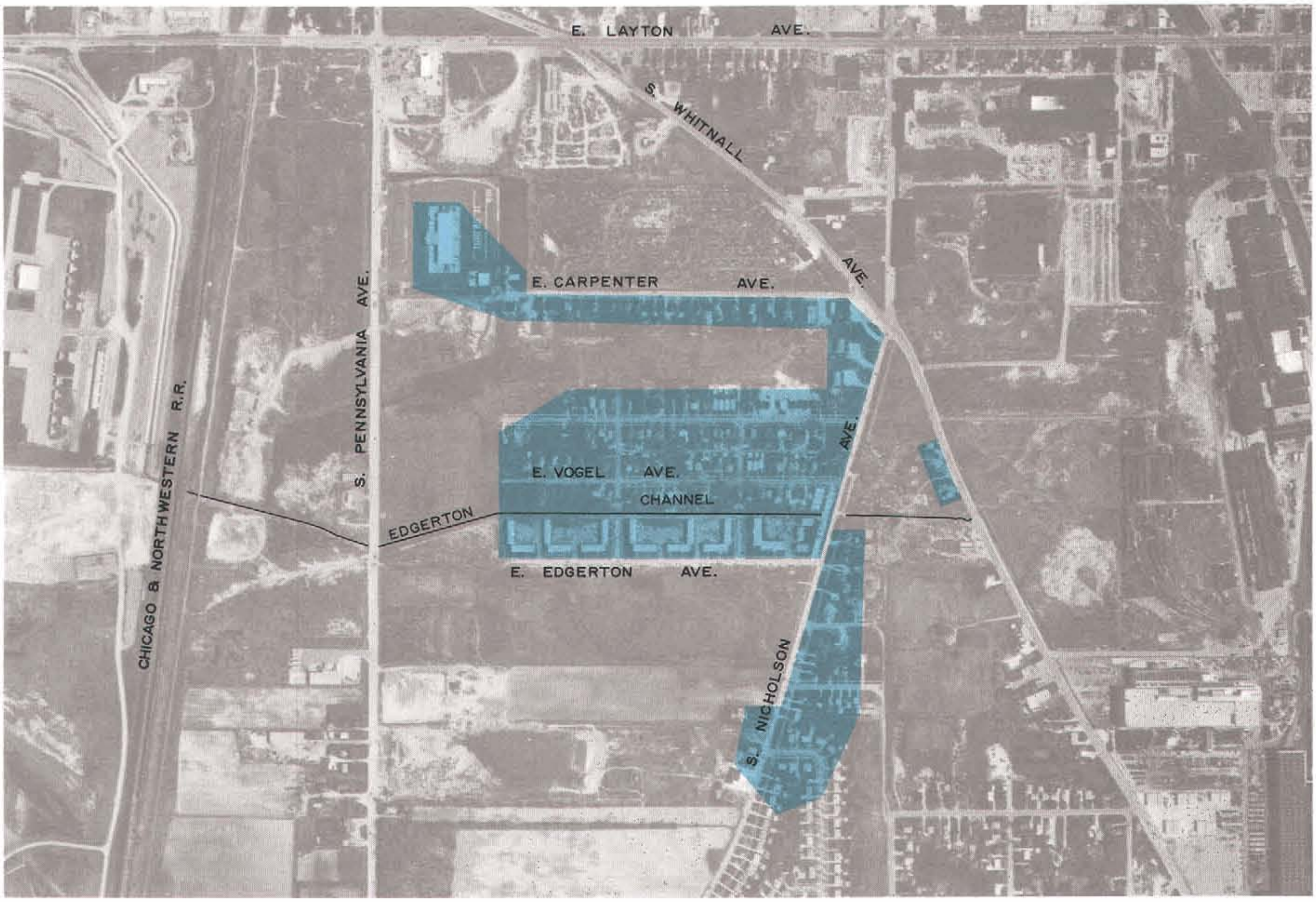
The new channelization would consist of a concrete trapezoidal channel having a bottom width of 10 feet and concrete sidewalls constructed at a slope of 3 on 1, with partial vertical concrete retaining walls to reduce the top width where necessary. A transition section would be necessary between the existing airport channelization and the proposed trapezoidal channel. The channel top width would be limited to 50 feet by the existing drainage easement from the Chicago & North Western Railway crossing at River Mile 5.34, the western Cudahy city limits, to the Pennsylvania Avenue crossing at River Mile 5.54. From Pennsylvania Avenue to River Mile 5.90, about 400 feet west of the frontage road, the easement would restrict the channel top width to 40 feet, from River Mile 5.90 to the existing frontage road crossing at River Mile 5.98 to 30 feet, and from the Nicholson Avenue crossing at River Mile 5.99 to just downstream of the Whitnall Avenue crossing at River Mile 6.12 to 50 feet.

The invert of the improved channel would match the existing channel invert at the upstream terminus of the channelization at River Mile 5.28. The channel bottom slope would be approximately 0.0024 foot per foot from the downstream end at River Mile 5.28 to the existing frontage road, at which point the new channel bottom elevation would be 2.5 feet below that of the existing channel bottom. Upstream of Nicholson Avenue the bottom slope would be about 0.0063 foot per foot. Drop structures required at Nicholson Avenue, River Mile 5.99, and at the upstream terminus at Whitnall Avenue, River Mile 6.12, would be approximately 2.7 and 1.5 feet, respectively.

The channelization would require the alteration or demolition and replacement of five stream crossings: the Chicago & North Western Railway, the railroad

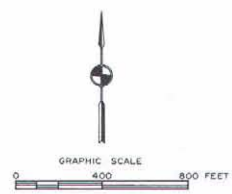
Map 49

STRUCTURE FLOODPROOFING ALONG THE EDGERTON CHANNEL IN THE CITY OF CUDAHY



LEGEND

AREA IN WHICH APPROXIMATELY 169 STRUCTURES ARE TO BE FLOODPROOFED AND APPROXIMATELY 11 ARE TO BE ELEVATED.



Structure floodproofing and structure elevation were examined as an alternative means of resolving existing and forecast flood problems along the Edgerton Channel in the City of Cudahy. Under this floodland management measure, up to 169 structures would be floodproofed and approximately 11 structures would be elevated above the 100-year recurrence interval flood stage. While this measure was shown to be technically practicable and economically feasible, it is unlikely that floodproofing would be completely and effectively carried out on a voluntary basis. Overland flooding and some of the attendant problems would, consequently, remain.

Source: SEWRPC.

Table 71

PRINCIPAL FEATURES, COSTS, AND BENEFITS OF FLOODLAND MANAGEMENT ALTERNATIVES FOR THE CITY OF CUDAHY

Number	Alternative: Name	Alternative: Description	Technically Feasible?	Economic Analysis[a,b]: Capital Cost: Item	Capital Cost (thousands)	Annual Amortized Capital Cost (thousands)	Annual Operation and Maintenance Cost (thousands)	Total Annual Cost (thousands)	Annual Benefits (thousands)	Excess of Annual Benefits Over Costs (thousands)	Benefit-Cost Ratio	Economically Feasible?	Nontechnical and Noneconomic Considerations: Positive	Nontechnical and Noneconomic Considerations: Negative	Recommended?
1	No action	--	Yes	--	$ 0	$ 0	$0	$ 0	$ 0	$ - 93.5	--	No	--	--	No
2	Floodwater Diversion	1.4 miles of concrete lined conduit	Yes	Concrete-lined conduit	3,750	238	0	238	93.5	- 144.5	0.39	No	--	--	No
3	Structure Floodproofing and Elevating	a. Floodproof up to 166 residential and 3 commercial and industrial structures b. Elevate 11 residential structures	Yes	Floodproofing Elevating Subtotal	195.5 187.5 $ 383.0	24.3	0	24.3	93.5	69.2	3.85	Yes	Immediate partial flood relief at discretion of property owners Most of the costs could be borne by beneficiaries	Complete, voluntary implementation unlikely and therefore left with a significant residual flood problem Overland flooding and some attendant problems remain Some floodproofing is likely to be applied without adequate professional advice and, as a result, structure damage may occur	No
4	Major Channelization	a. 0.8 mile of major channelization b. Replacement of 4 stream crossings	Yes	Channelization Bridges Subtotal	798.6 770.0 $1,568.6	99.5	0.5	100.0	93.5	- 6.5	0.94	No	--	--	No
5	Major Channelization Channel Enclosure Composite	a. 0.5 mile of major channelization b. 0.3 mile of channel enclosure c. Replacement of 4 stream crossings	Yes	Channelization Channel Enclosure Bridges Subtotal	417.6 477.6 632.0 $1,527.2	96.9	0.5	97.4	93.5	- 3.9	0.96	No	Enclosure component would minimize the deposition of trash in the stream	--	No
6	Dikes and Floodwalls	a. 0.8 mile of dikes b. 0.9 mile of floodwalls c. Alteration of 1 stream crossing d. Installation of 8 storm water pumping stations	Yes	Dikes Floodwalls Bridges Pumping Stations Subtotal	334.9 924.4 34.0 600.0[c] $ 1,893.3	120.1	2.6	122.7	93.5	- 29.2	0.76	No	--	Aesthetic impact of visual barrier Pumping station operation and maintenance are critical to effective functioning of the system	No
7	Whitnall Detention Storage Reservoir	65-acre-foot detention reservoir	Yes	Land Acquisition Dike Outlet Culvert Subtotal	329.6 139.8 0.8 $ 470.2	29.8	1.8	31.6	77.3	45.7	2.45	Yes	Potential to retain public open space	Partial resolution of flood problem May encourage new flood-prone development	No
8	Detention Storage-Channel Enclosure-Bridge Alteration Composite	a. 65-acre-foot detention reservoir b. 0.3 mile of channel enclosure c. Replacement of 1 stream crossing	Yes	Land Acquisition Dike Outlet Culvert Channel Enclosure Bridge Subtotal	329.6 139.8 0.8 475.0 0.0 $ 945.2	60.0	2.0	62.0	93.5	31.5	1.51	Yes	Potential to retain public open space Minimize the deposition of trash in the stream	Storage component may encourage new flood-prone development	
9	Bridge and Culvert Alteration or Replacement	Replacement of from 1 to 4 stream crossings	No	--	--	--	--	--	--	--	--	--	--	--	No

[a] *Economic analyses are based on an annual interest rate of 6 percent and assume a 50-year amortization period and project life.*

[b] *Economic analyses were not done for technically impractical alternatives.*

[c] *Present worth cost based on a 25-year economic life.*

Source: SEWRPC.

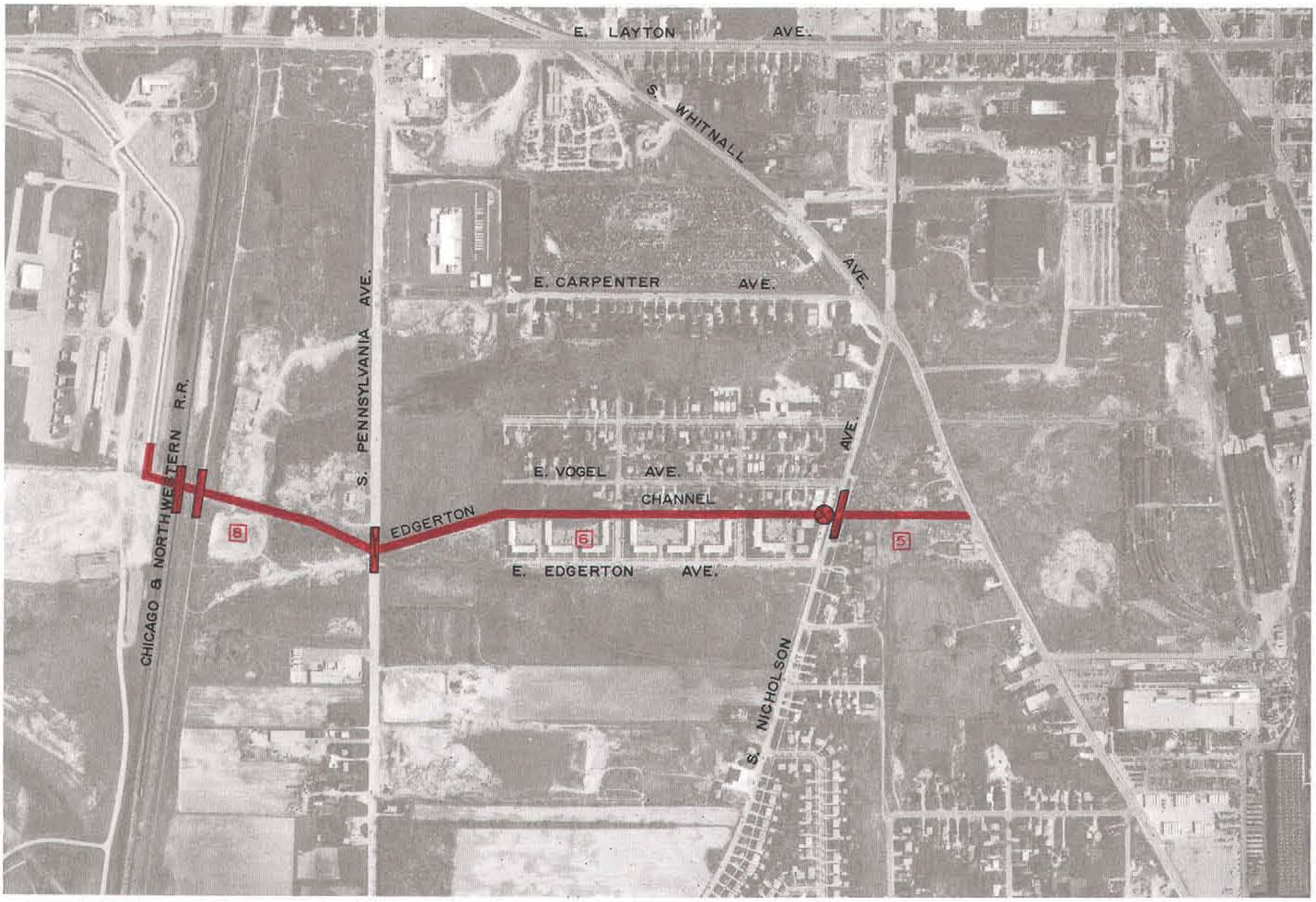
utility road, Pennsylvania Avenue, the existing frontage road, and Nicholson Avenue. The altered or replaced structures would be designed so as to span the entire improved channel and cause no backwater effects during a 100-year recurrence interval flood event. The existing frontage road crossing is a temporary structure and, therefore, would not be replaced. The cost of reconstructing the Pennsylvania Avenue crossing, however, was not charged against this alternative, since the structure is recommended for improvement in the adopted jurisdictional highway system plan for Milwaukee County in order to provide adequate traffic capacity.

Assuming that the aforementioned major channelization project would be fully implemented, and utilizing an interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost is estimated at about $99,500 consisting of the following: amortization of the $798,600 capital cost of the channel modifications, amortization of the $770,000 capital cost of bridge replacement, and $500 in annual operation and maintenance costs. Assuming that major channelization would completely eliminate all direct and indirect flood damages along the Edgerton Channel in the City of Cudahy, the average annual flood abatement benefit is estimated at about $93,500, yielding a benefit-cost ratio of 0.94, and an annual excess of costs over benefits of about $6,500. Therefore, major channelization may be considered technically feasible but economically unsound.

Major Channelization and Channel Enclosure: A combination major channelization-channel enclosure alternative for the Edgerton Channel is shown on Map 51. The physical characteristics of the major channelization and the attendant costs and benefits are set forth in Table 71. Under this alternative, major channel improvements would be carried out over a total reach of about 0.5 mile and the channel would be enclosed for a total reach of about 0.3 mile. Both the open channel improvement and the enclosed conduit would be located along the alignment of the existing channel from the terminus of the present airport channelization to the upstream limit of the proposed channelization at Whitnall Avenue.

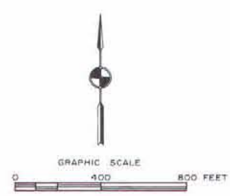
Map 50

MAJOR CHANNEL MODIFICATIONS ALONG THE EDGERTON CHANNEL IN THE CITY OF CUDAHY



LEGEND

- PROPOSED MAJOR CHANNEL--CONCRETE LINED
- 6 APPROXIMATE DEPTH OF PROPOSED CHANNEL IN FEET
- PROPOSED BRIDGE REPLACEMENT
- PROPOSED BRIDGE REPLACEMENT (COST ASSIGNED TO PREVIOUSLY ADOPTED PLAN)
- PROPOSED BRIDGE REMOVAL WITHOUT REPLACEMENT

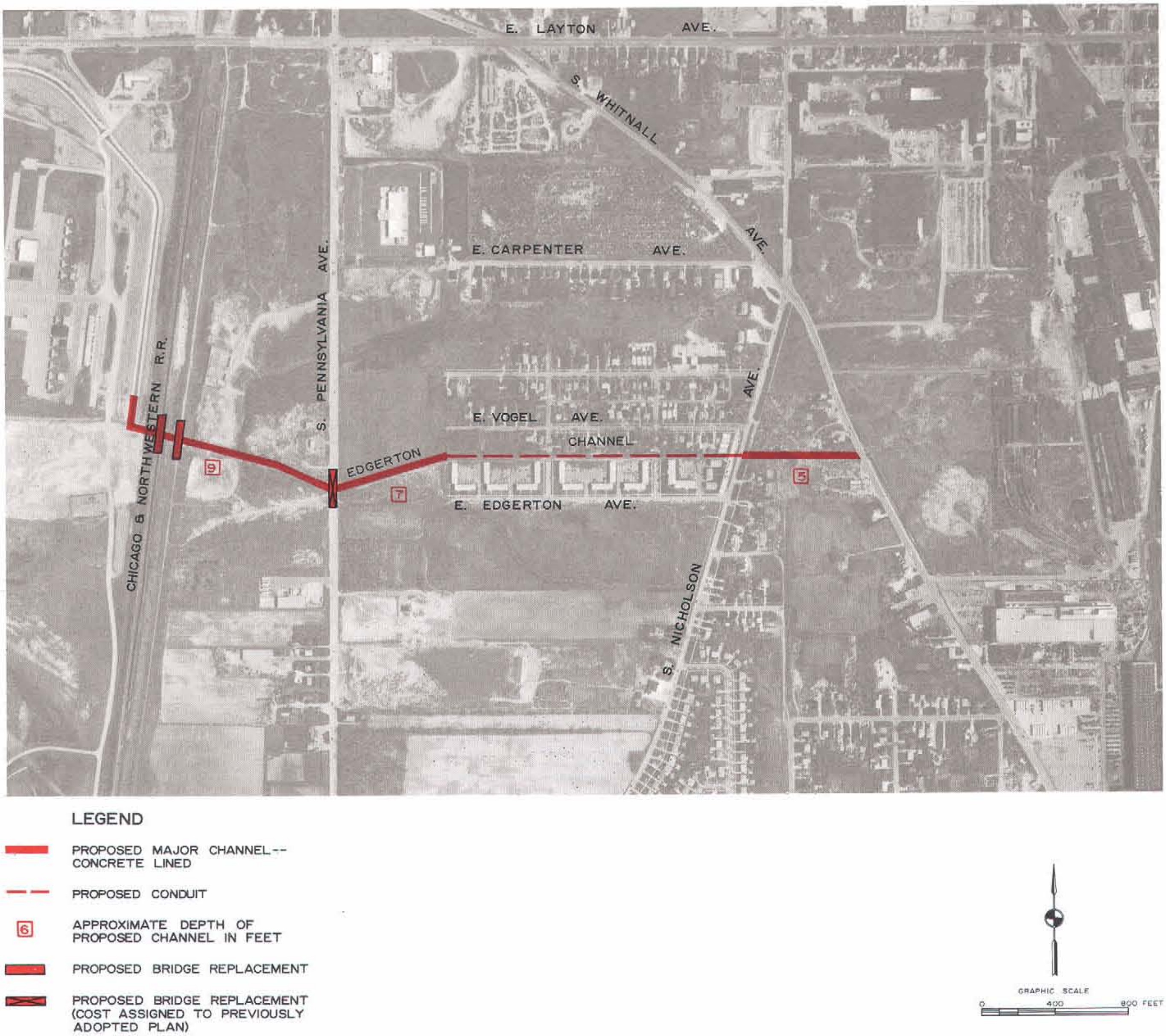


The deepening, widening, and placing of a concrete lining of approximately 0.8 mile of the Edgerton Channel, supplemented with the replacement of four stream crossings, was examined as a potential structural flood control measure. While technically practicable, this alternative was found to be economically unsound.

Source: SEWRPC.

Map 51

MAJOR CHANNELIZATION AND CHANNEL ENCLOSURE ALONG THE EDGERTON CHANNEL IN THE CITY OF CUDAHY



Enclosure of the Edgerton channel in that reach traversing existing development would resolve the problem of the accumulation of trash and debris in the channel as well as contain flood flows. Major channelization along adjacent reaches of the Edgerton Channel supplemented with the replacement of four stream crossings would also be required. While this alternative was found to be technically practicable and to provide intangible benefits, it was found to be economically unsound.

Source: SEWRPC.

The concrete trapezoidal channel portion would consist of two reaches, the first to replace about 2,000 feet of the existing channel extending from the terminus of the existing airport channelization at River Mile 5.28 to River Mile 5.66, about 700 feet upstream of the Pennsylvania Avenue crossing, and the second to begin just upstream of the Nicholson Avenue at River Mile 5.99 and to extend for about 650 feet to the Whitnall Avenue crossing at River Mile 6.12. The bottom of the improved channel would be 10 feet wide and the side slopes would be one vertical on three horizontal, except in reaches with a limited easement width where steeper side slopes of one on two would be required. The channel bottom profile and cross-sectional shape at the downstream end of the channel improvement would be designed to effect a hydraulically efficient transition to the existing airport channel. At Whitnall Avenue, the upstream limit of the proposed channel improvements, a drop structure would be necessary. Between River Mile 5.66 and the upstream side of Nicholson Avenue, River Mile 5.99, a reinforced concrete box culvert approximately 10 feet wide and 6 feet deep would connect the two reaches of open channel with proper transition sections provided.

The bottom grade of the improved channel would match the bottom grade of the upstream terminus of the existing airport channelization at River Mile 5.28, and would continue upstream at the same slope of the existing airport channelization, about 0.0005 foot per foot, through the Pennsylvania Avenue crossing, at which point the channel bottom slope would increase to about 0.0019 foot per foot. At a 2.7-foot drop structure on the upstream end—the box culvert at River Mile 5.99—the proposed channel slope would decrease to about 0.0063 foot per foot for the remainder of the channel improvement. This would result in lowering the existing Edgerton Channel by about 3.7 feet at Nicholson Avenue (River Mile 5.99), about 4.5 feet at Pennsylvania Avenue (River Mile 5.54), and about 2.1 feet at the Chicago & North Western Railway (River Mile 5.34).

The channelization would require the alteration or demolition and replacement of the existing Chicago & North Western Railway, utility road, and of the Pennsylvania Avenue bridges. The replacement structures would be designed and constructed in such a manner as to cause no backwater effects during a 100-year recurrence interval flood event. Individual replacement or modification of the existing frontage road and Nicholson Avenue crossings would not be necessary inasmuch as the reinforced concrete box culvert would be sufficient. The cost of reconstructing the Pennsylvania Avenue crossing, however, was not charged against this alternative, since the structure is recommended for improvement in the adopted jurisdictional highway system plan for Milwaukee County in order to provide adequate traffic capacity.

Assuming that the aforementioned major channelization and channel enclosure alternative would be fully implemented, and utilizing an interest rate of 6 percent and project life and amortization period of 50 years, the average annual cost is estimated to about $96,900 consisting of the following: amortization of the $417,600 capital cost of the open channel modifications, $477,600 capital cost of enclosed channel, $632,000 capital cost of bridge alteration or replacement, and $500 in annual operation and maintenance costs. Assuming that major channelization and channel enclosure would completely eliminate all direct and indirect flood damages along the Edgerton Channel in Cudahy, the average annual flood abatement benefit is estimated at about $93,500, yielding a benefit-cost ratio of 0.96, and an annual excess of costs over benefits of about $3,900. Therefore, this alternative may be considered technically feasible but economically unsound.

This alternative would, however, provide several intangible benefits not included in the direct tangible benefits utilized in the benefit-cost analysis. One such benefit, both aesthetic- and health-related in nature, would be the resolution of a long-standing problem—the deposition of debris and trash such as tires, shopping carts, garbage, and other domestic solid wastes in the channel. This unsightly situation poses a health hazard to residents of the area, in addition to having a detrimental effect on the stream water quality. The presence of such debris in the stream may cause additional flooding and storm water inundation problems by being transported downstream and accumulating on the upstream side of bridges, resulting in increased backwater, and by trapping vegetation, silt, and other deposits, thereby increasing the channel invert elevation above that elevation necessary for existing or planned storm sewer outfalls to drain properly. Another benefit associated with channel enclosure would be the elimination of stream bank erosion evident at several locations in the reach. Unaddressed, the erosion problem could cause serious foundation undermining problems, because numerous buildings are located close to the stream banks, as well as contribute to sediment deposition problems downstream. An additional benefit resulting from channel enclosure would be the potential for the creation of an open space corridor approximately 1.3 acres in size which could be seeded and landscaped.

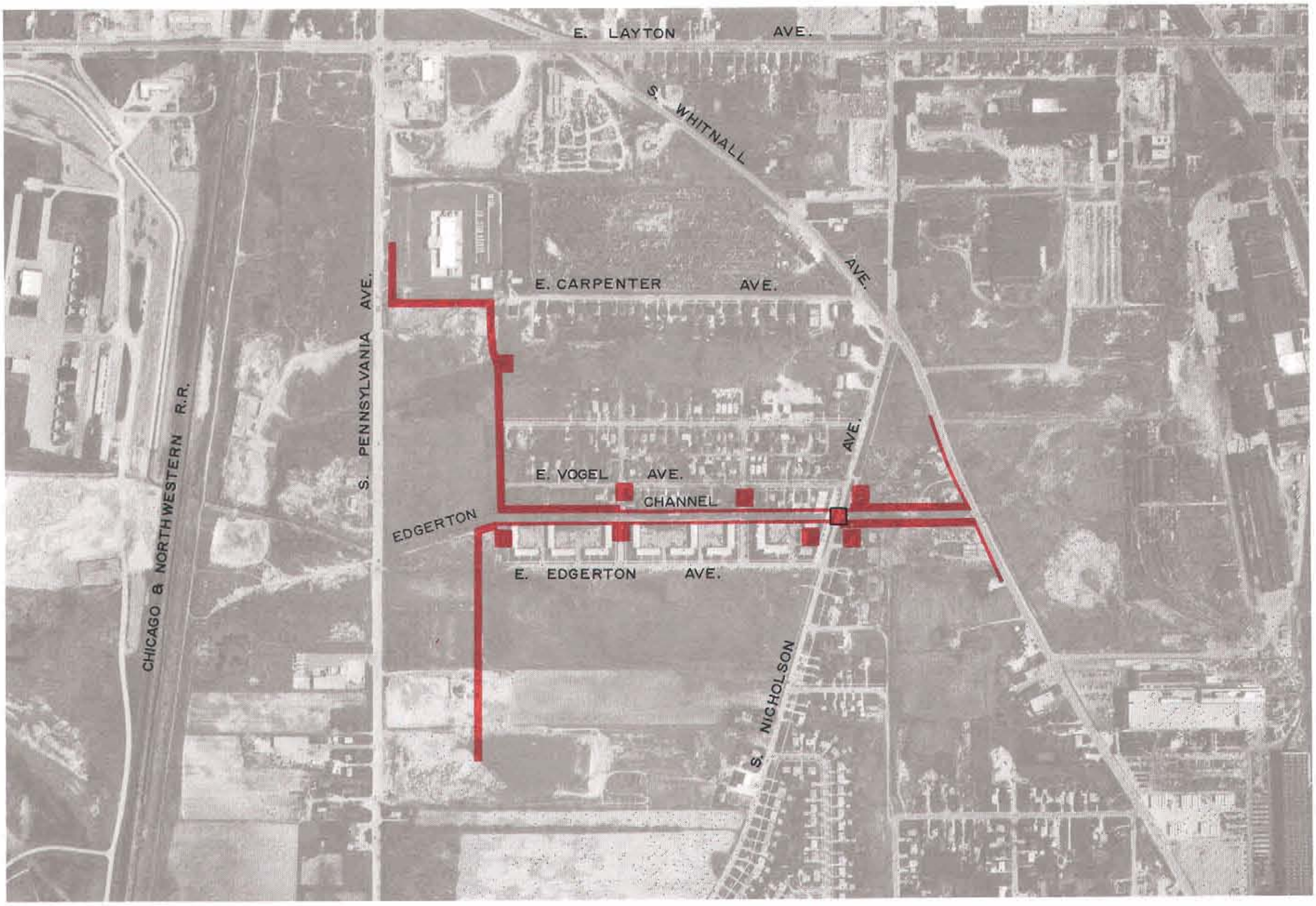
In conclusion, although the tangible, monetary benefits associated with this alternative are less than the estimated costs, the additional, intangible benefits resulting from the simultaneous solution of a local "people problem" are sufficient to consider this a viable alternative.

Dikes and Floodwalls

A dike and floodwall alternative was developed and analyzed for the lands subjected to flooding by the Edgerton Channel in the City of Cudahy in order to determine if such a structural measure would provide a technically sound, economically viable, and environmentally acceptable solution to the existing and anticipated future flood problem. The 100-year recurrence interval flood discharge under year 2000 land use plan conditions was used as the basis for the preliminary design of this alternative.

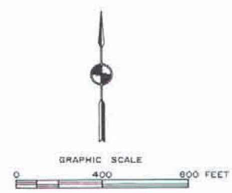
Map 52

DIKE-FLOODWALL SYSTEM ALONG THE EDGERTON CHANNEL IN THE CITY OF CUDAHY



LEGEND

- DIKE
- FLOODWALL
- PUMPING STATION
- PROPOSED SPECIAL BRIDGE STRUCTURE TO ENABLE ROAD CLOSURE DURING FLOOD EVENT.



The installation of a combination of earthen dikes, concrete floodwalls, and storm water pumping facilities intended to contain the flood flows and prevent inundation of riverine-area structures was examined as a possible measure to resolve existing and forecast flood problems along the Edgerton Channel in the City of Cudahy. While this measure was shown to be technically practicable, it was found to be economically unsound.

Source: SEWRPC.

The dike and floodwall alternative for the Edgerton Channel plan is shown on Map 52, while the physical characteristics of the dikes and floodwalls and the attendant costs and benefits are tabularized in Table 71. Under this alternative, a total of 1.7 miles of earthen dikes and concrete or sheet steel floodwalls similar to those shown in Figure 59 would be constructed in the floodlands adjacent to and on both sides of an approximately 0.5-mile reach of Edgerton Channel in the City of Cudahy. About 0.9 mile of earthen dike and about 0.8 mile of concrete or sheet steel floodwalls would be required. Extensive use of the more costly floodwalls rather than earthen dikes would be necessary along the approximately 0.3-mile flood-prone reach of Edgerton Channel immediately west of Nicholson Avenue due to space limitations imposed by the close proximity of the residential development. In order to convey the design flood flow with a minimum freeboard of two feet, the concrete floodwalls would exceed seven feet immediately downstream of the existing frontage road at River Mile 5.98.

The dike and floodwall alternative would require the construction of a new bridge at the Nicholson Avenue crossing in order to contain the floodwaters within the dikes and floodwalls. The existing frontage road crossing is a temporary structure and, therefore, would be removed and not replaced. In addition, the dike-floodwall alternative would have to include provisions for the construction of a minimum of eight major storm water lifts or pumping stations and backwater gates at the topographically low areas behind the dikes and floodwalls, as well as near the end of storm sewer outfalls that are tributary to the channel. These facilities would be required to prevent the movement of floodwaters from the channel into surrounding urban areas via these storm sewers and drainage channels, and to prevent the accumulation of lateral runoff behind the dikes and floodwalls creating local drainage problems.

Assuming that the dike and floodwall project would be fully implemented, and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost is estimated at $122,700, consisting of the following: amortization of the $1.26 million capital cost of the dike and floodwalls, including land acquisition costs, amortization of the $34,000 capital cost of new river crossings, amortization of the $600,000 capital cost of backwater control and pumping facilities, and $2,600 in annual operation and maintenance costs of the dikes, floodwalls, and pumping facilities. Assuming that the dike-floodwall system would completely eliminate all direct and indirect flood damages along Edgerton Channel in Cudahy, the average annual flood abatement benefit is estimated at about $93,500, yielding a benefit-cost ratio of 0.76 and an annual excess of costs over benefits of about $29,200. Therefore, the City of Cudahy dike and floodwall plan element, as described herein, may be considered technically feasible but economically unsound.

In addition to the unfavorable economic features of the dike-floodwall alternative, the excessive height of the floodwalls would make the structure works aesthetically unpleasing. This height would be necessitated by high flood stages relative to existing riverine area topography. The residents protected by the dikes and floodwalls, particularly those living nearest the channel, would generally have their view of the channel blocked and would have difficulty in gaining access to the channel.

Whitnall Avenue Detention Storage Reservoir

A detention reservoir is normally dry but retains water under flood conditions and later releases the floodwaters at a reduced controlled rate, thus reducing the potential for flooding. A detention reservoir located immediately east of Whitnall Avenue on the Edgerton Channel with the potential to resolve the flood problems in this reach is shown on Map 53. The reservoir would provide approximately 65 acre-feet of storage under a 100-year recurrence interval flood event with two feet of freeboard in an area of about 13 acres. An earthen embankment approximately 1,600 feet long and varying from 2 to 13 feet high would be located immediately east of and parallel to Whitnall Avenue.

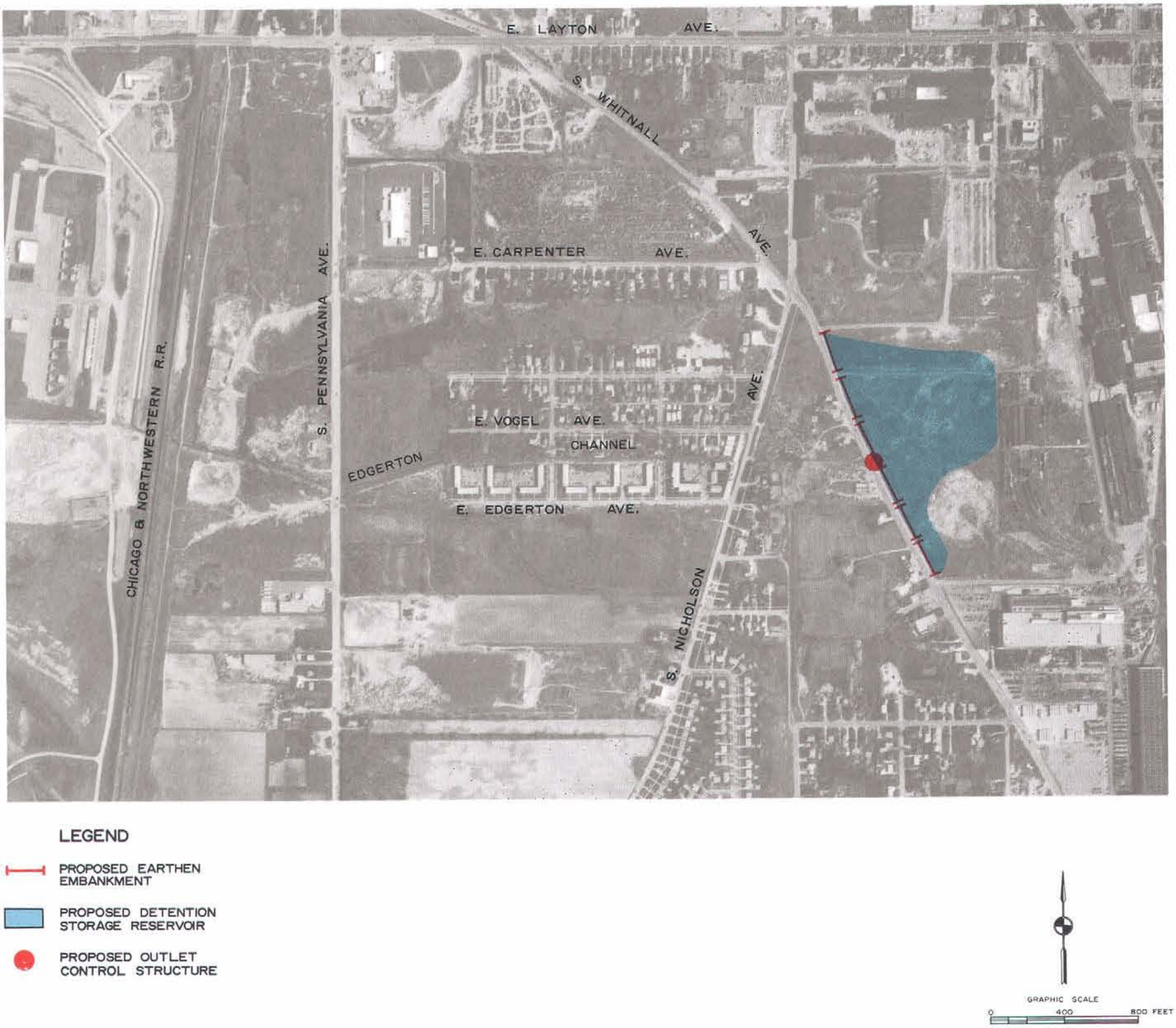
Using the simulation model, a hydrologic-hydraulic analysis of the reservoir was conducted to determine the effect on flows, stages, and flood damages in the reach immediately downstream. Assuming year 2000 plan land use and committed channel conditions, the detention reservoir may be expected to reduce the 100-year recurrence interval peak flows at Nicholson Avenue, River Mile 5.99, by more than half, from about 510 cfs to 210 cfs, and at the Chicago & North Western Railway, River Mile 5.34, from 620 cfs to 470 cfs. Flood stage profiles computed for the flood-prone reach with the reservoir indicated that stage decreases of about 1.5 to 2.1 feet may be expected under 100-year recurrence interval flood conditions and under year 2000 plan land use conditions.

The total capital cost of a detention reservoir at this site was estimated to be about $470,200, consisting of $329,600 for land acquisition, $139,800 for the earthen embankment along Whitnall Avenue, and $800 for the outlet structure. The equivalent average annual cost, assuming an economic life of 50 years and an annual interest rate of 6 percent, would be about $31,600, consisting of $29,800 for the annual amortized capital costs and $1,800 annual operation and maintenance cost.

The benefits associated with this alternative would consist of a reduction in average annual damages of $77,300, from $93,500 to $16,200, resulting from the abatement of a large portion of the flood damages in the reach between Pennsylvania Avenue and Nicholson Avenue and all of the flood damages upstream, or east, of Nicholson Avenue. The benefit-cost ratio would be about 2.5, and the annual excess of benefits over costs would be about $45,700. The analysis thus indicates that a detention reservoir on Edgerton Channel at Whitnall Avenue would be economically sound and a technically feasible means for abating about 80 percent of the average annual damages to the flood-prone areas immediately downstream in the City of Cudahy.

Map 53

DETENTION STORAGE RESERVOIR FOR THE EDGERTON CHANNEL IN THE CITY OF CUDAHY



A 13-acre flood detention reservoir on the Edgerton Channel at Whitnall Avenue in the City of Cudahy was examined as an alternative means of resolving existing and forecast flood problems along the Edgerton Channel in the City of Cudahy. Economic analyses indicated that the detention reservoir would substantially reduce flood discharges, flood stages, and flood damages along the flood-prone reach downstream in an economically sound manner. This detention reservoir, in combination with channel modifications, was accordingly recommended for inclusion in the watershed plan as a viable means of resolving the flood problems along the Edgerton Ditch.

Source: SEWRPC.

Whitnall Avenue Detention Storage Reservoir - Channel Enclosure - Bridge Alteration: Although the detention storage alternative results in only partial resolution of the flood problem, its favorable benefit-cost ratio indicates that, in combination with additional measures, it may be a good alternative. Therefore, the detention storage reservoir at Whitnall Avenue was evaluated in conjunction with enclosure of the channel from Nicholson Avenue at River Mile 5.97 downstream to River Mile 5.66 and alteration or replacement of the Pennsylvania Avenue crossing of the Edgerton Channel as shown on Map 54.

Under this alternative, the 100-year recurrence interval discharge would be reduced by more than half, from 510 cfs to 210 cfs. A 10 foot wide by 6 foot high reinforced concrete box culvert would completely contain the flow in the reach from River Mile 5.66 to River Mile 5.97, resolving problems of flooding, erosion, and deposition of trash. At the downstream end of the culvert the channel cross-sectional shape and channel bottom profile would be designed so as to provide an acceptable transition to the existing channel shape and grade. At the upstream end of the culvert a drop structure would be necessary. To reduce the backwater effects on the downstream end of the culvert, the existing bridge at the Pennsylvania Avenue crossing would have to be altered or replaced. The cost of reconstructing the Pennsylvania Avenue crossing, however, was not charged against this alternative, since the structure is recommended for improvement in the adopted jurisdictional highway system plan for Milwaukee County in order to provide adequate traffic capacity.

The total capital cost of the reservoir and channel enclosure was estimated at about $945,200, consisting of $329,600 for land acquisition, $140,600 for the earthen embankment along Whitnall Avenue and the reservoir outlet culvert, and $475,000 for the channel enclosure. The equivalent average annual cost would be about $62,000, consisting of $60,000 for the amortization of the aforementioned capital cost, assuming an annual interest rate of 6 percent and a project life and amortization period of 50 years, and $2,000 in annual operation and maintenance costs. Assuming the proposed detention reservoir, channel enclosure, and bridge alteration or replacement were fully implemented, the benefits of this alternative would consist of the elimination of all direct and indirect flood damages along Edgerton Channel in the City of Cudahy, or $93,500 in average annual flood damages. Thus, the benefit-cost ratio associated with this alternative would be about 1.51 and the excess of benefits over costs would be about $31,500. Therefore, this detention storage-channel enclosure-bridge alteration composite alternative may be considered technically feasible and economically sound.

Bridge and Culvert Alteration, Replacement, or Removal
The removal and possible replacement of selected bridges and culverts along the Edgerton Channel was examined as a potential means of reducing flood problems upstream of these crossings. The bridges so analyzed consisted of the Chicago & North Western Railway bridge at River Mile 5.34, the utility road bridge at River Mile 5.36, the Pennsylvania Avenue bridge at River Mile 5.54, the existing frontage road bridge at River Mile 5.98, and the Nicholson Avenue bridge at River Mile 5.99.

The hydraulic analyses utilized the 100-year recurrence interval flood discharge corresponding to year 2000 plan conditions and the assumption that the bridge concerned was either removed entirely and replaced or modified in such a manner as to cause no backwater effect.

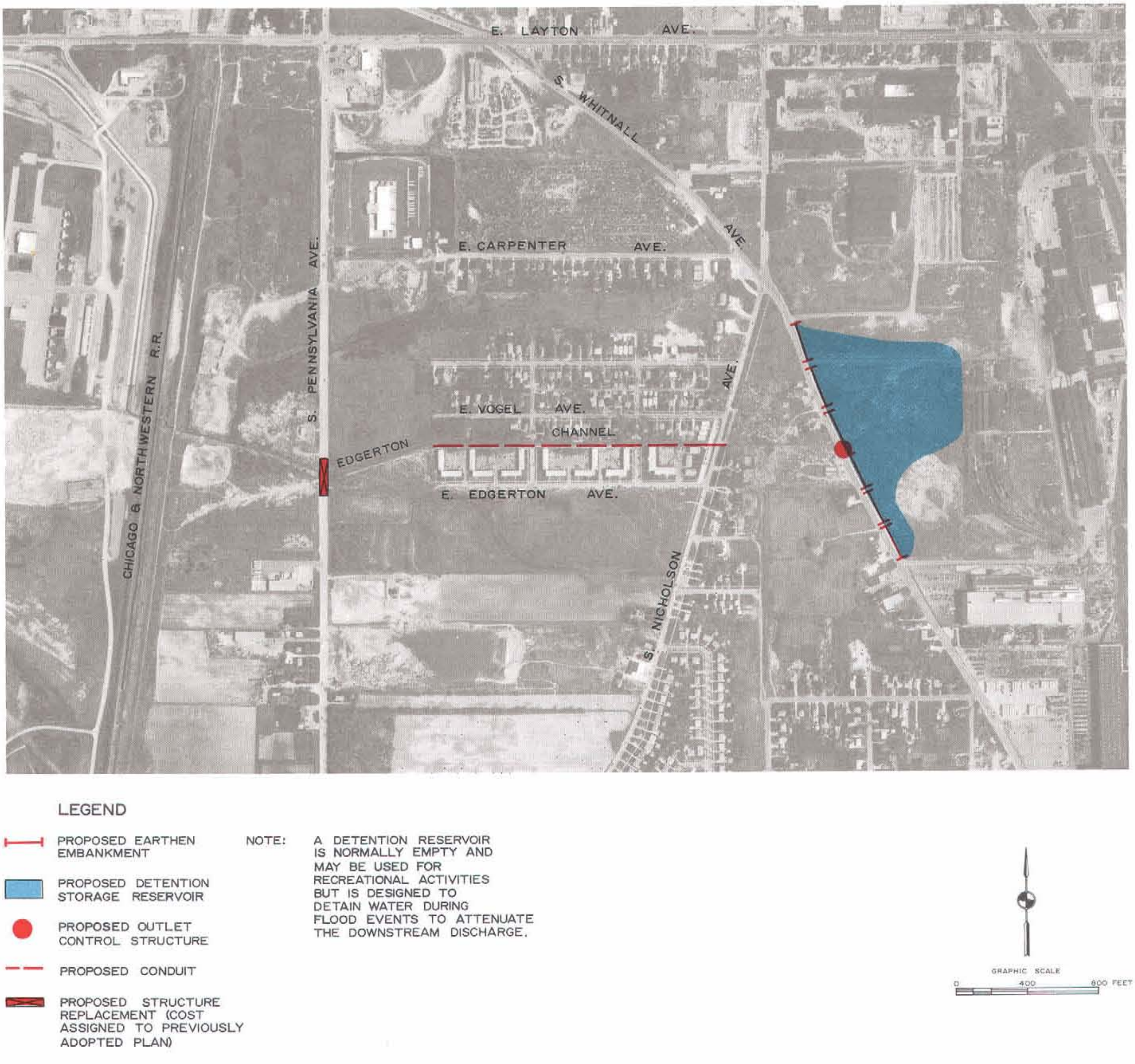
The Pennsylvania Avenue bridge was examined initially because it is the first bridge located downstream of the reach incurring the greatest flood damages. The replacement of the bridge with a hydraulically insignificant structure would result in 100-year flood stage decreases ranging from 1.4 feet immediately upstream to 0.3 foot at River Mile 5.72. Upstream of River Mile 5.72 the 100-year flood stage would not be significantly reduced. Consequently, the removal of this bridge alone would not significantly reduce flood damages.

Similarly, the removal of the Chicago & North Western Railway and utility road bridges did not significantly reduce stages. While these modifications would be expected to result in flood stage decreases in excess of one foot immediately upstream of these structures, flood stages and flood damages upstream of Pennsylvania Avenue would not be significantly altered. This indicates that the flood stages were the result of the inability of the existing channel to convey flood flows rather than the backwater effect of these bridges. A similar conclusion was reached for that reach upstream of the existing frontage road and Nicholson Avenue bridges through examination and analysis of these structures. consequently, it was concluded that bridge removal, alteration, or replacement alone will do little in regard to the mitigation of flood damages. Thus, this alternative, without complementary major channel modifications, could not be considered technically or economically feasible.

Impact of Proposed Lake Freeway
The adopted regional transportation plan recommends the construction of a freeway, known as the Lake Freeway, through the Kinnickinnic River watershed in a corridor along the Chicago & North Western Railway line. More specifically, the freeway is proposed to be located parallel to and immediately east of the railway line near the western limits of the City of Cudahy. Under one of two alternative preliminary engineering plans developed for that portion of the proposed Lake Freeway immediately east of General Mitchell Field, the storm water which presently flows into the General Mitchell Field drainage system at E. Grange Avenue and the Chicago & North Western Railway would be diverted along the east side of the freeway and discharged to the Wilson Park Creek—Edgerton Channel—immediately east of the freeway corridor. Provisions for the Lake Freeway crossing of the Wilson Park Creek and for this storm water diversion should be incorporated into any plans for the improvement of that reach of the Wilson Park Creek—Edgerton Channel—immediately east of the airport.

Map 54

DETENTION STORAGE-CHANNEL ENCLOSURE-BRIDGE ALTERATION ALONG THE EDGERTON CHANNEL IN THE CITY OF CUDAHY



Another alternative measure for abating existing and probable future flood problems along the Edgerton Channel in the City of Cudahy consists of a detention storage reservoir with the potential to retain public open space as well as to reduce the downstream flows, a conduit to enclose the channel through the existing development, and the replacement of one stream crossing. After reviewing the technical, economic, and environmental features of this and other alternatives, the Kinnickinnic River Watershed Committee initially recommended that the detention storage-channel enclosure-bridge alteration alternative be implemented.

Source: SEWRPC.

Concluding Statement

Seven different structural floodland management alternatives—floodwater diversion, major channelization, major channelization and channel enclosure, dikes and floodwalls, detention storage, detention storage and channel enclosure, and bridge alteration or replacement—and one nonstructural measure—structure floodproofing and elevation—were examined as possible solutions to the serious flood problem that exists along the Wilson Park Creek—Edgerton Channel—in the City of Cudahy. In addition, a ninth alternative, that of taking no action, is available to the public agencies concerned, and the flood damages attendant to this alternative provide an important basis for analyses of the potential benefits associated with each of the other alternatives.

The principal features of, and the cost and benefits associated with, each of the floodland management alternatives are summarized in Table 71, together with the major favorable and unfavorable nontechnical and noneconomic considerations likely to influence selection of the most desirable solution. Excluding the "no action" approach, all of the above structural and nonstructural alternatives were found to be technically feasible with the exception of the bridge and culvert alteration or replacement. Of the remaining seven measures, three were found to be economically sound and one additional alternative, although economically unsound, was found to have sufficient intangible benefits to be maintained as a viable alternative, thus providing four separate potential solutions to the flood problems along the Edgerton Channel in the City of Cudahy.

Even though structure floodproofing and elevation constitute a technically and economically feasible floodland management alternative for the City of Cudahy, this alternative was eliminated from further consideration for important reasons. First, complete implementation of a voluntary structure floodproofing and elevation program is unlikely and, with partial implementation, the City of Cudahy would be left with a significant residual problem whenever a major flood event occurs. Assuming that numerous individual property owners incur the necessary cost to implement floodproofing and further assuming that the floodproofing devices are adequately maintained, community officials may still be faced with the problem of reducing the flood threat to those structures that have not been voluntarily floodproofed. Second, other viable alternatives are available, each of which could be applied with a significantly higher likelihood of success in eliminating most of the Edgerton Channel flood problems. Third, even if a voluntary structure floodproofing program were completely carried out, the City of Cudahy would still be subjected to extensive overland flooding that would hamper routine access to and from some riverine area structures, would continue to periodically close local streets to automobile traffic, and would interfere with the rapid movement of emergency vehicles. Furthermore, yard and street damages and cleanup costs remain with the structure floodproofing removal alternative, and sanitary and storm sewers would continue to experience surcharging. Fourth, some floodproofing is very likely to be applied without adequate professional advice. As a result, structure damage is likely to occur, and once again city officials are likely to be asked to assist in resolution of the problem.

The major channelization-channel enclosure composite alternative was eliminated from further consideration because of the uneconomic features and the potential to achieve those intangible benefits associated with the channel enclosure through the detention storage-channel enclosure alternative. The intangible benefits, noted above for the major channelization and channel enclosure, are more specifically related to the channel enclosure component of this alternative, which may also be used in combination with the detention storage reservoir upstream.

Although detention storage does exhibit very favorable benefit-cost features, this measure would abate only about 80 percent of the flood problem in the City of Cudahy as measured by reduction in average annual flood damages, resulting in only a partial solution to the flood problem along the Edgerton Channel.

After due consideration of the various technical and economic features and other aspects of the detention storage-channel enclosure-bridge alteration composite alternative, it is recommended that a detention storage reservoir on the Edgerton Channel at Whitnall Avenue, in combination with enclosure of the channel from Nicholson Avenue downstream to River Mile 5.66, upstream of Pennsylvania Avenue, and alteration or replacement of the Pennsylvania Avenue crossing, be employed to resolve existing and probable future flood problems along the Edgerton Channel in the City of Cudahy.

BRIDGE AND CULVERT ALTERATION OR REPLACEMENT FOR TRANSPORTATION PURPOSES

Bridges and culverts that are inadequately designed from a hydraulic perspective can significantly increase flood stages and areas of inundation, and are also subject to closure during major flood events, thereby adversely affecting the function of the regional highway transportation system. The approach described for the selection of flood-prone reaches in the watershed included a search for bridges that may aggravate existing flood problems. The purpose of this section of the chapter is to identify those bridges and culverts that could be expected, by virtue of inadequate hydraulic capacity and overtopping of the approach roads or the structure, to interfere with the operation of the highway and railroad transportation system during major flood events.

The watershed development objectives and supporting principles and standards set forth in Chapter X specify that bridges shall accommodate, according to the categories listed below, the designated flood events without overtopping of the related roadway or railroad track and without resultant disruption of traffic floodwaters. The categories and designated flood events are:

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

2. 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.

3. Freeways, expressways, and railroads—a 100-year recurrence interval flood discharge.

It is evident that the severity of the flood to be passed by a bridge or culvert without overtopping increases in proportion to the importance of the crossing in the regional transportation system. The relative importance or functional classification of each roadway river crossing—that is, minor or collector streets, arterial streets and highways, and freeways and expressways—is established by the Commission design year 2000 regional transportation plan. The bridge standards are intended to assure that a sufficient number of critical river crossings will remain passable during major flood events so that the regional highway and railroad transportation system can function properly.

Information contained within the hydrologic-hydraulic summary tables set forth in Appendix F in combination with the above bridge standards was used to identify the existing bridges and culverts in the watershed that have substandard capacity during major flood events. As set forth in Table 72, two bridges and culverts may be expected to have substandard hydraulic characteristics under the year 2000 plan land use and planned channel conditions; and it is recommended that, when they are modified or replaced by local or state highway agencies or by railroads as a part of highway and railroad improvement programs, these crossings be designed to provide adequate capacity in accordance with recommended standards. Of the total number of substandard bridges and culverts, none are located on a minor or collector street where the 10-year recurrence interval standard is applicable; two are located on arterial streets and highways (other than freeways and expressways) where the 50-year recurrence interval standard is applicable; and none are located on freeways, expressways, and railroads where the 100-year recurrence interval standard is applicable.

The location, as well as the design, of all new bridges and culverts—that is, of structures proposed to be located over major streams at points within the watershed where presently no crossing exists—as well as the design of replacements of or modifications to existing bridges or culverts, should be based upon the applicable objectives and standards set forth in Chapter X of this volume. Of particular importance is the standard which requires that all new or replacement bridges and culverts be designed so as to accommodate 100-year recurrence interval flood discharge under year 2000 plan conditions without raising the corresponding peak stage by more than 0.1 foot above the peak stage for the 100-year recurrence interval flood, as established in the adopted comprehensive watershed plan. This provision is intended to assure that the new, modified, or replacement river crossings, including their approaches, will not aggravate existing flood problems, create new flood hazards, or unnecessarily complicate the administration of floodland regulations.

RECOMMENDED NONSTRUCTURAL FLOODLAND MANAGEMENT MEASURES

Of the 11 available nonstructural floodland management measures set forth in Table 69 and discussed earlier in this chapter, two have been considered in the chapter as specific alternatives for the City of Cudahy, an additional three are particularly effective for minimizing aggravation of existing problems and for preventing development of future flood hazards, and the six remaining nonstructural measures, when used in combination, have the potential to prevent the aggravation of existing flood problems, minimize the development of future flood hazards, and help to alleviate monetary flood losses incurred by owners of existing flood-prone property, and in case of emergency measures, may substantially reduce the threat to life and health of residents of flood-prone areas. The application of the three primary nonstructural floodland management measures—reservation of floodland for recreation and related open space uses, floodland regulations, and channel maintenance—and the six secondary measures, is described below.

Primary Measures

Reservation of Floodland for Recreation and Related Open Space Uses: The Kinnickinnic River watershed land use plan element recommends, as described in Chapter XI, the continued maintenance and preservation for open space purposes of 0.9 square mile of primary environmental corridor. Inasmuch as the corridor lands generally follow the alignment of the Kinnickinnic River from S. 16th Street to S. 69th Street, much of the open space land also encompasses the floodlands of this reach. Maintenance of existing public or private outdoor recreation and related open space lands and reservation—by public or private ownership or by easement—of additional land for these purposes constitute important effective means of implementing the recommended land use plan for the watershed. It is recommended, therefore, that the use of floodland areas for outdoor recreation and related open space activities be emphasized and carried out not only to implement the land use plan, but also to minimize the aggravation of existing flood problems and the development of new flood problems.

Floodland Regulations in the Wisconsin Floodplain Management Program: Wisconsin Statutes require that all counties, cities, and villages in the watershed with existing or potential flood hazards adopt reasonable and effective floodland regulations in accordance with the floodplain management program administered by the Wisconsin Department of Natural Resources. Of the six communities in the watershed, three have existing or potential flood hazard areas, namely, Milwaukee, West Allis, and Cudahy. Of these three communities,

Table 72

RIVER CROSSING IN THE KINNICKINNIC RIVER WATERSHED HAVING SUBSTANDARD HYDRAULIC CAPACITIES

Structure Identification[a]					Date of Construction or Major Reconstruction	Recommended Design Frequency (years)	Hydraulic Inadequacy	
Stream	Number[b]	Name	River Mile	Civil Division			Approach Road Overtopped	Bridge Deck Overtopped
Kinnickinnic River	100 280	Chase Avenue S. 43rd Street	2.40 2.80	City of Milwaukee City of Milwaukee	1931 N/A	50 50	X X	
Wilson Park Creek	--	--	--	--	--	--	--	--
Lyons Creek	--	--	--	--	--	--	--	--

[a] *This table identifies public bridges and culverts which, when considered in conjunction with their approach roadways, have substandard hydraulic capacities under year 2000 plan land use and planned channel conditions according to the water control facility standards set forth in Chapter X.*

[b] *Bridges and culverts are identified by structure number and are located on Map 26.*

Source: SEWRPC.

only the City of Milwaukee has adopted floodland or floodland-related regulations such as wetland, conservancy, or floodplain zoning that apply to floodlands in the Kinnickinnic River watershed. While these floodland and floodland-related regulations do control development in flood hazard areas, they do not meet the minimum requirements of the State of Wisconsin floodplain management program due to the absence of adequate flood hazard information, including the delineation of the limits of the 100-year recurrence interval floodlands. Flood hazard information suitable for floodland regulations purposes is now available for the watershed stream system as the result of the hydrologic-hydraulic analyses conducted under the Kinnickinnic River watershed planning program.

It is recommended, therefore, that the City of Milwaukee revise its floodland and floodland-related regulations so as to be fully consistent with the flood hazard data developed under the study for the year 2000 land use planning conditions. It is further recommended, based on the identification of existing or potential flood hazards under the watershed planning program, that the Cities of West Allis and Cudahy utilize the flood hazard data generated by the planning program in the preparation and adoption of floodland and floodland-related regulations.

More specifically, it is recommended that, in order to conserve the floodwater storage and conveyance capacity of the existing floodlands, abate future flood hazards and monetary flood damages, reduce the existing hazards to human health and safety caused by unwise occupation of the floodlands, and reduce the expenditures of public funds to secure the health and safety of floodland residents during periods of flooding, and in light of the highly urbanized nature of the watershed, the floodland and floodland-related land use regulations be designed so as to accommodate the existing development, preserve sufficient conveyance capacity for the 100-year flood flow through delineation and preservation in open use of a floodway, and require the floodproofing of all new urban development permitted in the floodplain fringe.

Channel Maintenance: As discussed earlier in this chapter, channel maintenance, consisting of periodic removal of sediment deposits, heavy vegetation, and debris, is necessary to: 1) maintain the integrity of flood stage profiles developed under this planning program; 2) maintain the channel invert below the invert of existing and planned storm water outfalls to allow these to function properly, and 3) reduce the probability that buoyant objects and debris will be carried downstream by floodwaters and accumulate at bridges and culvert inlets, thereby reducing their conveyance. It is strongly recommended that the operations of the responsible governmental units and agencies be formulated so that the conduct of such channel maintenance be included.

Secondary Measures

Federal Flood Insurance: While the federal flood insurance program does not solve flood problems or mitigate flood damages, it does provide a means for distributing monetary flood losses in the form of an annual flood insurance premium and, in those situations where the insurance premiums are subsidized, the federal flood insurance program also provides a way of reducing monetary flood losses to the owner. It is, therefore, in the best interest of watershed communities to participate in the federal flood insurance program.

While the ultimate decision to purchase flood insurance remains with individual property owners, initiative to establish the program within a particular community must be taken by the municipality having jurisdiction over zoning and building codes. The municipality must file a formal request with the U. S. Department of Housing and Urban Development for consideration for participation in the flood insurance program, including in its application an account of the historic flood problems in the community and a map of the community on which are delineated those flood-prone areas for which insurance is desired. Such application must also include copies of adopted floodland regulations or other adopted measures intended to prevent or reduce future flood damages. The community or unit of government must also submit assurances of future compliance, including resolutions indicating that flood problems will be continuously monitored and that such problems will be considered in all official actions affecting floodland use. Historic flood information and other flood hazard data developed under the Kinnickinnic River watershed planning program will be useful to watershed communities seeking full participation in the federal flood insurance program.

Based on the hydrologic-hydraulic analyses conducted under the watershed study, existing or potential flood problems have been identified in the watershed portions of the Cities of Milwaukee, West Allis, and Cudahy. These communities should act to participate in the federal flood insurance program. Although flood hazards have been identified in the Milwaukee County portion of the Kinnickinnic River watershed, that entire area has been incorporated and, therefore, it is not necessary for Milwaukee County to participate in the federal flood insurance program. Of the remaining communities, the Cities of Greenfield and St. Francis will likely participate in the program by virtue of having flood-prone areas outside of the Kinnickinnic River watershed.

As of the end of 1977, all of the communities located wholly or partly in the Kinnickinnic River watershed had taken the necessary affirmative steps to become eligible to participate in the federal flood insurance program. In response to those requests for participation under the emergency phase of the program, the U. S. Department of Housing and Urban Development has published preliminary flood hazard boundary maps for all of the above eligible civil divisions with the exception of the Village of West Milwaukee. In addition, the U. S. Department of Housing and Urban Development, in cooperation with the Wisconsin Department of Natural Resources, which coordinates its flood insurance program within the State, has authorized insurance rate studies for the Cities of Greenfield and Milwaukee.

It is recommended that the U. S. Department of Housing and Urban Development, in cooperation with the Wisconsin Department of Natural Resources, authorize the conduct of insurance rate studies in the Cities of West Allis and Cudahy in Milwaukee County. With completion of the above two authorized insurance rate studies and the recommended additional two insurance rate studies, property owners in all watershed communities having clearly identified flood problems will be able to participate in the regular flood insurance program.

The analysis conducted under the Kinnickinnic River watershed planning program anticipated the eventual conduct of flood insurance rate studies and, therefore, hydrologic-hydraulic data needed to prepare those studies have been generated under the watershed planning program. In particular, these data include 10-, 50-, 100-, and 500-year recurrence interval flood stage profiles and associated floodplain delineations. It is recommended that the contractors retained by the U. S. Department of Housing and Urban Development to conduct the flood insurance rate studies make maximum utilization of the flood hazard data developed under the watershed program.

Lending Institution Policies: As a result of the National Flood Insurance Program, private lending institutions in the southeastern Wisconsin area have generally assumed the responsibility for determining whether or not a property is in a flood-prone area and, if so, whether it requires the purchase of flood insurance before granting a mortgage for a structure on the property. It is recommended that lending institutions continue to determine the flood-prone status of properties prior to the granting of a mortgage, irrespective of the requirements of the National Flood Insurance Program, and that the principal source of flood hazard information within the Kinnickinnig River watershed be that developed under the watershed planning program and available through either local units of government or the Regional Planning Commission.

Realtor Policies: As noted earlier in this chapter, an executive order by the Governor of Wisconsin in 1973 strongly urges that real estate brokers, salesmen, and their agents inform potential purchasers of property of any flood hazards which may exist at the site. It is strongly recommended that this program be continued inasmuch as the purchaser of property, particularly a potential buyer of a residence or of a lot for construction of a residence, is not likely to be aware of the threat to life and property posed by an event as rare as a major flood.

Community Utility Policies: As discussed earlier in this chapter, local communities may adopt policies relating to the extension of certain public utilities and facilities such as sanitary sewers, water mains, and streets in recognition of the likely influence of the location and size or capacity of such utilities and facilities on the location of new urban development. It is recommended that the policies of governmental units and agencies having responsibility for such utilities and facilities within the Kinnickinnic River watershed be formulated so that the size, location, and use of those utilities and facilities be consistent with the flood-prone status of riverine areas. More particularly, it is recommended that these utility and facility policies be designed to complement the floodland regulation recommendations for the Kinnickinnic River watershed.

Land Use Controls Outside of the Floodlands: As described in Chapter XI, due to the highly urbanized nature of the watershed, only about 2.1 square miles of open land consisting of small areas throughout the watershed remain to be developed. In preparing a plan for the development of these areas and redevelopment of local areas, it is recommended that the hydrologic impact of the plan be considered in addition to its relationship with soil capabilities, long established and planned utility systems, and the natural resource base.

Emergency Programs: An emergency program to minimize the damage and disruption associated with flooding normally consists of a variety of devices and techniques that are tailored to the flood hazard characteristics of individual communities. It is particularly pertinent to note that historic data and simulation results reveal that most of the Kinnickinnic River watershed is classified as being hydrologically and hydraulically "flashy" in that major flood events are likely to be caused by intense rainfall events that are unpredictable as to location and time of occurrence, and that there may be only an hour of elapsed time between the initial rise of floodwaters and the occurrence of peak stages. It therefore follows that it is not practicable to establish a system to predict the location, magnitude, and time of occurrence of peak flood stages. In addition, these studies indicate that peak flood discharges within the Kinnickinnic River watershed for selected recurrence intervals may be expected to be several times larger than those that would occur in rural watersheds of similar size, soils, and topography.

It is recommended, therefore, that each watershed community develop procedures to provide floodland residents and other property owners with information about floods that are already in progress. While the optimum combination of measures comprising such an information system will differ from community to community, it is suggested that measures such as the following be considered: monitoring of National Weather Service flash flood watch bulletins and flash flood warning bulletins during periods when rainfall or snowmelt are occurring or are anticipated, patrolling riverine areas to note when bankfull conditions are imminent, emergency messages broadcast to community residents over radio and television, use of police patrol cars or other vehicles equipped with public address systems, and use of warning sirens having a special pattern to indicate that flooding is occurring, especially during nighttime hours. While emergency measures like those recommended above may alleviate some damage to property in flood-prone areas by providing property owners with time to prepare for the flood stage, their most significant benefit is that they provide a way to reduce the threat to the life and health of residents of flood-prone areas, particularly during nighttime hours when residents of riverine areas may not be aware of rising waters. None of the other floodland management alternatives available to watershed communities are directed explicitly to the protection of the inhabitants of existing flood-prone areas.

ACCESSORY FLOODLAND MANAGEMENT CONSIDERATIONS

During the Kinnickinnic River watershed planning program there emerged several items of interest which, although not pertaining directly to floodland management alternatives as set forth in this chapter, did relate to the overall existing and potential flood problems in the Kinnickinnic River watershed. These matters of concern were examined during the watershed planning process, and the resulting conclusions and recommendations based on that examination are described below.

Maintenance of Stream Gaging Network

When the Kinnickinnic River Watershed Planning Program was initiated in 1976, there were no continuous or daily stream gaging stations in the basin. As a result of the watershed study, the U. S. Geological Survey, in cooperation with the Commission and the Metropolitan Sewerage Commission of the County of Milwaukee, installed and has operated a continuous stage recorder gage at the S. 7th Street crossing of the Kinnickinnic River in the City of Milwaukee.

The U. S. Geological Survey has also maintained a low-flow partial record gage in cooperation with the Wisconsin Department of Natural Resources at S. 27th Street on the Kinnickinnic River. In addition to the above streamflow monitoring stations in the watershed, a total of 16 crest stage gages are operated in the basin by the Milwaukee-Metropolitan Sewerage Commissions, and a total of 17 staff gages are maintained by the City of Milwaukee in the Milwaukee portion of the watershed.

Continuous recording stream gaging stations, as well as partial record streamflow stations and crest stage stations, by monitoring river flows and stages at points strategically located within the watershed, can provide critical data required for future rational management of the surface water resources of the basin for the following reasons:

1. Discharge-frequency relationships derived from data provided by continuous recording stream gaging stations and by partial record stations in addition to flood stage profiles from crest-stage gages can be used to periodically refine the hydrologic and hydraulic simulation submodels developed and used in the Kinnickinnic River watershed study.

2. Stream gaging records, obtained in conjunction with coincident water quality monitoring data, can also be used to periodically refine the water quality simulation submodel used in the watershed study.

It is recommended that the continuous recorder gage installed at the S. 7th Street crossing of the Kinnickinnic River in the City of Milwaukee for purposes of the Kinnickinnic River watershed study continue to be operated in the vicinity subsequent to the completion of the committed channel improvements. A continuous flow stream gage is preferable at that location in this watershed because of the hydrologically and hydraulically flashy nature of the basin, which necessitates continuous discharge—that is, stage—measurements.

It is recommended that the partial record station operated in the basin by the U. S. Geological Survey at S. 27th Street on the Kinnickinnic River continue to be operated, and that the City of Milwaukee and the Milwaukee-Metropolitan Sewerage Commissions continue to maintain crest stage or staff gage networks.

The above stream gaging recommendations pertain primarily to continued monitoring of flood problems in the Kinnickinnic River watershed. It is significant to note, however, that in light of the highly urbanized nature of the watershed, continued streamflow monitoring would offer a unique opportunity for continued hydrologic, hydraulic, and water quality research in southeastern Wisconsin. Such research programs might be directed to a variety of topics, including the development of rainfall-runoff relationships for urban areas, the relationship between fallout and washout from the atmosphere and the quality of surface water, and the impact of street cleaning procedures in urban areas on the quality of runoff to the stream system.

Flood Characteristics of the Kinnickinnic River Estuary and of the Kinnickinnic River Immediately Upstream of the Estuary

As described in Chapter I of this report and as shown on Map 2, the estuary of the Kinnickinnic River consists of that 2.4-mile-long reach of the river lying downstream of the Chase Avenue bridge. The determination of flood stages and delineation of corresponding flood hazard areas for the estuary and for the river reach immediately upstream are complicated by the interaction between the Kinnickinnic River flood flows, channel-floodplain hydraulic characteristics, the presence of bridges and culverts, and stage fluctuations occurring in the estuary in response to fluctuating levels of Lake Michigan. Flood characteristics of the Kinnickinnic River estuary and the Kinnickinnic River reaches immediately upstream of the estuary were determined, as described below, by reviewing previous analyses of estuary stages and by conducting a special hydraulic analysis.

Factors Influencing Flood Stages: For purposes of determining flood stages in the estuary portion of the river and in the stream reach immediately upstream of the estuary, the estuary and the lower reaches of the stream may be partitioned into three zones as shown in Figure 66. The principal criteria used in identifying the zones are the factors likely to influence flood stages within each zone.

Zone I consists of the downstream-most portion of the estuary within which flood stages are determined primarily by stages in the adjacent lake; that is, river discharge into and through Zone I has negligible effect on flood stage. In the case of the Kinnickinnic River, Zone I is that downstream-most portion of the estuary in which flood stages are determined primarily by fluctuations in Lake Michigan levels and are not significantly influenced by flood flows from the Kinnickinnic River watershed.

Zone II is that portion of the river that is sufficiently far upstream of Zone I so as to be beyond the influence of flood stages within Zone I. Flood stages in Zone II are a function of flood discharge and of local hydraulic conditions such as channel-floodplain geometry and roughness and the backwater effect of bridges and culverts. In the case of the Kinnickinnic River, Zone II is that portion of the Kinnickinnic River that is sufficiently far upstream of the estuary so as to be beyond the influence of stage fluctuations occurring in Zone I.

Zone III is the transition reach within which stages are determined partly by the factors that determine stages in Zone I and partly by factors that determine stages in Zone II. That is, flood stages within Zone III are, like Zone I, influenced by lake stages and, like Zone II, influenced by flood discharge and local hydraulic conditions such as channel-floodplain geometry and roughness, and the backwater effect of bridges. In the case of the Kinnickinnic River, Zone III consists of a combination of the upper portion of the estuary and the river reach immediately upstream in which stages are affected in part by fluctuations in Lake Michigan levels.

The above model or representation of the estuary portion of a river and the river reach immediately upstream of the estuary serves as the basis for the hydraulic analysis described below. The overall purpose of the analysis is to accurately determine 10-, 50-, and 100-year recurrence interval flood stage profiles within the lower reaches of the Kinnickinnic River for year 2000 planned land use conditions.

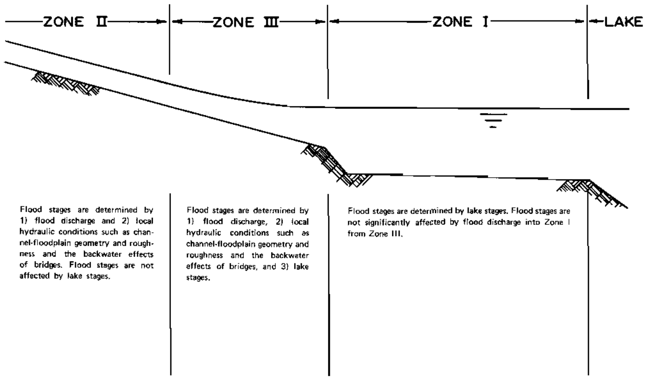
Historic Stages in the Estuary: The analysis of flood stages along the Lower Kinnickinnic River was initiated by a review of the statistical analysis of historic estuary stages near the Menomonee River-Milwaukee River confluence as originally performed under the Menomonee River watershed planning program.[14]

Based on the 74-year period of record extending from 1901 through 1974, the mean water elevation of the estuary of the Milwaukee, Menomonee, and Kinnickinnic Rivers as determined from stage records maintained by the City of Milwaukee at the S. Water Street bridge is 579.5 feet above National Geodetic Vertical Datum or 1.1 feet below City of Milwaukee Datum. The Water Street bridge is located at River Mile 0.78 on the Milwaukee River—0.1 mile downstream of the Milwaukee

[14] *SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume Two, Alternative Plans and Recommended Plan, pp. 182-185, October 1976.*

Figure 66

SCHEMATIC REPRESENTATION OF FLOOD STAGE CHARACTERISTICS IN AN ESTUARY AND IN THE RIVER REACH IMMEDIATELY UPSTREAM



Source: SEWRPC.

River-Menomonee River confluence and 0.6 mile upstream of the Milwaukee River-Kinnickinnic River confluence. The median of the annual maximum stages of the Milwaukee-Menomonee-Kinnickinnic River confluence is 581.0 feet above National Geodetic Vertical Datum, or 0.4 foot above the City of Milwaukee Datum. Stage fluctuations at the observation location have ranged from a low of 575.7 feet above National Geodetic Vertical Datum, or 4.9 feet below City of Milwaukee Datum, in 1926 to a high of 583.6 feet above National Geodetic Vertical Datum, or 3.0 feet above the City of Milwaukee Datum, in 1917 and again in 1973. Stage fluctuations near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers, which approximate a maximum range of 8.0 feet, are illustrated in Figure 67, which shows the historic states for the 74-year record extending from 1901 through 1974.

The 74-year series of maximum annual estuary stages was used to construct the estuary stage-frequency relationship shown in Figure 68. This stage-frequency relationship is very similar to that reported by the U. S. Army Corps of Engineers.[15] For example, the Commission analysis indicates a 100-year recurrence interval estuary stage of 583.8 feet above National Geodetic Vertical Datum, whereas the Corps analysis based on Milwaukee-area historic Lake Michigan stage data indicates a 100-year recurrence interval lake stage of 583.7 feet above National Geodetic Vertical Datum. Similarily, the Commission analysis indicates a two-year recurrence interval estuary stage of 580.8 feet above National Geodetic Vertical Datum, whereas the Corps analysis obtains a stage of 580.7 feet above National Geodetic Vertical Datum. Estuary stage-frequency relationships are important not only because they establish flood stages in the estuary, but also because they are the basis, as described below, for backwater calculations needed to develop flood stages along the Kinnickinnic, Menomonee, and Milwaukee Rivers upstream of the estuary.

As noted above, the estuary stage-frequency relationship as shown in Figure 68 is based on historic stages for the 74-year period 1901 through 1974. Consideration was given, under the Kinnickinnic River watershed planning program, to the need for updating the statistical analysis using maximum annual stages for years subsequent to 1974. However, an examination of stage records indicated that extreme high or low lake stages did not occur during 1975, 1976, and 1977 and, therefore, it was not deemed necessary to refine the statistical analysis to include the three additional years of record.

Identification of Flood Stage Zones along the Lower Kinnickinnic River: As noted above, an estuary and the reaches of a river immediately upstream of an estuary can be partitioned into three zones for purposes of accurately determining flood stages. The procedure used to partition the lower Kinnickinnic River into the three zones is described below.

Procedure: Historic low, median, and high maximum annual stages of, respectively, 578.0, 581.0, and 583.6 feet above National Geodetic Vertical Datum were used as the beginning for backwater computations at River Mile 0.82 on the Kinnickinnic River. These computations were extended upstream, assuming committed channel modifications, through the S. 6th Street crossing of the Kinnickinnic River at River Mile 2.83. This upstream termination point was selected so as to be well within Zone II; that is, well upstream of the influence of Lake Michigan stages on river stages. The discharges used in these computations were those expected to occur under year 2000 plan conditions with committed channel modifications consisting of 100-, 50-, and 10-year recurrence interval peak flood discharges of 7,400, 6,500, and 4,550 cfs, respectively, for the reach from River Mile 0.82 to River Mile 1.42, and 7,000, 6,200, 4,350 cfs, respectively, for the reach from River Mile 1.43 to River Mile 2.83.

Results: The results of the computations are shown in Figure 69 in the form of a set of 10-, 50-, and 100-year recurrence interval flood stage profiles for each of three—low, median, and high—maximum annual estuary stages.

Interpretation of the Results: The flood stage profiles shown in Figure 69 indicate the existence of the three zones, as shown schematically in Figure 66, and permit an identification of the limits of each zone for the lower Kinnickinnic River. Zone I, which is that river reach within which flood stages are determined by Lake Michigan stage and are independent of Kinnickinnic River discharge, extends from the confluence with the Milwaukee River at River Mile 0.00 upstream 1.28 miles to the S. Kinnickinnic Avenue crossing of the river.

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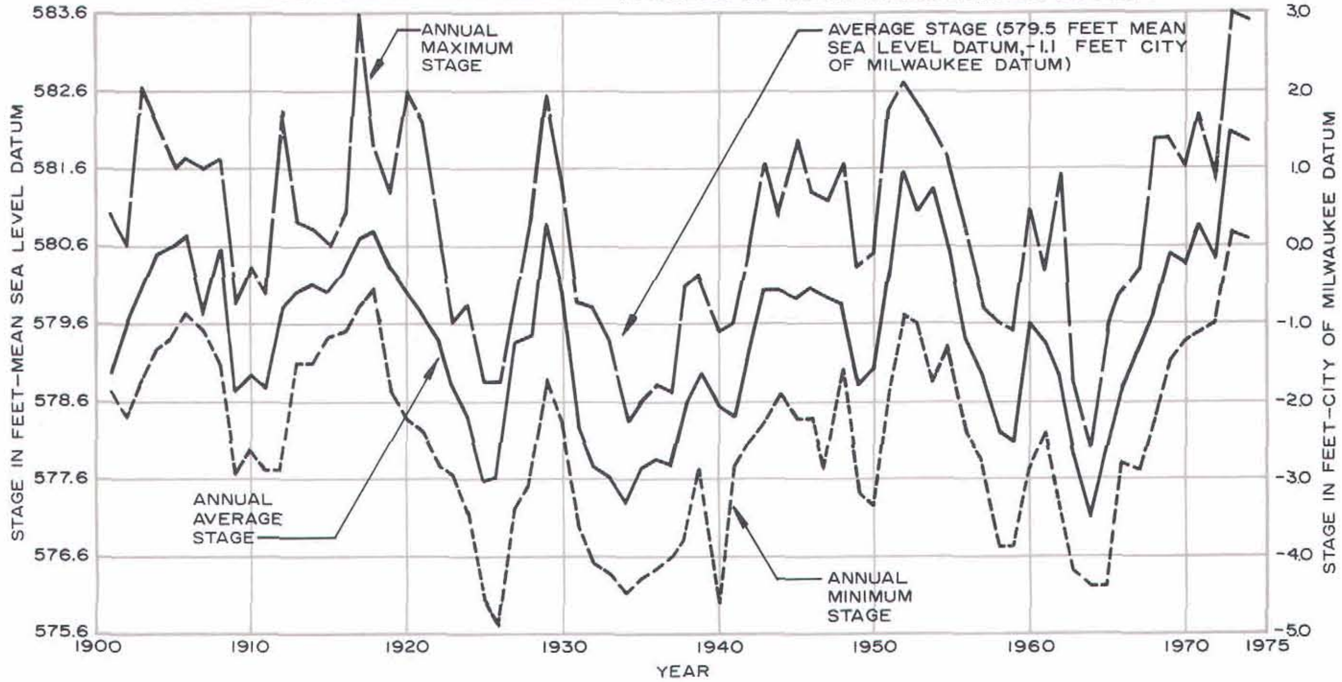
[15] *L. T. Schutze, "Great Lakes Open-Coast Flood Levels," Proceedings of a Seminar on Nonstructural Floodplain Management Measures, May 4-6, 1976, Co-sponsored by the Hydrologic Engineering Center and the Institute for Water Resources, U. S. Army Corps of Engineers, pp. 173-188.*

Figure 67

HISTORIC STAGES AT THE WATER STREET BRIDGE ON THE MILWAUKEE RIVER: 1901-1974



NOTE:
1. THE ANNUAL AVERAGE LAKE MICHIGAN STAGE FOR 1909 WAS OBTAINED BY INTERPOLATION
2. THE WATER STREET BRIDGE IS LOCATED 0.1 MILES DOWNSTREAM OF THE MENOMONEE RIVER-MILWAUKEE RIVER CONFLUENCE

Source: City of Milwaukee Bureau of Engineering and SEWRPC.

Zone II, which is that river reach within which flood stages are a function of flood discharge and local hydraulic conditions and are independent of Lake Michigan stages, is bounded at the downstream end by Chase Avenue at River Mile 2.40 and extends upstream encompassing the rest of the watershed stream system. As indicated in Figure 69, Chase Avenue is that point on the Kinnickinnic River below which flood stages for a given discharge are markedly influenced by Lake Michigan stages but upstream of which flood stages are independent of estuary effects.

Zone III, which is that reach within which flood stages are influenced both by estuary stages and by flood discharge and local hydraulic conditions, is bounded on the downstream end by S. Kinnickinnic Avenue at River Mile 1.28 and at the upstream end by S. Chase Avenue at River Mile 2.40. Figure 69 indicates that for a given flood discharge, flood stage profiles within Zone III vary with estuary stages, and that for given starting stages in Zone I, flood stages within Zone III vary according to flood discharge.

Determination of Flood Stages in Zones I, II, and III: Having demonstrated the existence of the three zones and identified the limits of each, the next step in the analysis of the flood stages was to determine the 10-, 50-, and 100-year recurrence interval flood stages in each of the three zones. Flood stages for Zone I are indicated in the stage-frequency relationship presented in Figure 67, and therefore no additional analysis was needed for Zone I. The 10-, 50-, and 100-year recurrence interval flood stage profiles for Zone I are shown in Figure 70. Additional hydraulic computations, as described below, were required for Zones II and III.

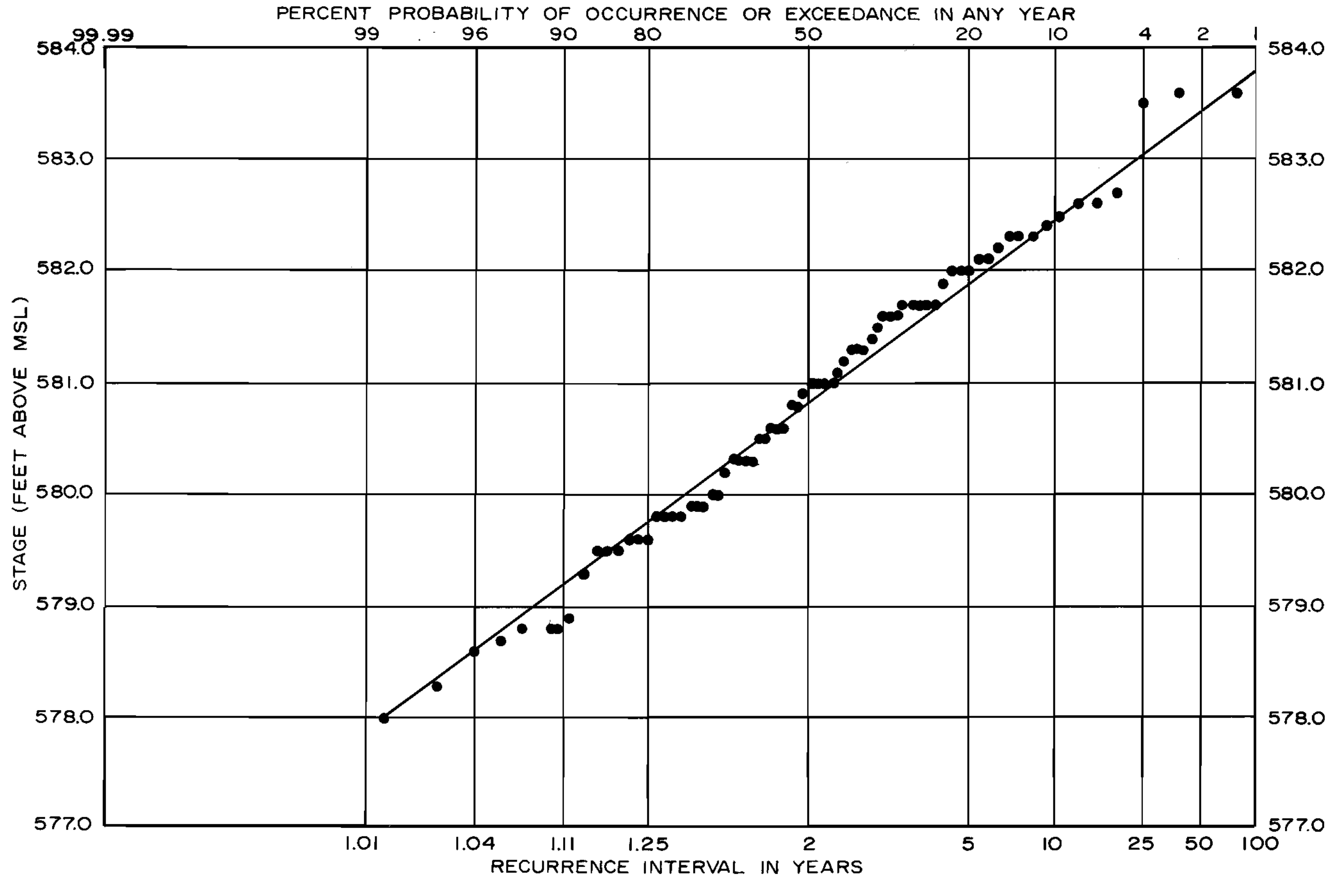
Flood stage profiles for Zone II, the entire Kinnickinnic River stream system upstream of S. Chase Avenue, were developed by backwater computations performed using Hydraulic Submodel 2. These computations were conducted for 10-, 50-, and 100-year recurrence interval discharges, and the results for the Lower Kinnickinnic River are shown in Figure 70.

Flood stages for Zone III were determined by merging the estuary stage and the flood stage computed using backwater computations initiated at normal depth for specific recurrence intervals.[16] The estuary stages used are those indicated in Figure 67 and identical to Zone I

[16] *A joint probability of occurrence statistical analysis conducted using monthly average estuary stages and monthly instantaneous peak discharges indicated that the incorporation of such extensive data into the determination of flood stages for this reach did not produce significantly different results.*

Figure 68

ESTUARY STAGE-FREQUENCY RELATIONSHIP BASED ON STAGES RECORDED AT THE WATER STREET BRIDGE ON THE MILWAUKEE RIVER: 1901-1974



NOTE: THE WATER STREET BRIDGE IS LOCATED 0.1 MILE DOWNSTREAM OF THE MENOMONEE RIVER-MILWAUKEE RIVER CONFLUENCE.

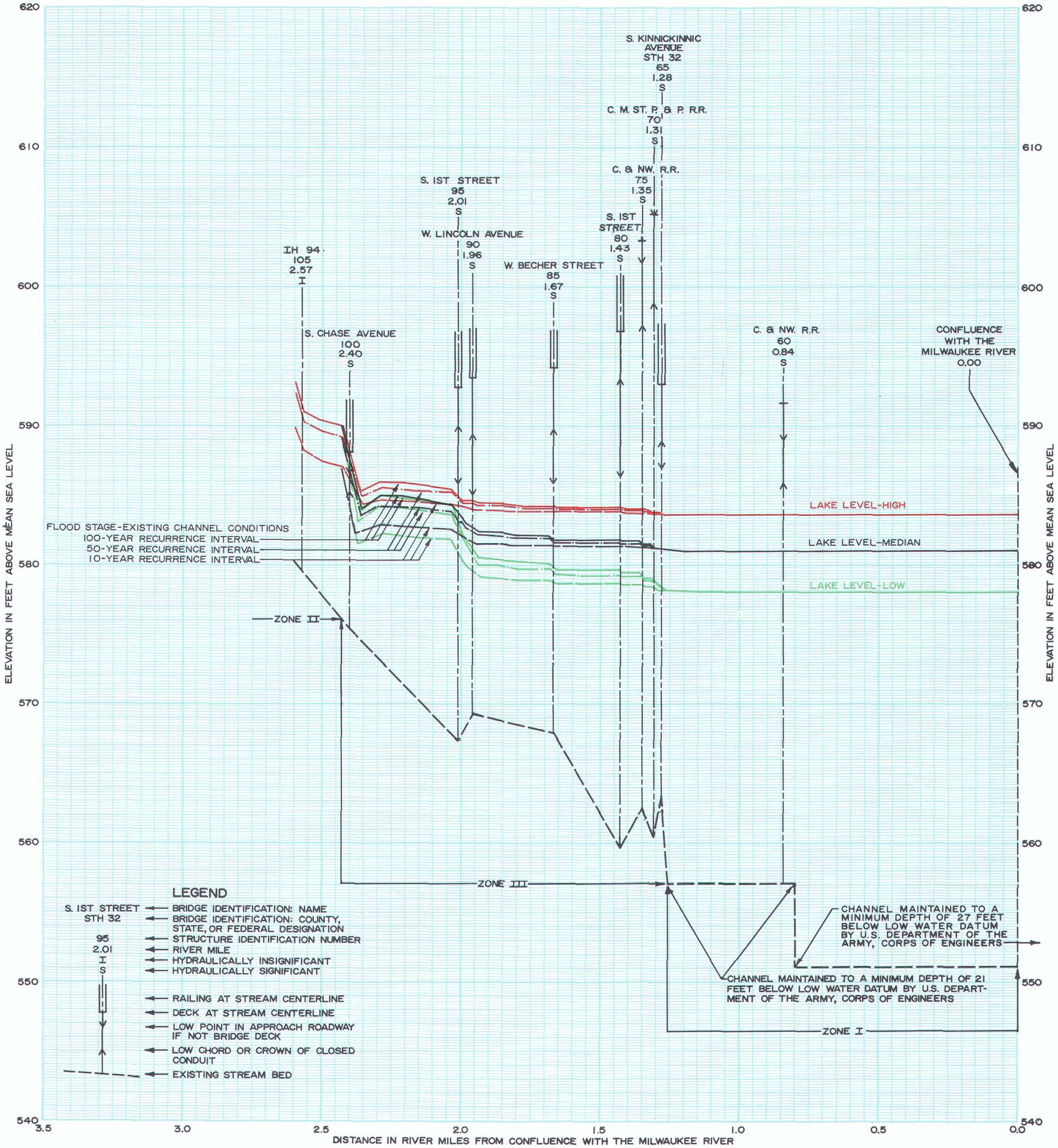
Source: SEWRPC.

flood stages. Backwater computations, starting at the normal depth of flow to eliminate the influence of estuary stages, were conducted along that portion of the Kinnickinnic River extending from River Mile 1.28 upstream through Zone III using Hydraulic Submodel 2. The 10-, 50-, and 100-year recurrence interval flood stages under year 2000 plan conditions for Zone III, as shown in Figure 70, consist of Zone I stages extended upstream until exceeded by the flood stages determined by the backwater computations initiated at normal depth.

Significance of Flood Protection Elevations Recommended by Milwaukee-Metropolitan Sewerage Commissions: As a means of mitigating future flood damages, the Milwaukee-Metropolitan Sewerage Commissions have issued the public notice included as Figure 71 indicating high water problems in the estuary area. The notice recommends that materials, facilities, and equipment located in basements within the area be protected or so placed that water rising to an elevation of 584.6 feet above National Geodetic Vertical Datum—4.0 feet above City of Milwaukee Datum—will cause no damage. Such a recommendation applies to that 2.40-mile-long reach of the Kinnickinnic River downstream of the Chase Avenue bridge. Based on the above analysis, which indicates the 100-year recurrence interval flood stage in that reach of the Kinnickinnic River 583.8 feet above National Geodetic Vertical Datum—0.8 foot below the flood protection elevation—it follows that the recommended flood protection elevation established by the Commission can continue to be applied only to that 2.01-mile reach of the Kinnickinnic River downstream of S. First Street. Consideration should be given to raising the flood protection elevation in this reach 1.2 feet to provide 2.0 feet of freeboard above the 100-year recurrence interval stage. A flood protection elevation of at least two feet above the 100-year recurrence interval peak flood stage profile for year 2000 planned conditions as shown in Figure 70 should be established along the Kinnickinnic River upstream from S. First Street.

Figure 69

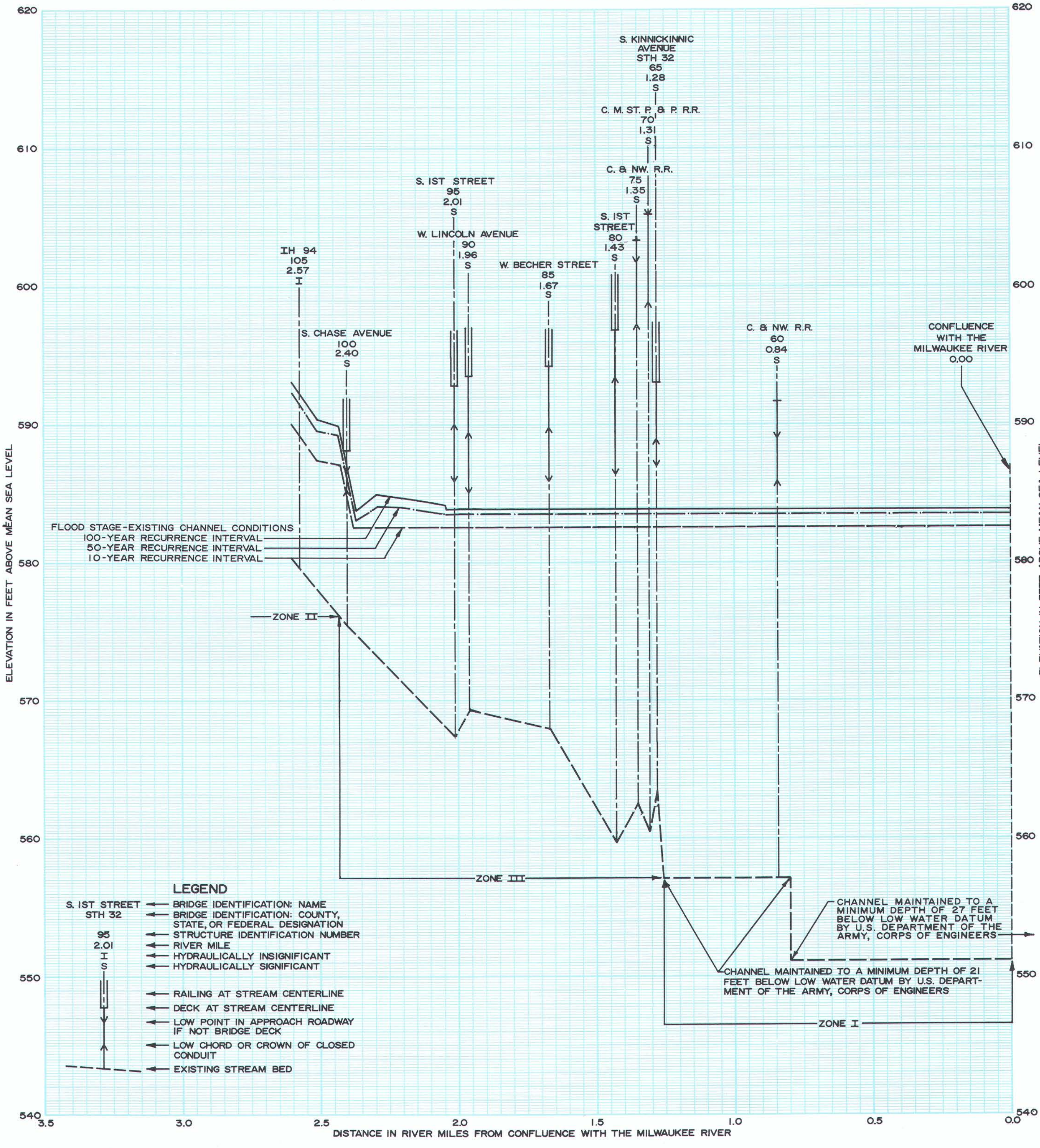
FLOOD STAGE PROFILES FOR THE LOWER KINNICKINNIC RIVER FOR THE 10-, 50-, AND 100-YEAR RECURRENCE INTERVAL FLOOD DISCHARGES UNDER YEAR 2000 PLAN CONDITIONS ASSUMING HISTORIC LOW, MEDIAN, AND HIGH MAXIMUM ANNUAL ESTUARY STAGES



Source: SEWRPC.

Figure 70

FLOOD STAGE PROFILES FOR THE LOWER KINNICKINNIC RIVER FOR THE 10-, 50-, AND 100-YEAR RECURRENCE INTERVAL FLOOD DISCHARGES UNDER YEAR 2000 PLAN CONDITIONS ASSUMING 10-, 50-, AND 100-YEAR RECURRENCE INTERVAL ESTUARY STAGES



Source: SEWRPC.

Figure 71

NOTICE ISSUED BY MILWAUKEE-METROPOLITAN SEWERAGE COMMISSIONS RELATIVE TO BASEMENT FLOODING CAUSED BY SEWER BACKUP: MARCH 1952

GENERAL NOTICE

TO: Building Owner and/or Occupant

Record high lake levels predicted for this year may seriously interfere with the operation of both the City and Metropolitan Sewerage Commission sewer systems by raising the levels of the rivers. This will result in direct interference with the outlets of the combined storm and sanitary sewers in the downtown area, as well as the separate sanitary sewers in other districts.

Under conditions of high lake levels, rapidly melting snow or heavy rains may result in surcharging the sewer system to a point where flooding of basements may occur.

It therefore becomes necessary for all residences, stores, commercial establishments or other buildings to protect themselves to an elevation of plus four.

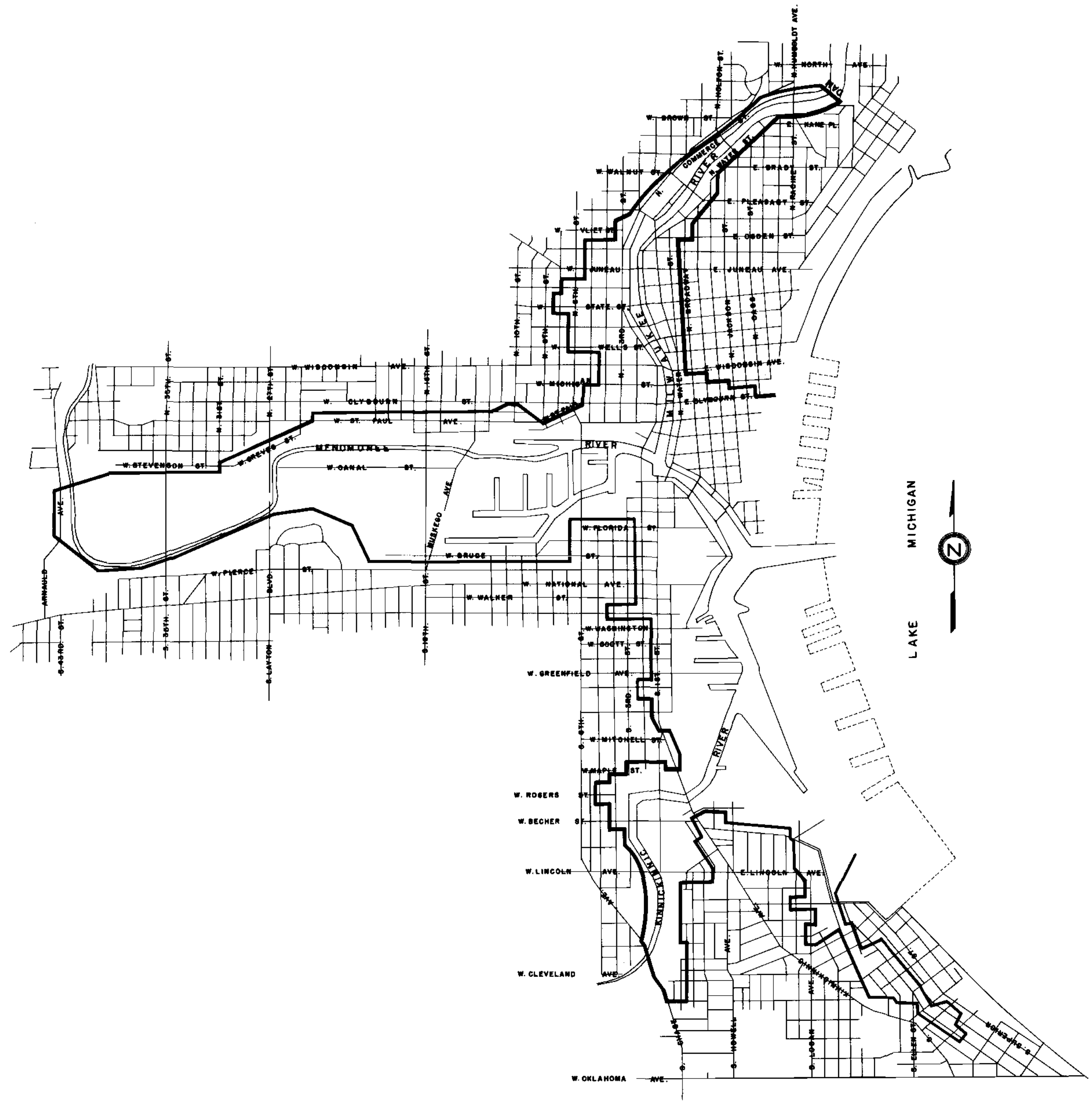
This means that materials, facilities and equipment located in basements should be protected or so placed that water rising to an elevation of four (4) feet above City of Milwaukee datum will cause no damage.

The accompanying map shows the outline of the area most likely to be affected.

CITY and METROPOLITAN SEWERAGE COMMISSIONS

March 26, 1952

NOTE: Four feet above City of Milwaukee datum is equivalent to 584.6 feet above Mean Sea Level datum.



Source: Milwaukee-Metropolitan Sewerage Commissions.

SUMMARY

Floodland management may be defined as the planning and implementation of a combination of measures intended to reconcile the floodwater conveyance and storage function of floodlands with the space and related social and economic needs of society. This chapter presents a recommended floodland management plan element for inclusion in a comprehensive plan for the Kinnickinnic River watershed. Alternatives to the recommended element also are presented, together with a comparative evaluation of the recommended element and the alternatives thereto.

The available floodland management measures from which the recommended management plan element was synthesized may be broadly subdivided into two categories: structural measures and nonstructural measures. A total of five structural floodland management measures were identified for possible application, either individually or in various combinations, to specific flood-prone reaches of the watershed, including: 1) floodwater storage facilities, 2) floodwater diversion facilities, 3) dikes and floodwalls, 4) major channel modifications, and 5) bridge and culvert modifications or replacement. Eleven nonstructural measures were identified consisting of: 1) reservation and acquisition of floodlands for recreation and related open space use, 2) floodland use regulation, 3) channel maintenance, 4) federal flood insurance, 5) lending institution policies, 6) realtor policies, 7) community utility policies, 8) regulation of land use outside of the floodlands, 9) emergency programs, 10) structure floodproofing, and 11) structure removal. Structural measures tend to be more effective in achieving the objectives of floodland management in riverine areas that have already been urbanized, while nonstructural measures are preventative in that they are generally more effective in riverine areas that have not yet been developed for flood damage-prone uses but have the potential for such development.

A hydrologic and hydraulic flood flow simulation model was used to quantitatively evaluate the response of the Kinnickinnic River watershed to the planned land use and the committed channel modification on the flood flow behavior of the watershed. The simulation model studies indicated that 100-year recurrence interval peak flood flows may be expected to increase up to 60 percent. These relative increases are small compared to those found in a developing but less urbanized area, due to the high degree of urbanization already present in the watershed.

The economic analyses of alternative floodland management measures require that the flood damage susceptibility of a river reach be quantified in monetary terms for comparison to the cost of alternative floodland management measures. Information derived from the historic flood survey, combined with the results of hydrologic-hydraulic simulation, indicated that only one reach, on Wilson Park Creek—Edgerton Channel—in the City of Cudahy, would have a significant flooding problem after completion of the committed channel modifications. The monetary flood risks for this reach were estimated, on an average annual basis, at $47,000 under existing land use-channel conditions, and at $93,500 under year 2000 planned land use and committed channel modification conditions, an increase of about 100 percent.

The following three technically practicable and economically feasible alternatives were developed for resolution of the flood problems along the Wilson Park Creek—Edgerton Channel—in the City of Cudahy: 1) structure floodproofing and elevation which would produce an annual benefit of $93,500 at an annual cost of $24,300 for a benefit-cost ratio of 3.8; 2) detention storage which would produce an annual benefit of $77,300 at an annual cost of $30,600 for a benefit-cost ratio of 2.5; and 3) a composite detention storage-channel enclosure alternative which would produce a benefit of $93,500 at an annual cost of $62,000 for a benefit-cost ratio of 1.5. After careful review of the technical and economic aspects of these three alternatives and three additional technically feasible alternatives found to be economically unsound, and after due consideration of the various nontechnical and noneconomic positive and negative features of each as identified under the planning program, it is recommended that the composite detention storage-channel enclosure-bridge alteration alternative be used to resolve existing and probable future flood problems along the Edgerton Channel in the City of Cudahy.

Analyses conducted under the watershed planning program resulted in the identification of two bridges and culverts that could be expected, by virtue of inadequate capacity and overtopping of the approach roads or the structure, to interfere with the operation of the highway and railroad transportation system during major flood events. Of the total number of substandard bridges and culverts so identified, none are located on minor or collector streets, two are located on arterial streets and highways other than freeways and expressways, and none are located on freeways, expressways, and railroads. It is recommended that when these structures are modified or replaced by the responsible highway agencies or by the railroad companies as part of necessary highway and railroad improvement programs, these crossings should be designed to provide adequate capacity in accordance with the standards set forth in Chapter X. It is also recommended, in accordance with the adopted standards set forth in Chapter X, that all new or replacement bridges and culverts be designed so as to accommodate the 100-year recurrence interval flood discharge under year 2000 plan conditions without raising the corresponding peak stage by more than 0.1 foot above the peak stage as established in the adopted comprehensive watershed plan.

Of the 11 available nonstructural floodland management measures identified for possible application in the Kinnickinnic River watershed, the following three were found to be particularly effective for minimizing aggravation of existing problems and for preventing development of future flood problems: 1) reservation of floodlands for recreation-related open space uses through measures

such as private development or public acquisition of the land or of an easement; 2) floodland use regulations as accomplished through zoning, land subdivision, sanitary, and building ordinances; and 3) channel maintenance. It is recommended that the use of floodland areas for outdoor recreation and related open space activities be emphasized and carried out not only to implement the land use plan—particularly the open space preservation and outdoor recreation plan subelements which seek to preserve recreational, aesthetic, ecological, and cultural resources of the watershed—but also to minimize the aggravation of the existing flood problems and development of new flood problems. In order to fully protect the floodlands of the watershed in accordance with this recommendation, existing floodland and related regulations would have to be modified for explicit application to Kinnickinnic River watershed floodlands or new floodland regulations prepared by the Cities of Milwaukee, West Allis, and Cudahy.

Although the availability of federal flood insurance does not resolve any existing flood problems, it does provide a means for distributing monetary flood losses in the form of an annual flood insurance premium and, in those situations where insurance premiums are subsidized, the federal flood insurance program also provides a way of reducing monetary flood losses to the owner. Significant steps have been taken by watershed communities toward participation in the federal flood insurance program in that all the communities located wholly or partly in the Kinnickinnic River watershed have taken the necessary steps to become eligible to participate in the federal flood insurance program. Furthermore, the U. S. Department of Housing and Urban Development has authorized insurance rate studies for the Cities of Greenfield and Milwaukee. It is recommended that the U. S. Department of Housing and Urban Development, in cooperation with Wisconsin Department of Natural Resources, authorize the conduct of additional insurance rate studies in the Cities of West Allis and Cudahy. It is further recommended that the contractors retained by the U. S. Department of Housing and Urban Development to conduct the flood insurance rate studies make maximum use of the flood hazard data developed under the watershed program. Finally, it is recommended that owners of property in flood-prone areas purchase flood insurance to provide some financial relief for losses sustained during future floods.

Under the national flood insurance program, private lending institutions require the purchase of flood insurance on property in flood-prone areas before granting a mortgage for a structure on the property. It is recommended that lending institutions continue to determine the flood-prone status of properties prior to granting of a mortgage, and that the principal source of flood hazard information be that developed under the watershed planning program. A 1973 executive order by the Governor of Wisconsin urges real estate brokers, salesmen, and their agents to inform potential purchasers of property of any flood hazard which may exist at the site. It is recommended that this program be continued so that potential property buyers are aware of the threat of life and property posed by flood events.

Local communities may adopt policies relating to the extension of certain public utilities and facilities in recognition of the likely influence of the location and size or capacity of such utilities and facilities on the location of new urban development. It is recommended that the policies of governmental units and agencies having responsibility for such utilities and facilities within the watershed be designed to complement the floodland regulation recommendations for the Kinnickinnic River watershed and the recommended primary environmental corridor protection plan subelement.

As a floodland management measure, an emergency program is intended to minimize the damage and disruption associated with flooding. It is recommended that each watershed community develop a warning system or procedure to provide floodland residents and other property owners with information about floods already in progress. In developing a warning system, it is suggested that the following measures be considered: monitoring of National Weather Service flash flood watch bulletins and flash flood warning bulletins during periods when rainfall or snowmelt are anticipated, emergency messages broadcast to community residents over radio and television, use of police patrol cars or other vehicles equipped with public address systems, and use of warning sirens having a special pattern to indicate a flood threat.

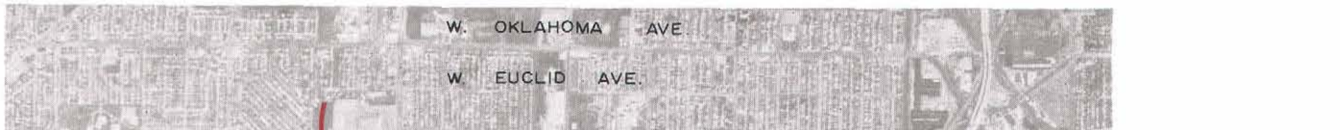
The continuous recording stream gaging station, as well as the partial record streamflow station and crest stations located within the Kinnickinnic River watershed, provide critical data required for future rational management of the surface water resources. Discharge-frequency relationships, floodstage profiles, and other information obtained from gaging station records can be used to periodically refine the hydrologic-hydraulic simulation model developed and used in the Kinnickinnic River watershed study. It is recommended that the continuous streamflow monitoring gage installed at the S. 7th Street crossing of the Kinnickinnic River continue to be operated in the immediate vicinity subsequent to completion of this study. It is also recommended that the partial record station operated by the U. S. Geological Survey at S. 27th Street on the Kinnickinnic River continue to be operated, and that the City of Milwaukee and the Milwaukee-Metropolitan Sewerage Commissions continue to maintain the existing crest and staff gage network.

Flood characteristics of the estuary and the lower reaches of the Kinnickinnic River were determined using a previous analysis of estuary stages and by conducting a special hydraulic analysis. This analysis defined three zones, each identified according to the factors likely to influence flood stages within it. Zone I is the estuary and downstream-most portion of the river where stages are determined primarily by stages in the adjacent lake and only negligibly influenced by discharges. Zone II is that portion of the river sufficiently far upstream so as to be beyond the influence of lake stages and where flood stages are primarily determined by discharges and local hydraulic conditions. Zone III is the transition reach where flood stages are determined partly by those factors that determine stages in Zone I and partly by those that determine flood stages in Zone II.

The analysis of estuary stages used the analysis of historic estuary stages performed under the Menomonee River watershed planning program and which was based upon historic stages for the 74-year period 1901 through 1974. The three zones were identified by performing backwater computations using a range of estuary stages and flood discharges. Zone I was identified as the 1.28-mile-reach of the estuary and river from the confluence with the Milwaukee River to the Kinnickinnic Avenue crossing; Zone II as that reach of the Kinnickinnic River upstream of Chase Avenue; and Zone III as the 1.12-mile reach between Kinnickinnic Avenue and Chase Avenue. Flood stages were then determined for each zone: the aforementioned estuary stage-frequency analysis was utilized for Zone I; Hydraulic Submodel II backwater computations for Zone II; and both the stage-frequency analysis and Hydraulic Submodel II backwater computations for Zone III. Based on this detailed flood stage analysis, it is recommended that the flood protection elevation recommended by the Milwaukee-Metropolitan Sewerage Commissions be revised so as to provide two feet of freeboard above the determined 100-year recurrence interval flood stages.

Map 47A

COMMITTED CHANNEL MODIFICATIONS IN THE KINNICKINNIC RIVER WATERSHED
WILSON PARK CREEK FROM W. EUCLID AVENUE TO S. 6TH STREET



The recommended comprehensive plan for the Kinnickinnic River watershed includes previously committed channel modifications in that portion of Wilson Park Creek from W. Euclid Avenue to S. 6th Street. These modifications would enhance the flood conveyance capacity through the widening, deepening, and lining of the channel as shown above. The channel improvements in Wilson Park Creek were considered to be important to the abatement of storm water drainage problems, as well as overland flooding. These committed improvements, along with other committed improvements on the main stem of the Kinnickinnic River from S. 5th Street to S. 16th Street, served as a point of departure for the analysis of alternative flood control measures for the watershed.

Source: SEWRPC.

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Chapter XIII

ALTERNATIVE WATER QUALITY MANAGEMENT MEASURES

INTRODUCTION

The inventory and analysis phases of the Kinnickinnic River watershed planning program identified certain water resource-related problems including flooding and water pollution. The objective of the Kinnickinnic River watershed planning program is to assist in the abatement of these problems by developing a workable plan which can be used to guide development within the watershed into a safer, more healthful, and more economic pattern, a pattern which is properly related to the sustaining ability of the underlying natural resource base without intensifying existing problems or creating new developmental and environmental problems.

The purpose of this chapter is to present alternative plans for water pollution abatement, and to provide a basis for the selection of the best plan from among these alternatives for incorporation into the comprehensive plan for the watershed. More specifically, to this end the chapter analyzes the extent to which water pollution abatement measures pertinent to the Kinnickinnic River watershed but developed under other Commission planning programs would mitigate or eliminate the point source pollution problems that exist in the watershed; presents alternative measures for the resolution of the nonpoint source pollution problems that exist in the watershed and have not been addressed in other Commission studies; and, based on evaluation of the technical, economic, and environmental performance of the alternatives considered, recommends a set of water quality management measures for incorporation into the overall plan for the watershed.

In the planning process used by the Commission, the formulation of a set of watershed development objectives, including water use objectives and supporting standards, provides an important basis for alternative plan design and evaluation. An initial set of water use objectives and supporting standards was presented in Chapter X of this report, together with other related objectives and standards. The Commission has always recognized that the formulation of objectives and standards may have to be an iterative process[1] in which, as a result of plan design and evaluation, certain objectives initially proposed may have to be dropped because their satisfaction has been proven unrealistic; new objectives may be suggested; and conflicts between inconsistent objectives balanced out. This formulation of objectives and standards must proceed hand in hand with plan design and evaluation. As indicated later in this chapter, the Kinnickinnic River watershed study provided one of the few cases in the Commission experience in which initially formulated objectives and standards were revised as a result of the plan design and evaluation process, and the revised objectives and standards recommended for adoption by state and federal regulation agencies.

Because the water quality management plan elements prepared under other Commission studies already include recommendations for resolution of some of the water quality problems within the watershed, namely, for the abatement of the point sources of pollution such as combined sewer overflows, separate sewer overflows, and industrial wastewater discharges, the preparation of the water quality management plan element of the Kinnickinnic River watershed plan emphasized the development of recommendations for the abatement of the nonpoint sources of pollution. The water quality management measures described herein were designed and should be considered as adjuncts to the basic land use development proposal advanced in Chapter XIII to facilitate the attainment of regional and watershed development objectives. The water quality management measures are thus subordinate to the basinwide land use plan element, and the incremental costs of these measures can be separated from that element.

As noted in Chapter X of this report, the evaluation of a particular alternative measure relative to other alternatives intended to resolve identified problems is a sequential process during which the measure is subjected to several levels of review, including technical, economic, environmental, financial, legal, and administrative feasibility, and political acceptability. In order to provide comparative evaluation of the various alternative water quality management measures, and thus assist in the selection of a recommended comprehensive watershed plan, the technical, economic, and environmental aspects of each alternative water quality management measures considered are presented in this chapter.

It should again be noted that the water quality management plan element for the Kinnickinnic River watershed, as described herein, is a systems level plan, and as such, has three functions:

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

2. Determination of the overall pollutant reductions required to achieve the desired levels of water

[1] *See, for example, SEWRPC Planning Report No. 7, Land Use-Transportation Study Volume 2, Forecasts and Alternative Plans, June 1966, page 2.*

quality and suggestion of methods and techniques for achieving the target reductions; and

3. Identification of the best overall 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.

With respect to the organization of the material presented in this chapter, the surface water quality problems of the watershed are first briefly reviewed, together with the likely sources of those problems. Next, the steps that have already been taken, or have been committed to be taken, for the resolution of these water quality problems are presented. Alternative solutions to the problems not addressed in other Commission programs are explored, and the basis for the selection of a recommended water quality management plan element provided. The techniques used to estimate the extent and severity of water quality problems are also described, and the available control measures discussed, particularly those for diffuse source control.

BASIS FOR THE DEVELOPMENT AND ANALYSIS OF ALTERNATIVE WATER QUALITY MANAGEMENT PLAN ELEMENT

In an urban setting like the Kinnickinnic River watershed, man's activities affect, and are affected by, the quality of surface and groundwaters. Waters are defined herein to be polluted when foreign substances caused by, or related to, human activity are present in such form and concentration as to render the water unsuitable for desired beneficial use. Thus surface water use objectives and supporting water quality standards become an important basis for plan design and evaluation.

Water Use Objectives

For purposes of the water quality analyses set forth in Chapter VII of this report, and for the initial analyses set forth in this chapter, the water quality standards have been used which correspond to the "warm water fishery and aquatic life, recreational use, and minimum standards" water use objective established under the areawide water quality planning program in conformance with the national water quality objectives cited in Public Law 92-500. Thus, the standards set forth in Tables 27 in Chapter VII and 67 in Chapter X of this report are intended to permit use of essentially all of the surface waters of the Kinnickinnic River watershed for full body contact recreation and for support of a warm water fishery. The water use objectives and supporting water quality standards set forth in Tables 27 and 67 specify a minimum dissolved oxygen level, a maximum temperature, a maximum fecal coliform count, a maximum residual chlorine, a maximum ammonia-nitrogen level, and a pH range. In addition, by explicit and implicit reference to other federal and state regulations,[2] the water use objectives and standards incorporate recommended maximum or minimum levels for certain other water quality indicators, including a broad range of toxic and hazardous substances.

Historically, water quality standards were developed for application to specified periods of low flow, such as a 7 day-10 year low flow conditions, in order to determine the effects of point sources. Under this historic approach, it was assumed that diffuse sources of pollution had an insignificant effect on water quality conditions and that the worst water quality occurred during periods of low flow. More recent studies, including those conducted by the Commission under its areawide water quality management planning program, however, indicate that the water quality standards may be violated during periods of high flow, as well as during periods of low flow, particularly following long periods of dry weather during which a buildup of pollutants takes place on the land surface, with washoff during a succeeding rainfall event. This finding requires a new approach to the application of water standards—an approach which considers the assessment of the proportion of the total time that water quality conditions can be expected to be in compliance with specified standards. Under this approach, statistical analyses were conducted on the results of the continuous water quality simulation modeling to determine the percent of time a given standard may be expected to be exceeded, including during periods of high and moderate flows as well as during periods of low flow. A 95 percent compliance level was selected for those parameters which directly affect aquatic organisms—dissolved oxygen, temperature, ammonia-nitrogen, residual chlorine, and pH. A 90 percent compliance level was selected for those parameters which do not directly affect aquatic organisms, but are primarily related to recreational use—fecal coliforms.

The inventories and plan design investigations conducted under the watershed study indicated that the attainability of the federally mandated "warm water fishery and aquatic life, recreational use, and minimum standards" water use objective in the Kinnickinnic River watershed is affected by several factors. The existing and committed channel modifications for flood control, which result in concrete lined channels, have a significant detrimental effect on the benthic flora and fauna necessary to establish and maintain any fishery as well as on the recreational potential. These channel improvements are irrevocable in the sense that they are a necessary working solution to the widespread and costly flooding problems caused by the historic development for urban use of the floodplains of the watershed and by the increased runoff and peak flood discharges produced by the extensive urbanization in the watershed. As described in Chapter VI of this report, urban development within the Kinnickinnic River watershed has for many years occupied natural floodplains. This development of floodplains, coupled with the extensive urbanization of the water-

[2]*See U.S. Environmental Protection Agency, Quality Criteria for Water, EPA Report No. 440/9-76-003, Washington, D.C., 1976, and National Academy of Sciences, National Academy of Engineering, Water Quality Criteria-1972, EPA Report No. R3-73-003, Washington, D.C., 1974.*

shed, has necessitated the construction of major channel improvements and has resulted in a committed decision for further channel improvements as described in Chapter XII of this report.

Any aquatic growth which may occur in improved channels may be expected to be of a temporary nature due to the flushing effect of the high velocities which occur under even moderate flood flows. Because of this temporary nature of any aquatic growth, any fishery would probably consist of species such as central mudminnows, carp, goldfish, and black bullheads. Such a fishery is more limited than the warm water fishery provided for in the existing water use objectives, which fishery would include such species as bluegill, brook stickleback, green sunfish, and black-nosed dace. Attendant water quality standards for a limited fishery can be lower than for a warm fishery. The water quality standards for a "limited fishery and aquatic life, limited recreational use, and minimum standards" objective, as established under the Commission areawide water quality management planning program, are set forth in Table 73. The inventories and design studies indicate this water use objective and the supporting water quality standards to be more realistic for the Kinnickinnic River watershed than the originally proposed objectives and standards.

It is recognized that given effective plan implementation, future water quality conditions may exceed the recommended new standards somewhat, and it is possible that these standards could be raised as plan implementation proceeds and the impacts thereof on actual water quality conditions are measured, to prevent degradation of water quality below the new existing conditions.

The levels of pollution control which are technically practicable and economically sound also influence the extent to which the "fishable-swimmable" water use objective can be achieved. Knowledge of the effectiveness of diffuse source pollution control measures other than storm water collection and treatment is limited due to the relatively recent interest in such measures. However, the degree of pollution control which can probably be achieved by various methods can be estimated from recent case studies.[3] It is estimated that technically practicable control measures to reduce the pollutants released and carried by urban storm water runoff vary in effectiveness from 5 percent of the uncontrolled release for improved leaf and lawn clipping collection and disposal to 50 percent of the uncontrolled release for construction erosion control practices. On an individual basis, most control measures other than storm water treatment and erosion control practices may be expected to attain less than a 30 percent reduction of released pollutants over uncontrolled conditions. Storm water treatment may be expected to attain up to 50 percent reduction of released pollutants when compared to uncontrolled conditions.

Historic Surface Water Pollution

An intensive and careful examination of available water quality data for the Kinnickinnic River watershed, as described in Chapter VII of this report, indicates that the surface waters of the watershed are severely polluted. Of the eight possible categories of pollution, six—toxic, organic, nutrient, pathogenic, sediment, and aesthetic—are known to exist in the Kinnickinnic River watershed. The other two categories of pollution—thermal and radiological—are not known to exist in the watershed. The surface water pollution in the watershed is widespread in that it occurs on the entire length of both the Wilson Park Creek and the Kinnickinnic River.

The most serious type of surface water pollution present in the watershed is pathogenic pollution as indicated by a widespread occurrence of high fecal coliform bacteria counts. These fecal coliform counts, which are indicative of the presence of human and animal wastes, appear to be attributable to sanitary and combined sewer overflows, surface runoff, and possibly unknown dry weather discharges from combined and sanitary sewers. The second most serious pollution problem is the presence of toxic substances, particularly chlorides, mercury, cadmium, and PCB's. The third most serious pollution problem is that of excessive nutrients, particularly phosphorus, under wet weather conditions. In addition to the pathogenic, toxic, and nutrient pollution, sediment pollution indicated by the need to conduct maintenance dredging in the commercially navigable downstream portion of the Kinnickinnic River and organic pollution in the form of high biochemical oxygen demand are causes for concern, as is the aesthetic pollution that pervades the watershed surface water system.

Pollution Sources

The following pollution sources have been identified in the Kinnickinnic River watershed: sanitary and combined sewerage system flow relief devices, industrial wastewater discharges, and urban storm water runoff. Raw sanitary sewage enters the surface water system of the watershed through five types of flow relief devices: combined sewer outfalls and sanitary sewer crossovers, bypasses, relief pumping stations, and portable pumping stations. A total of 22 combined sewer outfalls and 30 sanitary sewerage system flow relief devices are known to exist in the watershed. Of the total annual discharge from the Kinnickinnic River watershed, approximately 8 percent is estimated to enter the stream system via combined sewer outfalls and about 0.5 percent is estimated to enter the stream system via the other four types of flow relief devices. Industrial discharges, consisting primarily of cooling and process water, also directly and indirectly enter the watershed stream system. A total of 84 industrial discharges—more than one-half of which consists of cooling water discharges—are known to exist within the watershed, entering the surface waters through 60 outfalls.

[3] *See SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume 3, Urban Storm Water Runoff, July 1977.*

Table 73

WATER QUALITY STANDARDS CORRESPONDING TO THE "LIMITED FISHERY AND AQUATIC LIFE, LIMITED RECREATIONAL USE, AND MINIMUM STANDARDS" OBJECTIVES FOR SURFACE WATERS[a] IN THE KINNICKINNIC RIVER WATERSHED

Parameter	Standard[b]
Dissolved Oxygen	• Shall be greater than or equal to 3.0 milligrams per liter (mg/l)
Temperature	• Shall be less than or equal to 89°F for warmwater fish • No changes that may adversely affect aquatic life • Natural daily and seasonal temperature fluctuations are to be maintained
Fecal Coliform	• Shall not exceed a monthly geometric mean of 200 membrane filter fecal coliform counts (MFFCC) per 100 milliliters (ml) based on not less than five samples per month • Shall not exceed a geometric mean of 400 MFFCC per 100 ml in more than 10 percent of all samples during any month • A sanitary survey to assure protection from fecal contamination is the chief criterion in determining suitability for recreation use
pH	• Shall be within the range of 6.0 to 9.0 units • There shall be no change greater than 0.5 unit outside the natural seasonal maximum and minimum
Total Residual Chlorine	• Shall be less than or equal to 0.50 mg/l
Ammonia-Nitrogen	• Shall be less than or equal to 3.5 mg/l
Miscellaneous Parameters and Conditions	• 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 Report No. 440/9-76-003, U. S. Environmental Protection Agency, Washington, D. C., 1976, and Water Quality Criteria-1972, EPA Report No. R3-73-033, 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, of undefined toxicity to fish and other biota shall be resolved in accordance with the methods specified in Water Quality Criteria-1972; Standard Methods for the Examination of Water and Wastewater, 14th Edition, American Public Health Association, New York, 1975; or other methods approved by the Wisconsin Department of Natural Resources • All waters shall meet the following conditions 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

[a] *Perennial and intermittent streams and storm water runoff.*

[b] *Surface water quality is to be such as to satisfy the dissolved oxygen, temperature, pH, total residual chlorine, and ammonia-nitrogen standards 95 percent of the time; fecal coliform and total phosphorus standards 90 percent of the time; and toxic and hazardous substance standards at all times.*

Source: SEWRPC.

Other major sources of water pollution in the watershed include direct runoff from the land, and interflow—that is, subsurface flow—and base flow. Direct runoff from the land and interflow occur during and immediately after rainfall or snowmelt events, whereas groundwater discharge occurs between such events. Most of the direct runoff from urban areas enters the surface water system through the storm water outfalls located along the major stream system, with the remaining direct runoff entering the streams via combined sewers, open storm water channels, or as sheet flow—that is, overland flow not occurring in well defined channels. Water quality surveys indicate that high concentrations of pollutants such as phosphorus, coliform bacteria, and biochemical oxygen demand are most likely to occur during wet weather conditions—that is, conditions in which runoff from the urban areas dominates. The average annual sediment yield from the watershed is high—being estimated at more than 400 tons per square mile—reflecting the high degree of urbanization of the basin. In addition, the high chloride levels noted in the surface waters may be attributed to the large quantities of deicing salt applied to the streets and highways of the watershed. The limited data available also indicate that excessive concentrations of toxic and hazardous substances such as mercury and PCB's have occurred recently in the surface waters of the Kinnickinnic River watershed.

Measures Already Underway or Committed to Resolve Pollution Problems

Substantial efforts have already been initiated to abate some of the major sources of water pollution and thereby resolve some of the pollution problems of the Kinnickinnic River watershed. These efforts are briefly described below and related to the pollution sources described above.

The 27-square-mile combined sewer service area in Milwaukee County, which includes a 4.5-square-mile area tributary to the Kinnickinnic River, is the subject of an intensive preliminary engineering study presently being conducted by the Milwaukee-Metropolitan Sewerage Commissions. This study is directed at finding the most cost-effective means for abating pollution from combined sewer overflows. This study, which is scheduled for completion in 1978, builds upon previous work conducted by the Regional Planning Commission under the Milwaukee River watershed planning program[4] and is to provide firm recommendations for construction of combined sewer conveyance and treatment facilities so as to abate this major source of pollution from the entire combined sewer service area.

Sewerage system flow relief devices other than combined sewer overflows—that is, crossovers, bypasses, relief pumping stations and portable pumping stations—are regulated by means of the Wisconsin Pollutant Discharge Elimination System (WPDES). As described in Chapter X of this report, the State Pollutant Discharge Elimination System was established by the Wisconsin Legislature in direct response to the requirements of the Federal Water Pollution Control Act of 1972. The System requires the issuance of a state permit for legal discharge of any pollutant into the waters of the State, including the groundwaters. More specifically, permits are required for crossovers, bypasses, relief pumping stations, and portable pumping stations. The permits specify abatement requirements and a schedule of compliance setting forth dates by which various stages of requirements imposed by the permits shall be achieved. With respect to sanitary sewerage system flow relief devices, it is envisioned that the pollution discharge permit system will continue as the primary vehicle for elimination of these devices. The Wisconsin Pollutant Discharge Elimination System is also being used to determine the nature of, monitor, and regulate industrial discharges to the surface water and groundwater systems, and is the primary vehicle by which the quantity and quality of those discharges will be controlled. The proposed schedule for elimination of all separate sanitary sewer overflows in the Kinnickinnic River watershed is set forth in Table 74 of this report.

On July 1, 1975, the Southeastern Wisconsin Regional Planning Commission initiated an areawide water quality planning and management program directed in part at abatement throughout the Region of another important source of pollution—diffuse or nonpoint source pollution—from both rural and urban areas[5]. The water quality management planning program for southeastern Wisconsin is intended to update, extend, and refine the previous water quality related studies and plans completed by the Commission, and thereby to meet the requirements of Section 208 of the Federal Water Pollution Act.

Analytic Framework and Assumptions

The foregoing summary of water pollution problems and of pollution sources in the Kinnickinnic River watershed, and the review of efforts underway or planned to abate or eliminate those sources and thereby mitigate the pollution problems, indicates that progress is being made toward the abatement of pollution in the Kinnickinnic River watershed. In consideration of the basic pollution abatement program already in progress, the water quality analyses conducted under the Kinnickinnic River watershed planning program—including simulation modeling studies—were conducted within the following framework and were based on the assumptions set forth in Table 74.

Combined Sewer Overflows: The water quality analyses conducted under the watershed study do not address the 4.9-mile reach of the Kinnickinnic River located downstream of S. 27th Street, nor the 4.54-square-mile

[4] *SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed, Volume 1, Inventory Findings and Forecasts, 1970, and Volume 2, Alternative Plans and Recommended Plan, 1971.*

[5] *SEWRPC Study Design for the Areawide Water Quality Management Planning Program; SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975.*

Table 74

POLLUTION ABATEMENT MEASURES UNDERWAY OR PLANNED IN THE KINNICKINNIC RIVER WATERSHED AND RELATED WATER QUALITY ANALYSES CONDUCTED UNDER THE KINNICKINNIC RIVER WATERSHED PLANNING PROGRAM

Pollution Source	Pollution Abatement Measure Underway or Planned	Related Water Quality Analysis Conducted under the Kinnickinnic River Watershed Planning Program
22 combined sewer overflows discharging to the Kinnickinnic River downstream of S. 27th Street under wet weather conditions	Preliminary engineering study underway to provide recommendations for abatement—scheduled for completion in late 1978	Water quality analysis not conducted in the combined sewer service area because the principal impact area is the estuary, which is generally excluded from the watershed planning program, and because of concurrent preliminary engineering study
30 sanitary sewer flow relief devices—crossovers, bypasses, relief pumping stations—discharging primarily to the Kinnickinnic River during wet weather conditions	Wisconsin Pollutant Discharge Elimination System (WPDES) requires a permit for each device and a pollution abatement schedule. Watershed plan assumes total elimination of pollution from flow relief devices through WPDES by July 1, 1986	Pollution load assumed to be eliminated
60 industrial point sources discharging primarily to the Kinnickinnic River	WPDES requires a permit for each device and a pollution abatement schedule. Watershed plan assumes gradual abatement of pollution from industrial discharges by July 1, 1983	Sources with significant flow or pollution load are included in simulation model
Surface and groundwater discharge from urban and rural lands	SEWRPC preparing a "Section 208" areawide water quality management plan	Conduct simulation studies to project the likely impact—if any—of planned incremental urban development and to determine if alternative diffuse source pollution abatement measures should be considered. Evaluate the effect of diffuse source pollution control measures applied to urban and rural lands and recommend the level of control necessary and associated measures

Source: SEWRPC

combined sewer service area tributary to this reach for two reasons. First, the 2.4-mile-long reach of the Kinnickinnic River located downstream of the Chase Avenue crossing is part of the Milwaukee Harbor estuary, and—as explained in Chapter I of this report—the watershed study was not intended to deal with the complex water quality problems of the estuary. This approach to the estuary area was adopted at the outset of the Kinnickinnic River watershed planning program because the Kinnickinnic River-Menomonee River-Milwaukee River-Lake Michigan estuary constitutes an integrated hydraulic-water quality system that must be analyzed in its totality. Second, the watershed study sought to avoid duplication of the planning and engineering studies directed at abatement of combined sewer overflow underway by the Milwaukee-Metropolitan Sewerage Commissions. As already noted, these studies are intended to provide firm recommendations for construction of sewage conveyance and treatment facilities for the abatement of pollution from the entire combined sewer service area and the attainment of water quality objectives in the stream reaches affected by combined sewer overflows.

Other Flow Relief Devices: The water quality plan element of the Kinnickinnic River watershed plan, while assuming such elimination, does not include an explicit analysis of alternative ways of eliminating sanitary sewerage system flow relief devices, that is, crossovers, bypasses, relief pumping stations, and portable pumping stations. The Kinnickinnic River watershed plan accepts, as committed, the ultimate elimination of discharge from those devices as recommended in the adopted regional sanitary sewerage system plan and as intended by the Wisconsin Pollutant Discharge Elimination System as described in Chapter IX of this report.

As described in Chapter VII of this report, a comparative analysis of the pollution loads contributed by combined sewer overflows, sanitary sewerage system flow relief devices, and washoff from the land surface was conducted. The results indicated that flow relief devices contribute a relatively small proportion of the total pollution load on the Kinnickinnic River system. Consequently, these were neglected in the simulation of existing conditions and were considered to be eliminated under future conditions. Although the analysis indicated that the flow relief devices contribute small quantities of pollution to the surface water relative to those contributed by storm water runoff, pollutant contributions from flow relief devices may constitute local health hazards and create objectionable aesthetic conditions. Therefore, efforts should be continued to eliminate the discharge of any raw sanitary sewage through flow relief devices.

Industrial Discharges: The water quality management plan element of the Kinnickinnic River watershed plan also assumes that industrial wastewater discharges to the surface water system of the watershed will be abated through the Wisconsin Pollutant Discharge Elimination System. The control recommendations applicable to the Kinnickinnic River watershed under the Wisconsin Pollutant Discharge Elimination System permit a forecast to be made of the quality and characteristics of industrial discharges which may be expected in the design year of the plan, utilizing the trends in economic activity levels presented in SEWRPC Technical Report No. 10. The assumed year 2000 discharge characteristics of significant point sources in the Kinnickinnic River watershed are presented in Table 75. By comparison with the information provided in Table 56 in Chapter VIII of this report for existing discharge characteristics, it is evident that the major change consists of increased quantities to be discharged, with little or no modification expected in the pollutant concentrations.

Existing and Year 2000 Planned Land Use Conditions: The existing land use conditions and year 2000 planned land use conditions in the Kinnickinnic River watershed, as described in Chapter III and Chapter XI of this report, respectively, provided the basis for estimating the probable consequences of land use changes and, more importantly, to examine the diffuse source pollution problem and alternate solutions thereto under the water quality management plan element.

Existing and Committed Channel Modifications: The water quality analysis and water quality simulation modeling incorporated the existing channel modifications as described in Chapter V of this report and also the committed channel modifications on the Kinnickinnic River and on Wilson Park Creek as described in Chapter XII of this report.

Extent and Severity of Water Quality Problems

Before alternative water quality control measures may be developed and evaluated, it is necessary to determine the extent and severity of existing and anticipated future water quality problems. Identification of the types of pollution problems and of their probable sources was based on the historic data presented in Chapter VII of this report, and on the results of simulation modeling studies, all as related to the water quality standards. The historic water quality information provided data on various types of pollution not assessable by simulation, such as toxic substances and sediment. Although strict standards are not applicable to these types of pollution, their presence does influence the use of the water resource. The water quality simulation model was used to quantify both existing and probable future water quality conditions and to assess the impact of implementing the year 2000 land use plan and various alternative pollution control measures. The simulation model results were compared to the water quality standards representing the intended uses in order to identify and define the pollution problems and probable sources.

Use of the Simulation Model: As noted in Chapter VIII of this report, the principle purpose of developing and calibrating the water resource simulation model under the Kinnickinnic River watershed study was to provide a tool for quantifying watershed hydrologic, hydraulic, and water quality characteristics under existing and various possible future development conditions and management measures within the watershed. The results of applying the water quality submodel to the watershed are discussed in this chapter.

In using the water quality submodel to analyze the impact of the year 2000 land use plan and alternative pollution abatement measures on water quality conditions, the watershed land surface and stream system were represented as shown on Map 41 in Chapter VIII and described in Table 57 of this report for existing (1975) land use-floodland development conditions and as described in Table 76 for the year 2000 planned land use-floodland development condition. The watershed land surface was represented by nine hydrologic-water quality segments and the stream system was represented by three reaches. Input data base development and calibration of the water quality submodel are described in Chapter VIII of this report. Stream flow and water quality were continuously simulated for the three-year period beginning January 1, 1969 and ending December 31, 1971, through application of the hydrologic-hydraulic-water quality simulation model to the stream system indicated on Map 41. This time period was selected as being representative of the ten-year period beginning in January 1965, which was the most recent and most complete decade of published historic record available at the outset of the watershed study. Water quality levels and stream flows were computed at three sites within the Kinnickinnic River watershed, each located at the downstream end of each reach, or water quality analysis area.

In order to further define and quantify the water quality problems which currently exist in the Kinnickinnic River watershed, as described in Chapter VII of this report, the instream water quality conditions were simulated using the water quality submodel and input data representing the existing land use and channel conditions and indus-

Table 75

SELECTED INFORMATION ON INDUSTRIAL WASTEWATER DISCHARGES REPRESENTED IN THE WATER QUALITY SUBMODEL: YEAR 2000 PLAN

Reach	Quantity	Subbasin	Name	Average Annual Parameter Values: Flow (cfs)	Temperature (°C)	Five-day Biochemical Oxygen Demand (mg/l)	Dissolved Oxygen (mg/l)	Ammonia-Nitrogen (mg/l)	Nitrate-Nitrogen (mg/l)	Nitrite-Nitrogen (mg/l)	Organic Nitrogen (mg/l)	Othophosphate Phosphorus (mg/l)	Chloride (mg/l)	Total Dissolved Solids (mg/l)	Fecal Coliform (MFFCC/ 100 ml)
1	1	WPC-2	Ladish Company	1.123	13.3	0.8	10.60	0.03	0.24	0.03	0.20	0.06	13.0	200	0.0
3	10	WMD-1	Briggs & Stratton Corporation	2.788	30.0	0.0	7.63	0.00	0.03	0.00	1.10	0.01	0.0	579	0.0
		WMD-1	Murphy Diesel Company	0.039	36.6	0.0	6.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0
		WMD-1	Teledyne Wisconsin Motor	0.062	16.0	11.7	4.48	0.40	0.22	0.00	1.24	0.04	23.3	300	0.0
		WMD-2	Eaton Corporation	0.311	25.78	15.0	4.12	0.00	0.00	0.00	0.00	0.05	22.5	300	0.0
		WMD-3	Allied Smelting Corporation	0.251	9.0	0.0	11.59	0.00	0.00	0.00	0.00	0.00	0.0	340	0.0
		WMD-3	Froedtert Malt Corporation	0.028	13.68	0.0	10.42	0.00	0.00	0.00	0.00	0.00	0.0	300	0.0
		WMD-3	General Electric Company—Products Department	0.181	16.3	1.2	9.95	0.00	0.00	0.00	0.00	0.00	0.0	300	0.0
		WMD-3	General Electric Company—Medical Systems Division	0.73	13.2	0.0	10.60	0.00	0.00	0.00	0.00	0.00	0.0	300	0.0
		WMD-3	Kurth Malting Corporation	0.206	11.3	0.0	11.08	0.00	0.00	0.00	0.00	0.00	0.0	300	0.0
		WMD-3	Wehr Steel Company	0.532	26.6	0.0	8.07	0.00	0.00	0.00	0.00	0.01	0.0	300	0.0

Source: SEWRPC and WPDES

Table 76

SELECTED INFORMATION ON LAND SEGMENTS REPRESENTED IN THE WATER QUALITY SUBMODEL: YEAR 2000 PLAN

Land Segment Identification Number	Stream Reach Identification Number	Area Square Miles	Percent of Reach	Hydrologic Land Segment Type: Meteorological Station	Hydrologic Land Segment Type: Impervious Category	Average Annual Diffuse Surface Loading Rates (pounds/acre/day)[a] Impervious Surface: Biochemical Oxygen Demand	Ammonia-Nitrogen	Nitrate-Nitrogen	Nitrite-Nitrogen	Organic Nitrogen	Orthophosphate Phosphorus	Chloride	Total Dissolved Solids	Fecal Coliform	Pervious Surface: Biochemical Oxygen Demand	Ammonia-Nitrogen	Nitrate-Nitrogen	Nitrite-Nitrogen	Organic Nitrogen	Orthophosphate Phosphorus	Chloride	Total Dissolved Solids	Fecal Coliform
1	1	2.83	45.0	Milwaukee	High	0.160	0.011	0.030	0.0005	0.022	0.005	3.9	13.5	415	0.086	0.048	0.002	0.001	0.017	0.007	0.046	40.4	160
2	1	2.20	35.0	Milwaukee	Medium	0.143	0.014	0.030	0.0006	0.038	0.005	3.9	13.5	415	0.115	0.048	0.002	0.002	0.077	0.014	0.046	40.4	775
3	1	1.26	20.0	Milwaukee	Extra-High	0.234	0.334	0.045	0.0007	0.058	0.005	3.9	13.5	720	0.115	0.048	0.006	0.001	0.067	0.016	0.025	24.6	160
4	2	3.19	65.0	Milwaukee	High	0.152	0.013	0.041	0.0005	0.024	0.005	3.9	13.5	430	0.103	0.027	0.004	0.001	0.012	0.013	0.027	29.4	100
5	2	1.23	25.0	Milwaukee	Medium	0.152	0.019	0.028	0.0005	0.026	0.005	3.9	13.5	430	0.118	0.027	0.004	0.004	0.012	0.011	0.042	34.6	100
6	2	0.49	10.0	Milwaukee	Low-Medium	0.144	0.013	0.024	0.0005	0.024	0.005	3.9	13.5	430	0.118	0.027	0.004	0.001	0.039	0.019	0.042	29.4	390
7	3	3.83	68.3	West Allis	High	0.145	0.010	0.040	0.0005	0.021	0.005	3.9	13.5	400	0.146	0.031	0.003	0.001	0.013	0.020	0.047	38.0	100
8	3	1.05	18.8	West Allis	High	0.145	0.012	0.041	0.0005	0.021	0.005	3.9	13.5	400	0.146	0.031	0.003	0.001	0.013	0.017	0.020	31.0	100
9	3	0.72	12.9	West Allis	Extra-High	0.128	0.010	0.015	0.0005	0.021	0.005	3.9	13.5	400	0.242	0.080	0.008	0.001	0.013	0.017	0.023	31.0	100

[a] *Except fecal coliforms which are in millions of organisms/acre.*

Source: SEWRPC

trial point source discharges. The simulation results for existing conditions provided a basis of comparison for the simulation of probable future conditions and for determining the effects of future land use, channel conditions, and alternative point source controls and land management measures on water quality.

Continuous water quality simulation produces sufficient water quality data to allow water quality-duration relationships to be developed. These relationships may be used to quantitatively evaluate the impact of the full spectrum of hydrologic-hydraulic-water quality phenomena on instream water quality levels as well as to provide comparison to water quality standards. The water quality-duration relationships for existing conditions as well as future conditions are presented herein as a convenient basis for comparison to the applicable water quality standards, as well as to illustrate the overall impact of the hydrologic-hydraulic-water quality processes that were simulated.

Simulation Results: The simulation of existing water quality conditions indicated that the water quality is quite similar in the three stream reaches modeled. Because these stream reaches flow through quite similar areas of development, all served by separate sanitary sewerage facilities, such similarity is to be expected. Also, as might be expected, the modeling results indicate water quality conditions very similar to those indicated by the historic information described above.

Simulation of the Kinnickinnic River watershed under year 2000 planned land use conditions included not only the plan-proposed changes in land use, but also the committed channel modifications described earlier in this report and the anticipated increases in industrial point source discharges. Due to the relatively "clean" nature of existing point source discharges with respect to the conventional pollutants considered in this study, very few modifications of these sources will be required by the year 2000. Since there are no significant changes anticipated in the point source discharges, it was not necessary to simulate the year 2000 planned land use and channel conditions with the point source discharges omitted.

The simulation of the water quality conditions under year 2000 planned channel and land use conditions without any additional pollution control measures indicates that relatively small changes from existing water quality conditions should be expected. Some small changes in water quality conditions may be expected to occur in the watershed as indicated by a shift in the water quality-duration relationships presented in Figures 72, 73, and 74. More specifically, for analysis areas 1 and 2, Wilson Park Creek, these changes may be expected to consist of improvements in the dissolved oxygen content and ammonia-nitrogen concentration, and fecal coliform counts and, for analysis area 3, the upper Kinnickinnic River, slight improvements in the chloride concentration and fecal coliform counts. These small improvements in water quality conditions are not the result of any decrease in the pollutant loadings, which may be expected to increase under year 2000 conditions as shown in Table 77 and discussed below, but rather the result of increased discharges by "clean" point sources and reduced benthic releases due to channel improvements. The constant nature of and relatively low pollutant concentrations in the point source discharges result in increases in point source flows of about 50 percent on Wilson Park Creek and of about 20 percent on the upper Kinnickinnic River, to have a favorable impact on the overall water quality-duration relationships. The extensive channel improvements committed to be constructed within the plan design period, and therefore reflected in the year 2000 simulation, include a considerable length of concrete-lined channel on Wilson Park Creek. This improvement may be expected to be associated with a reduction in the release of pollutants from bottom sediments because of their smooth, uniform surface and flushing effect of increased water velocities.

Average annual pollutant transports in the Kinnickinnic River watershed are shown in Table 77 for existing land use and channel conditions and for year 2000 planned land use conditions with committed channel modifications without any additional pollution control measures for the three water quality analysis areas as determined using the water quality simulation model. The mass discharge data indicate that the average annual pollutant yield may be expected to increase under year 2000 plan conditions, with the increases ranging from 0 to approximately 26 percent. A comparison of the diffuse mass loads to the mass discharges for a given analysis area shows that the diffuse sources of pollutants, as opposed to known point sources, produce a substantial portion of the total average annual yield. Although only shown for PO_4 and NH_3, similar relationships may be expected to exist for other constituents.

Comparison of Simulation Results to Water Quality Standards: Water use objectives and supporting water quality standards provide a reference framework for determination of the extent and severity of water quality problems. Water quality standards used in the comparison of simulation results are those corresponding to the "limited fishery and aquatic life, limited recreational use, and minimum standards" water use objective as set forth in Table 73. As described earlier in this chapter, this objective and the supporting water quality standards, are reduced from the federally mandated "warm water fishery and aquatic life, recreational use, and minimum standards" objective originally proposed, in light of the irrevocable extensive channel modifications existing in, and commited for, the watershed. As indicated in Table 73, the specified limits for dissolved oxygen, temperature, ammonia-nitrogen, pH, and residual chlorine—the parameters linked directly with the aquatic organisms—must be met at least 95 percent of the time. Similarly, the specified limits for fecal coliform—primarily related to recreational use—must be met at least 90 percent of the time.

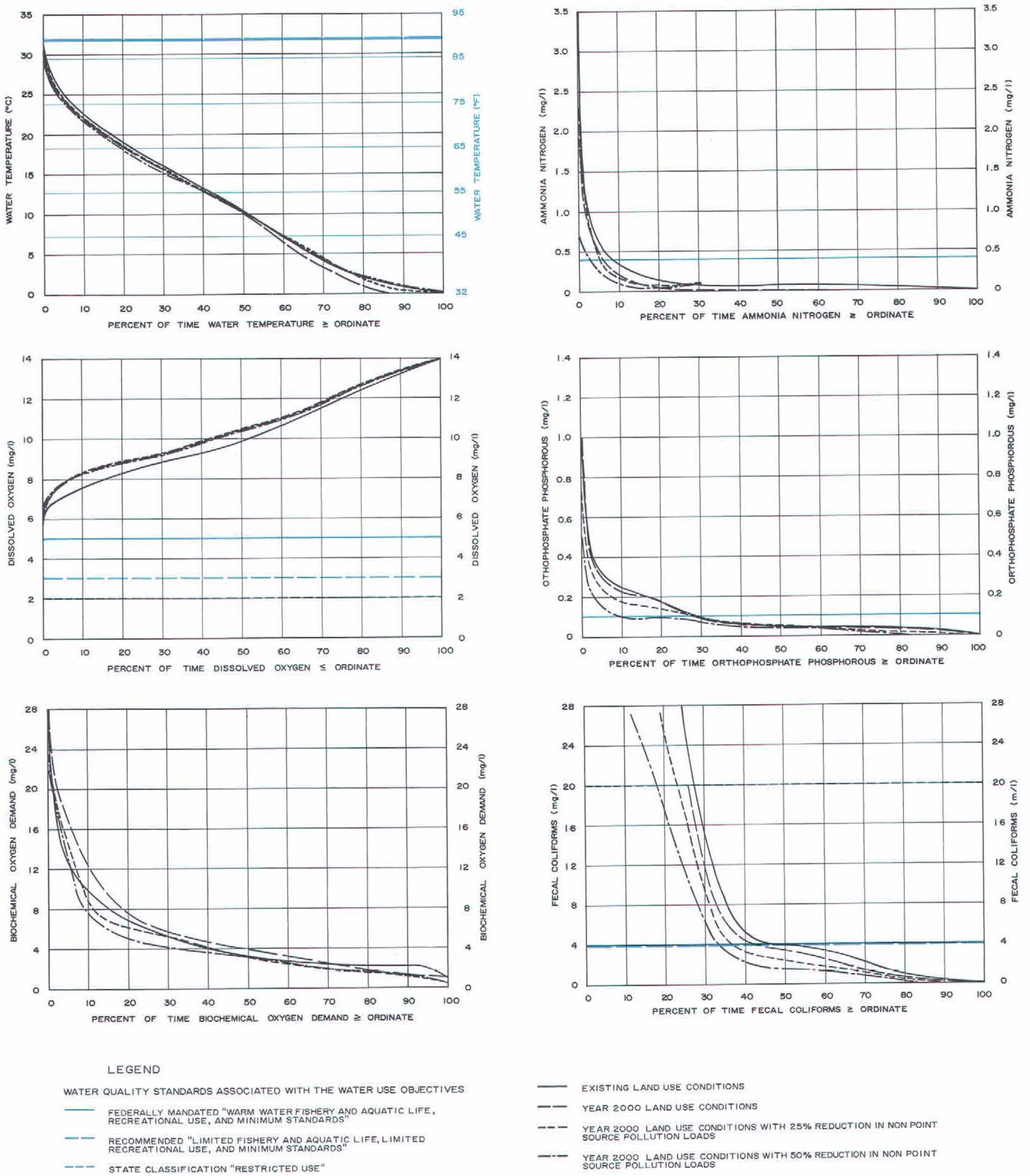
Figures 72, 73, and 74 indicate the estimated probabilities that the applicable water quality standards will be satisfied under the existing conditions for each of the three water quality analysis areas in the Kinnickinnic River watershed. Standards specified include values for dissolved oxygen, temperature, fecal coliform, and ammonia-nitrogen. As indicated, the standards for dissolved oxygen, temperature, and ammonia-nitrogen may be expected to be achieved. However, the limits for fecal coliform may be expected to be met only 55, 45, and 70 percent of the time for water quality analysis areas 1, 2, and 3, respectively. As indicated on Figures 72, 73, and 74, under year 2000 plan conditions but without additional pollution control measures, as for existing conditions, the water quality standards for dissolved oxygen, temperature, and ammonia-nitrogen may be expected to be consistently achieved, while the specified limits for fecal coliform may be expected to be violated a significant proportion of the time.

Identification of Pollution Problems and Probable Sources: From the results of the analyses described above, it is evident that the pollution problems are similar for all of the stream reaches simulated. The primary water quality problem in terms of achieving the "swimmable" water use objective and corresponding standards is that of excessive fecal coliform counts. With regard to the development of aquatic life and limited fishery objectives, the high levels of toxic substances, including chlorides, are the restricting constituents.

As described above, sanitary system flow relief devices were assumed to be eliminated within the watershed by the design year of the plan. Also as described above, nearly all of the industrial point source discharges currently meet and may be expected to continue to meet the effluent standards established under the Wisconsin Pollution Discharge Elimination System. Therefore, the remaining sources of flow to the stream system, namely storm water runoff and unknown intermittent discharges, must be assumed to be the cause of the substandard water quality conditions. This is consistent with conclusions based on historic water quality surveys described in Chapter VII which indicate that the highest concen-

Figure 72

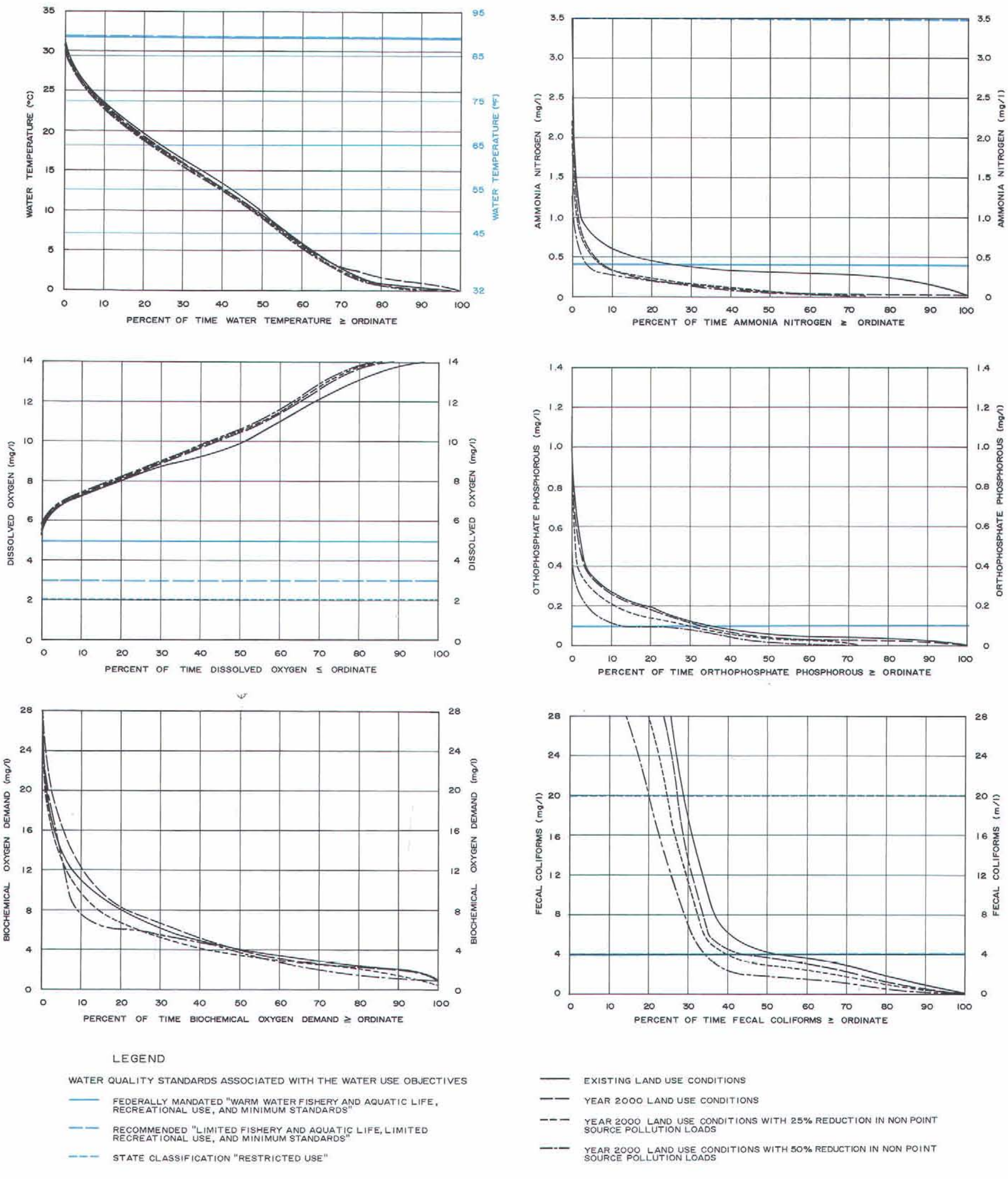
WATER QUALITY CONSTITUENT-DURATION RELATIONSHIPS FOR WILSON PARK CREEK AT S. 13TH STREET



Source: SEWRPC.

Figure 73

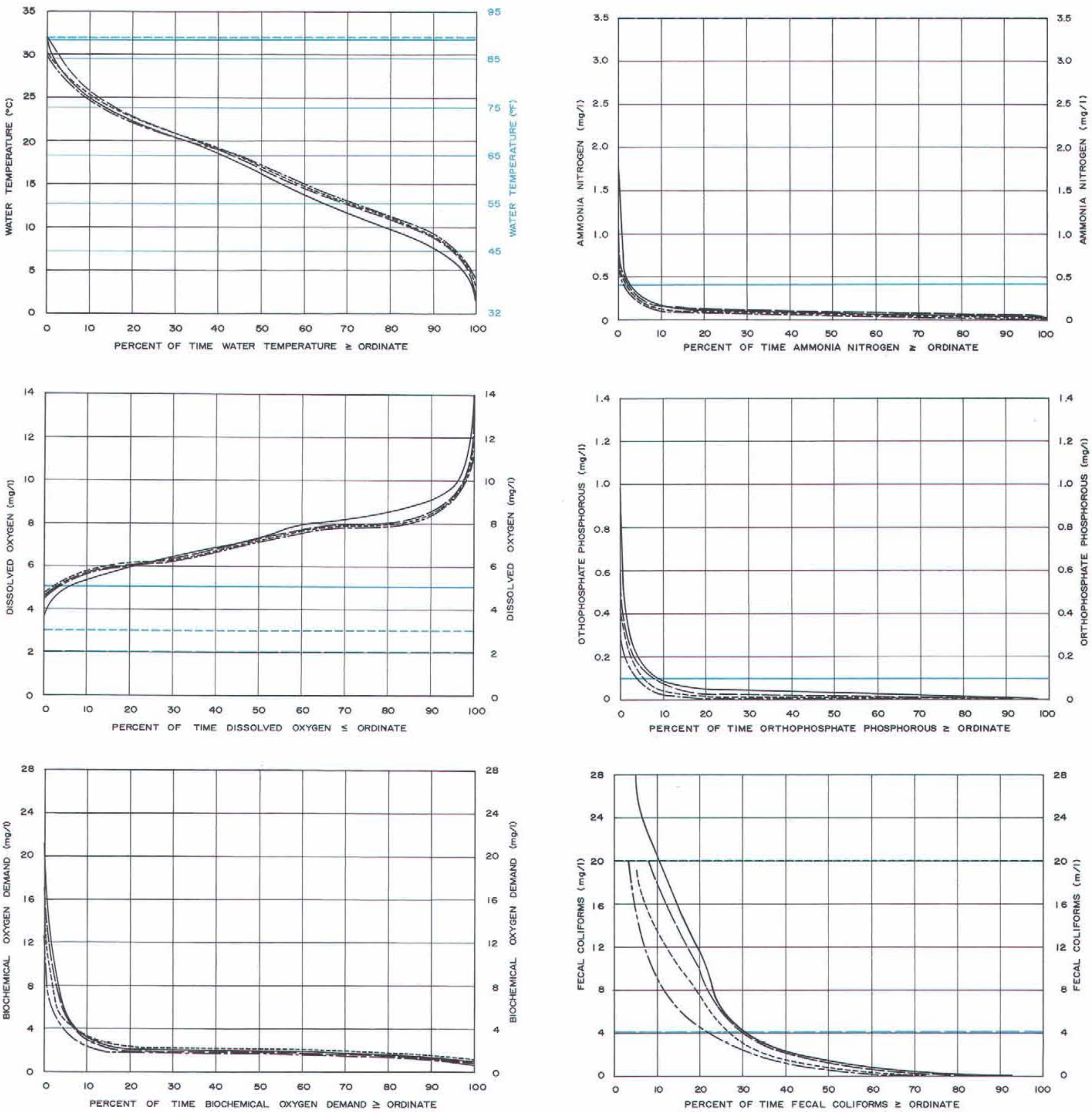
WATER QUALITY CONSTITUENT-DURATION RELATIONSHIPS FOR WILSON PARK CREEK AT THE KINNICKINNIC RIVER



Source: SEWRPC.

Figure 74

WATER QUALITY CONSTITUENT-DURATION RELATIONSHIPS FOR THE KINNICKINNIC RIVER AT S. 31ST STREET EXTENDED



LEGEND

WATER QUALITY STANDARDS ASSOCIATED WITH THE WATER USE OBJECTIVES

- FEDERALLY MANDATED "WARM WATER FISHERY AND AQUATIC LIFE, RECREATIONAL USE, AND MINIMUM STANDARDS"
- RECOMMENDED "LIMITED FISHERY AND AQUATIC LIFE, LIMITED RECREATIONAL USE, AND MINIMUM STANDARDS"
- STATE CLASSIFICATION "RESTRICTED USE"

- EXISTING LAND USE CONDITIONS
- YEAR 2000 LAND USE CONDITIONS
- YEAR 2000 LAND USE CONDITIONS WITH 25% REDUCTION IN NON POINT SOURCE POLLUTION LOADS
- YEAR 2000 LAND USE CONDITIONS WITH 50% REDUCTION IN NON POINT SOURCE POLLUTION LOADS

Source: SEWRPC.

Table 77

POLLUTANT TRANSPORT IN THE KINNICKINNIC RIVER WATERSHED UNDER EXISTING AND PLANNED CONDITIONS WITHOUT ANY ADDITIONAL POLLUTION CONTROL MEASURES

Reach or Analysis Area	Location			Tributary Area		Constituent	Average Annual Pollutant Transport[a]					
							1,000 pounds			pounds per acre		
							Existing Land Use and Channel Conditions	Year 2000 Plan Land Use and Committed Channel Modifications Without Any Additional Pollution Control Measures		Existing Land Use and Channel Conditions	Year 2000 Plan Land Use and Committed Channel Modifications Without Any Additional Pollution Control Measures	
	Stream	River Mile	Description	Square Miles	Acres		Mass[b] Discharge	Mass[b] Discharge	Diffuse[c] Mass Load	Mass[b] Discharge	Mass[b] Discharge	Diffuse[c] Mass Load
1	Wilson Park Creek	2.57	S. 13th Street	6.28	4020	Biochemical Oxygen Demand Ultimate	84.2	96.4	–	21.0	24.0	–
						Ammonia–Nitrogen	7.2	8.2	9.1	1.8	2.0	2.2
						Nitrate–Nitrogen	21.0	22.0	–	5.2	5.5	–
						Nitrite–Nitrogen	0.7	0.8	–	0.2	0.2	–
						Organic Nitrogen	20.9	23.1	–	5.2	5.8	–
						Orthophosphate Phosphorus	2.0	2.6	2.6	0.5	0.6	0.7
						Total Dissolved Solids	9,750	10,930	–	2,420	2,720	–
						Chloride	1,820	2,180	–	450	540	–
2	Wilson Park Creek	0.00	At the Kinnickinnic River	11.19	7160	Biochemical Oxygen Demand Ultimate	143.2	158.6	–	20.0	22.2	–
						Ammonia–Nitrogen	12.8	13.8	14.5	1.8	1.9	2.0
						Nitrate–Nitrogen	37.6	38.8	–	5.2	5.4	–
						Nitrite–Nitrogen	1.4	1.4	–	0.2	0.2	–
						Organic Nitrogen	34.9	37.4	–	4.9	5.2	–
						Orthophosphate Phosphorus	3.7	4.4	5.5	0.5	0.6	0.8
						Total Dissolved Solids	17,380	18,710	–	2,430	2,610	–
						Chloride	3,520	3,765	–	490	530	–
3	Kinnickinnic River	5.16	S. 31st Street Extended	5.61	3590	Biochemical Oxygen Demand Ultimate	86.0	91.9	–	24.0	25.6	–
						Ammonia–Nitrogen	5.2	5.3	6.9	1.5	1.5	1.9
						Nitrate–Nitrogen	21.9	21.9	–	6.1	6.1	–
						Nitrite–Nitrogen	0.6	0.7	–	0.2	0.2	–
						Organic Nitrogen	15.1	15.3	–	4.2	4.2	–
						Orthophosphate Phosphorus	2.4	2.3	2.4	0.7	0.6	0.7
						Total Dissolved Solids	15,080	16,330	–	4,200	4,550	–
						Chloride	1,940	1,960	–	540	550	–

a Based on three years (1969-1971) of continuous simulation.

b Incorporates surface, subsurface, and point inflows with instream processes.

c Load to the stream from diffuse sources.

Source: SEWRPC.

trations of potential pollutants such as phosphorus, coliform bacteria, and biochemical oxygen demand are most likely to occur during wet weather conditions, while hazardous substances enter the waters at various and unknown times. Urban storm water runoff, a diffuse source of pollution, serves as a transport mechanism for the pollutants which accumulate on the land surface by means of direct runoff from the land and by interflow—that is, subsurface flow—both of which occur during and immediately after a rainfall or snowmelt event, and by base flow—that is, groundwater discharge between such events. Since the actual source of the pollutants is the land surface itself, it is difficult to determine the precise origin of a pollutant without a detailed field survey and extensive water quality monitoring data. However, a preliminary identification of the sources is possible using regional data assembled under the Commission's areawide water quality management planning program.

To provide a means of identifying the relative nonpoint source pollution potential of subbasins within the watershed and to supplement the hydrologic-hydraulic water quality simulation findings, a technique developed under the Commission's areawide water quality planning program, and herein referred to as the Nonpoint Source (NPS) Pollution Priority technique, was used. Under this method, cultural features including proportions of industrial, open, and transportation land uses, percent impervious area, exterior housing conditions, type of storm water drainage system, and method of sewage disposal (and natural physical features including land slope and stream density) are used to systematically analyze the expected water quality effects of urban land use development. The NPS Pollution Priority technique uses an Urban Pollution Potential Index (UPPI) computed for each subbasin on the basis of the above factors to allow a relative comparison of the subbasins. The criteria used in developing a UPPI for each subbasin are summarized in Table 78, and the actual development of the procedure is discussed in more detail in SEWRPC Planning Report No. 30, A Water Quality Management Plan for Southeastern Wisconsin, Volume Two, Chapter IV, "Alternative Plans."

In applying the NPS Pollution Priority technique to the Kinnickinnic River watershed, the indices were computed for each subbasin, the basic unit used in the data inventory and analyses for the hydrologic-hydraulic water quality simulation. The subbasins are related to the physical drainage, land use, land cover, and land slope characteristics, and provide a sound basis for plan preparation and implementation. Map 55 indicates the overall pollution potential for the watershed is moderate in comparison with other urban areas in the Region. There are substantial areas within the watershed, however, with a high potential for contributing pollution to the surface waters by runoff. These high potential areas should receive first attention of local water quality studies to identify the specific and most cost-effective water quality improvement.

ALTERNATIVE NONPOINT SOURCE WATER QUALITY MANAGEMENT PLAN ELEMENTS

The problems to be addressed in development of alternative water quality management plan elements were determined from historic water quality information and from simulation of existing and probable future water quality conditions to be excessive fecal coliform counts, high levels of toxic substances, and excessive nutrients. It was also determined that the primary source of the pathogenic and nutrient pollutants was the urban land surface and subsurface rather than the known point sources. For the toxic substances, however, the limited data indicate that occasional or intermittent unreported discharge of toxic and hazardous substances from point sources may be occurring within the watershed and must be eliminated, as must any significant contribution of such substances from storm runoff and snowmelt. The water quality problems in the upper Kinnickinnic River were found to be similar to, although less severe than, those found in Wilson Park Creek. The water quality management plan for the watershed is envisioned as consisting of the point source pollution abatement measures recommended in other regional plan elements together with recommended levels of reduction in diffuse source loadings and suggested control measures for achieving this level of reduction and for eliminating toxic and hazardous substances entering the surface waters.

Alternative Reductions in Diffuse Source Loadings

A wide variety of management measures are available for controlling diffuse, or nonpoint, sources of water pollution. The task of formulating a plan element for the abatement of these diffuse sources of pollution requires a somewhat different approach than would be used for the abatement of point source pollution problems or flooding problems. There do exist different physical measures for nonpoint source abatement, and combinations of these measures and of the geographic application of these measures can be developed. However, at the systems level, the examination of alternative abatement plans must be limited to the level or degree of control necessary for each water quality analysis area. The development of site-specific practices requires a detailed consideration of a great many factors including not only land use, soils, subsurface characteristics, and existing management practices, but property ownership, public works equipment and practices, investment policies, available technical and financial resources, and the methods by which public agencies may desire to seek plan implementation. The complexity of urban land use patterns and the still relatively primitive state-of-the-art of control of pollution from urban storm water runoff preclude the identification of site-specific practices at the systems level of water quality management planning.

The development of alternative water quality management plan elements in this chapter is accordingly limited to evaluation of various levels of source control measures for each analysis area under year 2000 plan land use and channel conditions. Although only some of these measures may be necessary to achieve the desired level of reduction in pollutant loadings, the site-specific nature of the problem and limited available data prohibit the determination at the system level of the most appropriate measures. In determination of the diffuse source control alternatives, the required level of reduction in surface loadings was used as the basis for the development of each alternative. The control measures used to attain these approximate levels of reduction in surface loadings were selected from the spectrum of possible management measures as inventoried by the Commission under its areawide water quality planning program.[6]

Use of Simulation Model: Simulation model studies were used to determine the impact on surface water quality of the reductions in surface loadings. The simulation model inputs representing year 2000 plan land use conditions and channel modifications were altered to represent the reduction in surface loading rates. This was accomplished by reducing the constituent loading rates for both impervious and pervious surfaces as well as the subsurface flow concentrations by a factor consistent with the reduction desired. The subsurface flow concentrations were reduced to reflect the expected reduction in concentration of these potential pollutants in the groundwater as the result of implementation of land management practices. The reduction factor was applied equally to all simulated water quality constituents because the state-of-the-art in diffuse source pollution control measures does not permit differentiation.

[6]*See SEWRPC Technical Record No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume 3, Urban Storm Water Runoff.*

Table 78

POLLUTION POTENTIAL DESIGNATION CRITERIA FOR URBAN AREA

Urban Criteria[a]	Unit	Nonpoint Source Pollution Potential[b]		
		Low	Moderate	High
Percent Subbasin Industrial Land	Percent	Less than 6	6-25	More than 25
Percent Subbasin Open Land	Percent	Less than 10	11-50	More than 50
Percent Subbasin Transportation Land	Percent	Less than 10	11-25	More than 25
Percent Subbasin Impervious	Percent	Less than 30	30-48	More than 48
Exterior Housing Condition	Defect points[c]	Less than 4	4-10	More than 10
Storm Water Drainage System Type	–	Surface drainage pervious material channels	Portions of subbasin served by storm water management systems with subsurface conduits and impervious material channels	Storm water management, drainage system-subsurface conduits, and impervious material channels
Method of Sewage Disposal	– –	Sanitary sewer service	Portions of subbasin served by sanitary sewer service	Onsite sewage disposal systems
Land Slope	Percent	Less than 2	2-4	More than 4
Stream Density (stream length per unit area subbasin)	Feet per acre	Less than 5	5-10	More than 10

[a] *These criteria are applied to subbasins in the Region which contain significant amounts of urban land.*

[b] *UPPI points are allocated as follows, and summed to provide a subbasin rating:*

	Pollution Potential		
	Low	Moderate	High
UPPI points	0	1	2

[c] *The exterior housing condition is determined by the average number of defect points assigned to each surveyed housing unit in the subbasin during the Commission's Exterior Housing Condition Survey conducted in 1972.*

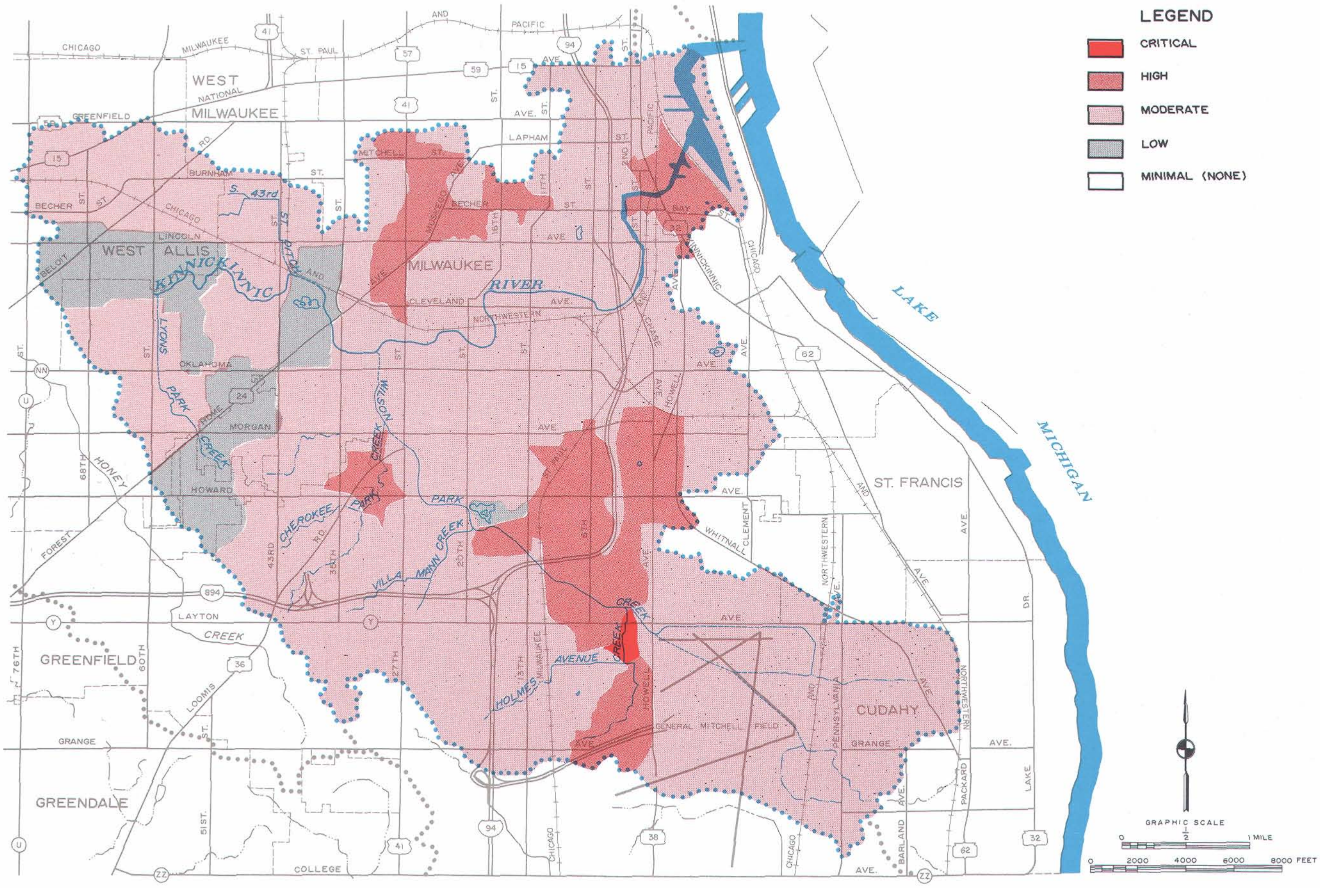
Source: SEWRPC

Simulation Results: The results of a 50 percent reduction in the surface loading rates are indicated by the constituent-duration curves shown in Figures 72, 73, and 74 as compared to the curves representing existing conditions and year 2000 plan land use and channel conditions. Comparison of the constituent duration relationships representing the year 2000 plan conditions with a 50 percent reduction on surface loading rates to the relationships for the year 2000 plan land use and channel conditions for all three simulated reaches indicates that very little change could be expected to occur in the temperature and in dissolved oxygen and ammonia levels during the summer months. The reductions in fecal coliform, phosphorus, and biochemical oxygen demand could be expected to be relatively modest. For example, the percent of time the fecal coliform standard of 400 membrane filter fecal coliform counts per 100 milliliters (MFFCC/100 ml) is exceeded in water quality analysis areas 1, 2, and 3 is 42, 45, and 30, respectively, under year 2000 plan land use and channel conditions, and 33, 34, and 22 under year 2000 plan land use and channel conditions with a 50 percent reduction in the surface loading rates. The concentration of orthophosphate-phosphorus, which is equaled or exceeded 5 percent of the time for water quality analysis areas 1, 2, and 3, may be expected to decrease from 0.30, 0.35, and 0.15 milligram per liter, respectively, under year 2000 plan land use and channel conditions to concentrations of 0.15, 0.17, and 0.08 milligram per liter, respectively, under year 2000 plan land use and channel conditions with a 50 percent reduction in the surface loading rates.

The results of a 25 percent reduction in the surface loading rates are also shown as constituent-duration curves in Figures 72, 73, and 74 and may be compared with such curves representing existing conditions, year 2000 plan land use and channel conditions, and year 2000 plan land use and channel conditions with a 50 percent reduction in surface pollutant loading. Comparison

Map 55

URBAN POLLUTION POTENTIAL IN THE KINNICKINNIC RIVER WATERSHED: 1975



Application of an indexing technique for determination of the pollution potential of runoff from urban areas based on cultural and natural physical features indicates that less than 1 percent of the watershed has a critical potential, 14 percent has a high potential, 77 percent has a moderate potential, and 8 percent has a low potential for contribution of pollutants to the stream system. Knowing the pollution potentials for given areas allows priorities to be established for further local water quality studies to identify specific water quality improvement measures.

Source: SEWRPC.

of the constituent-duration relationships representing the year 2000 plan conditions with a 25 percent reduction in the surface loading rates to the relationships for the year 2000 plan land use and channel conditions for all three simulated reaches indicates that very little change may be expected to occur in the temperature and in the dissolved oxygen and ammonia levels during the summer months. Modest reductions in fecal coliform, phosphorus, and biochemical oxygen demand could be expected. For example, the percent of time the fecal coliform standard of 400 MFFCC per 100 ml is exceeded in water quality analysis areas 1, 2, and 3 is 42, 45, and 30, respectively, under year 2000 plan land use and channel conditions, and 36, 40, and 27, respectively, under year 2000 plan land use and channel conditions with a 25 percent reduction in the surface loading rates. The concentration of orthophosphate-phosphorus equaled or exceeded 5 percent of the time for water quality analysis areas 1, 2, and 3, respectively, decreases from 0.30, 0.35, and 0.15 milligram per liter under year 2000 plan land use and channel conditions to concentrations of 0.24, 0.29, and 0.11 milligram per liter under year 2000 plan land use and channel conditions with a 25 percent reduction in surface loading rates.

Other Considerations: In addition to those constituents represented in the water quality submodel, the application of diffuse source control measures could be expected to result in the reduction of other constituents including toxic substances and sediment which accumulate on the land surface and are washed off during rainfall or snowmelt events. Due to the somewhat similar nature of toxic substances to phosphorus in terms of its association with minute particles, it is estimated that the reduction in toxic substances from diffuse sources would be similar to that of phosphate-phosphorus as shown in Figures 72, 73, and 74. Because sediment is basically a conservative substance in that it does not interact in the stream system, a reduction in the diffuse source of the sediment should result in a similar reduction in that portion of the sediment being transported by the stream from diffuse sources. As further noted below, much of the sediment transported in the Kinnickinnic River watershed is believed to originate from construction sites, or areas where the land surface has been otherwise distrubed. The reduction of sediment by other diffuse source control may be expected to have a minor impact as compared to the application of erosion control practices at the construction sites.

Costs: Implementation of control measures necessary to achieve 25 and 50 percent reductions in diffuse source pollutants is estimated to have average annual costs of about $660,000 and $1,130,000, respectively. These costs are in addition to the present expenditures and include measures such as public education programs, improved litter and pet waste control, restricted use of fertilizers and pesticides, reduced use of street deicing salts, critical area protection, increased leaf and vegetative debris collection, construction erosion control, increased street maintenance, and refuse collection and disposal, increased street sweeping intensity, improved industrial and commercial material storage facilities and runoff control, and increased catch basin cleaning. In the combined sewer are, the plan recommends no urban nonpoint source control of the deep tunnel conveyance, storage, and treatment alternative is selected, since all storm water runoff would be treated. In comparison, the present annual expenditures for refuse collection and disposal, storm sewer cleaning and maintenance, snow removal, winter street sanding and salting, and local water quality sampling and enforcement programs are estimated to be about $3,900,000 for the Kinnickinnic River watershed.

Conclusion: As indicated by comparison of the constituent duration relationships to the specified water quality standards, the overall improvement in water quality for both a 25 and a 50 percent reduction in diffuse source loading rates may be expected to be modest for some constituents and insignificant for others. In light of the costs estimated for these levels of reduction and the expected benefits in terms of water quality improvement, a lesser degree of diffuse source control is recommended.

Recommended Control Measures

The selection of nonpoint source pollution control measures at the systems planning level involves consideration of the character, extent, and severity of the identified water quality problems in light of the array of applicable control measures. In doing this, an attempt is made to select measures which will provide the necessary level of control at the least cost. Control measures suggested for the Kinnickinnic River watershed are shown in Table 79 along with estimated costs and other considerations. The costs of the diffuse source pollution control measures were estimated based on the information presented in SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control for Southeastern Wisconsin, Volume Three, Urban Storm Water Runoff, and Volume Four, Rural Storm Water Runoff.

Urban Land Uses: The seven urban measures indicated in Table 79—improved timing and efficienty of public works operations, deicing material control, litter and pet waste control ordinances, education programs, proper use of fertilizers and pesticides, erosion control in construction areas, and material storage and runoff control on industrial sites—are potentially applicable to the entire Kinnickinnic River watershed. Nearly all of the new urban development which may be expected to occur in the planning period in the watershed will be located in the Wilson Park Creek subwatershed. Therefore, the control of erosion from construction areas will be a major concern in the improvement of water quality in Wilson Park Creek and its tributaries. The existing and planned areas of industrial land use in the Kinnickinnic River watershed are relatively uniformly distributed over the watershed. However, concentrations of such areas do occur in the lower portion of the watershed near the harbor, that area of the watershed in the City of West Milwaukee, and in the upper Wilson Park Creek subwatershed near General Mitchell Field as indicated on Map 55 presented earlier in this report. The tributary areas along the lower Kinnickinnic River and the upper portion of the Wilson Park Creek are indicated on Map 55 to have a high potential for diffuse source pollution. Therefore, the industrial land uses in these areas should be examined in detail in any local implementation program to determine the necessary and proper control measures to be implemented.

The control of deicing material should be practiced throughout the entire watershed to reduce the salt loadings to surface waters. The guidelines suggested by the U.S. Environmental Protection Agency on salt application are given in Table 80. Prewetting of salt with methyl alcohol or propylene glycol (10-12 gallons at 50 percent per 300 pounds of salt) has been used in order to accelerate the action of salt which, in turn, reduces the total salt requirements.

Rural Land Uses: The amount of land within the Kinnickinnic River watershed presently in a rural land use classification is quite small, 147 acres, and is estimated to decrease to only 25 acres by the year 2000. Because of the small area involved, it is believed that minimum soil conservation practices can provide adequate diffuse source pollution control. Applicable basic conservation practices include contour plowing, crop rotation, critical area protection, diversion of storm runoff from sensitive areas, and pesticide and fertilizer management.

Additional Pollution Control Measures: Although reduction in diffuse source loadings through the source control measures described above may be expected to provide an improvement in surface water quality, several additional control measures are necessary to achieve the water use objectives and associated standards. These measures are additional nonpoint source controls more specific in their intent than the basic measures suggested above.

Table 79

RECOMMENDED DIFFUSE SOURCE WATER POLLUTION CONTROL MEASURES FOR THE KINNICKINNIC RIVER WATERSHED

Land Use	Control Measure[b,c]	Purpose	Techniques	Other Considerations	Estimated Average Annual Costs[a] Amortized Capital	Operation and Maintenance	Total
Urban	Improved timing and efficiency of street sweeping, leaf pickup, and catch basin cleaning	Reduce the quantity of pollutants available to be washed off the land surface	Modifications in work habits of public works personnel Rescheduling of public works activities Selection of equipment	May be incorporated into existing public works programs	--	$162,000	$162,000
	Deicing material control	Reduce chloride loadings to surface waters	Reduce salt applicaton on roads Salt only intersection and problem areas Provide proper salt storage locations	Will reduce damage to adjacent vegetation Reduction in quantities used will offset operation and maintenance costs involved			
	Litter and pet waste control ordinances	Prevent accumulation of litter and pet wastes in urban areas	Stricter enforcement of present ordinances Establishment and enforcement of additional necessary ordinance	May be incorporated into existing programs			
	Education programs	Make public aware of existing and potential water quality problems, their causes and solutions	Participate in regional and county programs Develop local awareness programs for citizens and public works officials Media presentations Local contacts and educational efforts	May be incorporated into existing programs of the Environment, Economic, Extension and Education Committee of the Milwaukee County Board of Supervisors			
	Proper use of fertilizers and pesticides	Eliminate the potential for runoff of these substances	Match application rate to need Eliminate applications in or near surface drainage ways	Reduction in quantities applied should offset costs involved			
	Erosion control in construction areas	Reduce sediment and attached pollutants yield	Construct temporary sediment basins Install straw bale dikes Use fiber mats; mulching and seeding Construct temporary diversion swales or berms upslope	Heavy metals and other toxic substances as well as nutrients are often attached to soil particles	$46,000	$ 11,000	$ 57,000
	Material storage and runoff control	Eliminate the potential for toxic and hazardous substances to enter surface waters	Enclose industrial storage sites with diversion channels Divert runoff to acceptable outlet or storage facility.	Will help to clean up the storage areas, improving their often unsightly appearance	$50,000	--	$ 50,000
Rural	Minimum conservation practices	Reduce sediment and pollutant yield	Contour plowing Crop rotation Critical area protection Diversion of runoff from sensitive areas Pesticide and fertilizer management	--	--	$ 3,000	$ 3,000
Total					$96,000	$176,000	$272,000

[a] *Based on a project life of 50 years and an annual interest rate of 6 percent.*

[b] *Higher levels of control consisting of measures such as increased leaf, vegatative debris, and refuse collection; increased catch basin cleaning; and increased street sweeping intensity were examined but found not to be cost-effective.*

[c] *In the Milwaukee combined sewer area, the plan recommends no urban nonpoint source control if the deep tunnel conveyance, storage, and treatment alternative is selected, since storm water runoff would be treated.*

Source: SEWRPC.

The problems of excessive fecal coliforms and presence of toxic and hazardous substances to be addressed by these measures are directly associated with the achievement of the recommended water use objectives—limited fishery and limited recreational use—and their associated water quality standards.

Fecal coliform counts in streams within the watershed during low flow, dry weather conditions exceed the standard associated with the recreational use objective. The possibilities of leakage and unintentional or unknown discharge from sanitary sewers should be examined, possibly through the use of shallow groundwater sampling and, if a problem is indicated, measures to correct it should be undertaken.

The elimination of toxic and hazardous substances from surface waters in the Kinnickinnic River watershed is essential to the development of any fishery. The implementation of diffuse source pollution control measures discussed above will help to reduce those substances, such as lead and pesticides, which are prevalent in a broad distribution over the land surface, and those substances entering the waters with runoff from industrial storage sites.

Additional sources of toxic and hazardous substances which should be controlled include accidental spills with attendant intermittent discharges through surface and floor drains connected to storm sewers and surface waters. The establishment of spill prevention and control plans, as accomplished by Milwaukee County for General Mitchell Field and by some industries, should be carried

Table 80

GUIDELINES FOR SNOW REMOVAL CHEMICAL APPLICATION RATES

Weather Conditions			Application Rate (pounds of material per mile of two-lane road or two-lanes of divided)			
Temperature	Pavement Conditions	Precipitation	Low- and High-Speed Multilane Divided	Two- and Three-Lane Primary	Two-Lane Secondary	Instructions
30° F and above	Wet	Snow	300 salt	300 salt	300 salt	Wait at least 0.5 hour before plowing
		Sleet or freezing rain	200 salt	200 salt	200 salt	Reapply as necessary
25-30° F	Wet	Snow or sleet	Initial at 400 salt; repeat at 200 salt	Initial at 400 salt; repeat at 200 salt	Initial at 400 salt; repeat at 200 salt	Wait at least 0.5 hour before plowing; repeat
		Freezing rain	Initial at 300 salt; repeat at 200 salt	Initial at 300 salt; repeat at 200 salt	Initial at 300 salt; repeat at 200 salt	Repeat as necessary
20-25° F	Wet	Snow or sleet	Initial at 500 salt; repeat at 250 salt	Initial at 500 salt; repeat at 250 salt	1,200 of 5:1 sand/salt; repeat same	Wait about 0.75 hour before plowing; repeat
		Freezing rain	Initial at 400 salt; repeat at 300 salt	Initial at 400 salt; repeat at 300 salt	1,200 of 5:1 sand/salt; repeat	Repeat as necessary
15-20° F	Dry	Dry snow	Plow	Plow	Plow	Treat hazardous areas with 1,200 of 20:1 sand/salt
	Wet	Wet snow or sleet	500 of 3:1 salt/calcium chloride	500 of 3:1 salt/calcium chloride	1,200 of 5:1 sand/salt	Wait about one hour before plowing; continue plowing until storm ends; then repeat application
Below 15° F	Dry	Dry snow	Plow	Plow	Plow	Treat hazardous area with 1,200 of 20:1 sand/salt

Source: U. S. Environmental Protection Agency.

out for all situations which have a potential for allowing such pollutants to enter surface waters at any time. Floor drains and drainage sumps in industrial structures and property which collect grease, oil, chemical, and other toxic hazardous substances should be altered as necessary to eliminate discharge to storm sewers or surface water courses. Possible alterations include discharge to the sanitary sewer system for disposal through the sewage treatment plant, pretreatment prior to discharge, and elimination of the discharge entirely through process modifications.

In the Upper Kinnickinnic River—water quality analysis area three—there exists a streambank erosion problem which should be rectified. Because the flood problems in this area are insufficient to warrant channel modifications or other structural means and it is desirable to maintain the parkway in a pleasing form, some type of control measures such as the placement of rip-rap or gabions in the reaches of the stream from S. 43rd Street to S. 60th Street where erosion occurs should be conducted.

WATER QUALITY MONITORING PROGRAMS

Maintenance of Water Quality Monitoring Work

As discussed in Chapter VII of this report, a variety of surface water quality monitoring efforts have been carried out within the Kinnickinnic River watershed. These monitoring programs include but are not limited to: 1) several surveys by the City of Milwaukee concerning the effects of the flushing tunnel; 2) periodic basin surveys by the Wisconsin Department of Natural Resources, begun in 1952; 3) a Commission water quality study conducted in 1964-1965; 4) a Commission continuing water quality monitoring program conducted from 1968 to the present; 5) a survey of toxic and hazardous substances conducted by the Wisconsin Department of Natural Resources in 1975-1976; and 6) a Wisconsin Department of Natural Resources Mitchell Field runoff study conducted in 1977. These studies were conducted for several specific purposes over a considerable period of time and included sampling of specific constituents as indicators of water quality.

A well-planned and executed water quality monitoring program can provide two important functions for the water quality management plan element of the comprehensive plan for the Kinnickinnic River watershed. First, water quality monitoring can perform a survelliance function in that periodic sampling and analysis of the stream system can detect undesirable levels of pollution and help to determine the probable source and thereby facilitate corrective action. Second, the water quality monitoring effort, using historic and existing data as a "benchmark," can be used to demonstrate and document the expected improvement in the quality of surface waters in the Kinnickinnic River watershed as the recommended water quality management plan element is implemented. An important work element being conducted under the Commission areawide water quality planning and management program is a detailed and systematic examination of the results of water quality monitoring efforts to date throughout the planning region, including the Kinnickinnic River watershed. In addition to assessing the long-term trends in stream water quality in the urbanizing Southeastern Wisconsin Region, the analysis of historic water quality monitoring data has resulted in recommendations for changes in a sampling program.

The proposed stream sampling program provides for sampling every five years at six sites in the Kinnickinnic River watershed. The sampling is proposed to begin with the 1980-81 water year and to be conducted on three consecutive days seasonally (the months of October, January, April, and July). On the second day of each seasonal sampling period, diurnal sampling—that is, four samples per day—would be conducted. In addition to the above, provisions for monitoring three storm events and a spring snowmelt event would be included.

Major parameters to be sampled as part of the proposed stream monitoring effort include: flow, temperature, dissolved oxygen, pH, specific conductance, ultimate carbonaceous biochemical oxygen demand, total biochemical oxygen demand, chemical oxygen demand, nitrite-nitrogen, nitrate-nitrogen, organic nitrogen, ammonia-nitrogen, soluble orthophosphate, total phosphorus, fecal coliform, fecal streptococcus, chloride, total suspended solids, and total dissolved solids. In addition, heavy metals (zinc, nickel, copper, lead, mercury, cadmium, and chromium), polychlorinated biphenyls (PCB's) and pesticides would be sampled, because these substances currently exist within the watershed and will be primary targets for abatement.

Monitoring for Diffuse Source Control Measures Effectiveness

Monitoring will be particularly important to determine the effectiveness of the specific nonpoint pollution abatement measures applied in plan implementation. Since the need for control of diffuse source pollution to achieve improved water quality has been recognized, implementation of control measures should not be delayed. However, urban diffuse source pollution control is a relatively new concept and very little is as yet known about the effectiveness of the various measures in relation to the various sources. Monitoring programs established in conjunction with, and closely related to, application of urban diffuse source control measures will provide the necessary insights into the effectiveness of various control measures. As each individual or group diffuse source control measure is implemented, a companion monitoring program carefully adapted to the tributary area and specific pollutants sources to be controlled should be designed and implemented in conjunction with the control measures.

SUMMARY

In an urban setting like the Kinnickinnic River watershed, man's activities affect, and are affected by, surface water quality. A careful examination of the available water quality data for the Kinnickinnic River watershed stream system for the period 1952 through 1977 indicates that the surface waters are severely polluted. Toxic, organic, nutrient, pathogenic, sediment, and aesthetic pollution are all known to exist in the surface waters of the Kinnickinnic River watershed. These problems are attributable to four major pollution sources: combined sewer overflows, sanitary sewerage systems flow relief devices, industrial discharges, and urban storm water runoff.

Substantial efforts have already been initiated to abate some of these sources of pollution. The 27-square-mile combined sewer service area in Milwaukee County, which includes a 4.5-square-mile area tributary to the Kinnickinnic River, is the subject of an intensive preliminary engineering study presently being conducted by the Milwaukee-Metropolitan Sewerage Commissions. This study is directed at finding the most cost-effective means for abating pollution from combined sewer overflows, including the 22 such overflows operating within the Kinnickinnic River watershed. This study, which is scheduled for completion in 1978, builds upon previous work conducted by the Regional Planning Commission under the Milwaukee River watershed study, and is to provide firm recommendations for the construction of combined sewer overflow abatement facilities.

The recently established Wisconsin Pollutant Discharge Elimination System is expected to result in a gradual abatement of pollution from sanitary sewerage system flow relief devices such as crossovers, bypasses, relief pumping stations, and portable pumping stations, including the 30 such devices operating within the Kinnickinnic River watershed. The Wisconsin Pollutant Discharge Elimination System is also expected to gradually result in the abatement of pollution originated from industrial wastewater outfalls, including the 60 such devices operating within the Kinnickinnic River watershed. Thus, programs currently underway should result in the elimination or abatement of all point sources of water pollution within the Kinnickinnic River watershed by the design year of the plan.

In consideration of the basic point source pollution abatement program already in progress within the Kinnickinnic River watershed, the design and evaluation of alternative pollution abatement plans under the watershed study were based upon the following assumptions. First, the combined sewer overflow problem in the lower reaches of the watershed was not to be addressed, both because that problem involves the Milwaukee-Menomonee-Kinnickinnic River-Lake Michigan estuary which is to be the subject of a separate study and because an intensive engineering study is already underway by the Milwaukee-Metropolitan Sewerage Commissions to provide firm recommendations for the construction of combined sewer overflow pollution abatement facilities. Second, preparation of the water quality management plan element for the watershed plan would not include an explicit analysis of alternative ways of eliminating sanitary sewerage system flow relief devices, since these devices will be eliminated through operation of the Wisconsin Pollutant Discharge Elimination System. Third, the abatement of industrial wastewater discharges to the surface water system will also be effected by the Wisconsin Pollutant Discharge Elimination System. Fourth, the water quality analyses and water quality simulation modeling should reflect the committed channel modifications on the Kinnickinnic River and on Wilson Park Creek in addition to the existing channel modifications in the watershed.

A series of water quality simulations was made using the water quality submodel under existing and planned development conditions and water quality management measures in order to quantitatively investigate the likely consequences of those conditions and measures and thereby contribute to the development of the water quality management plan element. The simulation model studies indicate that little change in the water quality over the watershed may be expected under the year 2000 land use plan and committed channel improvement conditions. The simulation model studies further indicate that the standards for dissolved oxygen, temperature, and ammonia-nitrogen may be expected to be achieved consistently, while the standard for fecal coliform may be expected to be met approximately 60 percent of the time under year 2000 plan conditions without the application of additional land management measures. An evaluation, using the simulation model, of two water quality management alternatives consisting of a 25 percent and a 50 percent reduction in the diffuse source pollutant loading rates indicated that only modest improvements in water quality would be achieved.

An empirical method recently developed by the Commission to systematically analyze the pollution potential of subbasins based on the natural and cultural features of the subbasins was applied to develop a relative pollution potential rating for each subbasin of the watershed. This rating may be used in determining priorities for rating the design and implementation of diffuse source control measures in the watershed.

In order to reduce the diffuse source pollution in the watershed, it is recommended that the communities use a judicious blend of education and regulation to encourage citizens to apply low-cost measures such as control of litter and pet waste, proper application of chemical and organic fertilizers and pesticides to lawns and shrubbery, and control of leaf and vegetative debris on private property and in public places. It is also recommended that erosion be controlled during demolition and construction activities and that proper storage and runoff control be provided for facilities handling materials which may be hazardous to the environment. It is further recommended that communities examine the manner in which municipal services such as street cleaning and maintenance and garbage collection are performed to determine if the amount of dust, dirt, and litter that accumulates on road surfaces and adjacent areas and that is, therefore, subject to washoff to the stream system can be significantly reduced with little or no increase in cost. It is also recommended that proper application and control of street deicing materials be practiced throughout the watershed to reduce the chloride loadings to surface waters. It is anticipated that implementation of the control measures described above, following a detailed study designed to determine the specific sources and solutions, will result in the achievement of the water quality standards not currently met.

The average annual cost for the implementation of the recommended pollution control measures for the attainment of a "limited fishery, limited recreational use, and minimum standards" water use objective in the Kinnickinnic River watershed is estimated to be $272,000 per year.

It is recommended that a water quality monitoring program be developed for the watershed to demonstrate and document the expected improvement of the surface waters and to providing surveillance data to detect and locate undesirable levels of pollution.

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Chapter XIV

RECOMMENDED COMPREHENSIVE PLAN

INTRODUCTION

The comprehensive plan for the Kinnickinnic River watershed is comprised of three major elements: 1) a land use base element, including open space preservation and outdoor recreation subelements; 2) a supporting floodland management element composed of structural and nonstructural subelements; and 3) a supporting water quality management element composed of various point and diffuse source pollution abatement subelements. The land use base element is based upon the adopted regional land use plan and the adopted regional park and open space plan. The floodland management and water quality management plan elements were selected from among the alternatives considered on the basis of an evaluation of the many tangible and intangible factors involved, with primary emphasis upon the degree to which the various alternatives met the established watershed development objectives in the most cost effective manner.

This chapter presents a description of the recommended comprehensive watershed development plan as synthesized from the best of the alternatives considered under each of the two major plan elements for which alternatives were considered, along with a presentation of the basis for the synthesis and an analysis of the attendant costs. The chapter also contains an evaluation of the ability of the recommended plan to meet the adopted watershed development objectives and standards and discusses the likely consequences of not implementing the plan. Finally, the public reaction to the recommended plan and the subsequent action of the Kinnickinnic River Watershed Committee are discussed.

BASIS FOR PLAN SYNTHESIS

The watershed development objectives which the comprehensive plan for the Kinnickinnic River watershed is designed to meet are set forth in Chapter X of this report. That chapter also sets forth the standards for relating these objectives to the physical development proposals which constitute the plan, thereby facilitating evaluation of the ability of each of the alternative plan proposals to meet the chosen objectives. The plan selection process was guided by the watershed committee and by the public reaction to the preliminary plan as presented at the public hearings on the plan. The dates and location of these hearings are set forth in Table 81. Minutes of the hearings have been published by the Commission and are available for review at the Commission offices.[1]

In each of the three preceding chapters[2] in which the various land use, floodland management, and water quality management plan elements have been described, alternative proposals as appropriate have been evaluated and recommendations made for inclusion of the best alternative in the comprehensive watershed plan. In this process of recommended plan selection, the various alternative plan elements were evaluated, with respect to their technical, economic, environmental, legal, financial, and administrative feasibility as well as with respect to their ability to meet the applicable watershed development objectives and supporting standards. Figure 75 illustrates the manner in which a plan element or subelement was sequentially subjected to several levels of 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 one land use or water control facility plan element can fully satisfy all of the watershed development objectives. The recommended comprehensive watershed plan must, therefore, consist of a combination of individual plan elements, with each plan element contributing toward the satisfaction of the development objectives. It should be noted that many of the alternative plan elements were specifically designed to satisfy certain watershed development objectives, and therefore the selection from among the alternatives depended largely upon analysis of the attendant costs. The various recommended plan alternatives, as set forth in Chapters XI, XII, and XIII of this report, are complementary in nature, and the recommended comprehensive watershed plan represents a synthesis of carefully coordinated individual plan elements which together should achieve most of the adopted watershed development objectives.

Because of the extreme difficulty, if not impossibility, of expressing all of the benefits and costs associated with the comprehensive watershed plan in monetary terms, the evaluation of the recommended comprehensive plan has been based primarily on its ability to satisfy the watershed development objectives and supporting standards. The economic analyses of certain of the individual plan elements and subelements, however, as set forth in previous chapters of this report, comprise important inputs to the plan selection process, particularly where the alternative plan elements or subelements were specifically designed to meet certain development objectives.

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[1]*See Minutes of Initial Public Hearing on Kinnickinnic River Watershed Study, March 9, 1977, and Minutes of Final Public Hearing on Kinnickinnic River Watershed Study, October 12, 1978.*

[2]*See Chapter XI, "Land Use Base and Park and Open Space Protection Measures"; Chapter XII, "Alternative Floodland Management Measures"; and Chapter XIII, "Alternative Water Quality Management Measures."*

Table 81

SCHEDULE OF PUBLIC HEARINGS ON THE
COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED

Type of Hearing	Presiding Agency	Place	Date and Time
Initial Public Hearing	Kinnickinnic River Watershed Committee	Pulaski Senior High School Milwaukee	March 9, 1977 7:30 p.m. - 8:55 p.m.
Final Public Hearing	Kinnickinnic River Watershed Committee	Pulaski Senior High School Milwaukee	October 12, 1978 7:30 p.m. - 8:20 p.m.

Source: SEWRPC

RECOMMENDED PLAN

Based upon the results of the analyses of the ability of the various plan elements to satisfy watershed development objectives and to exhibit acceptable benefit-cost features, as described in previous chapters of this report, the specific plan elements set forth below are recommended for inclusion in the comprehensive plan for the Kinnickinnic River watershed. Principal elements of the preliminary recommended comprehensive plan for the Kinnickinnic River watershed are shown in graphic summary form on Map 58.

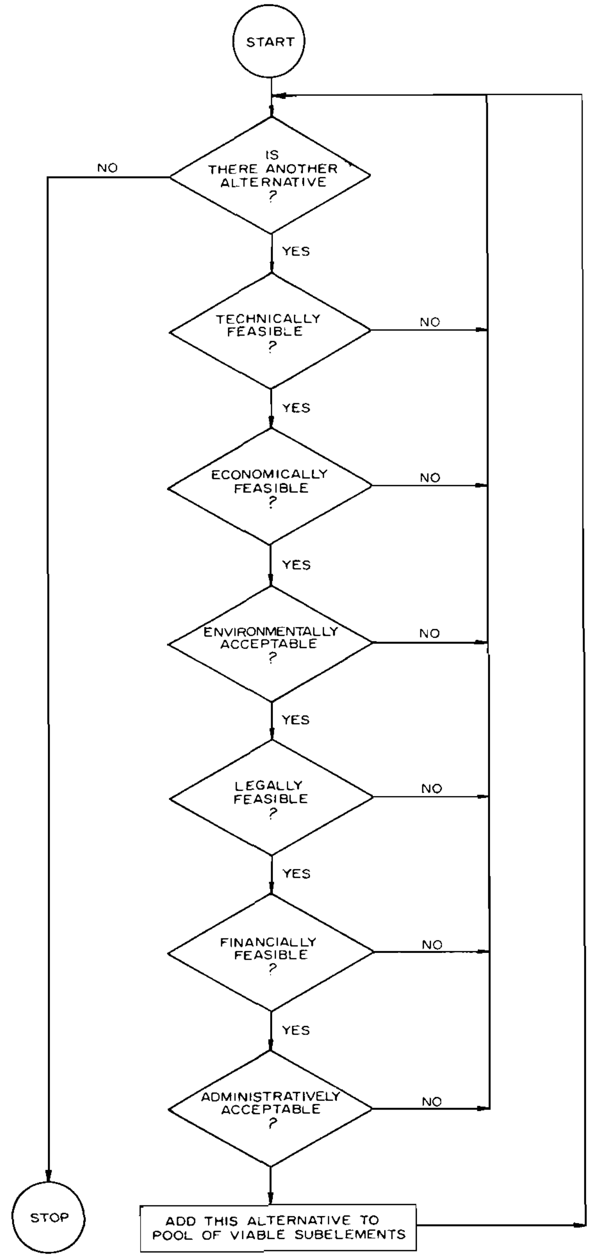
Recommended Land Use Plan Element

Overall Land Use: The controlled existing trend 1990 regional land use plan originally adopted by the Commission in 1966, and reevaluated and refined for the year 2000 by the Commission in 1977, is recommended for adoption as the land use base element for the Kinnickinnic River watershed plan (see Map 44 in Chapter XI). This land use plan element envisions use of a combination of public acquisition and public regulation of private holdings of land to guide and shape the spatial distribution of land uses within the watershed in order to achieve a safer, more healthful, and more pleasant, as well as a more efficient, land use pattern while meeting the forecast land use demand requirements. The land use base emphasizes continued reliance in the urban land market to determine the location, intensity, and character of future development within the Region and the watershed for residential, commercial, and industrial land uses. It does, however, propose to regulate, in the public interest, the effect of this market on development in order to provide for a more orderly and economical land use pattern and in order to avoid intensification of developmental and environmental problems within the Region and the watershed.

Urban Development: Forecasts indicate that the population of the Kinnickinnic River watershed may be expected to decrease from the 1975 level of about 165,000 persons to a 2000 level of about 160,000 persons, or about 3 percent. This future resident population, however, may be expected to consist of 60,800 households, or about 7,350 more households than in 1975, due to a decline in the average household size of 3.0 persons per household in 1975 to 2.6 persons per household in 2000. Employment may be expected to

Figure 75

TEST AND EVALUATION OF A PLAN SUBELEMENT



Source: SEWRPC.

reach approximately 84,000 jobs by 2000, an increase of about 7,000 jobs, or about 9 percent, over the 1975 level. Although the Kinnickinnic River watershed is almost entirely urbanized, with about 24 square miles, or 92 percent, of the watershed devoted to urban land uses in 1975, an additional 1.1 square miles of land are forecast to be converted to urban land use over the next two to three decades.

As indicated in Table 68 in Chapter XI of this report, the recommended land use plan proposes to add about 0.72 of a square mile of land to the existing stock of residential land within the watershed in order to meet the housing needs created by anticipated shifts in the distribution of population within the watershed and by decreasing household size and attendant increase in the number of dwelling units needed, even though the total population is expected to decline. This new urban development is proposed to occur at medium population densities, with gross residential population densities ranging from about 2,900 to about 8,000 persons per square mile. The new residential development would be located in areas served by a full range of public utilities and essential urban services, since the entire watershed is already served by public sanitary sewerage, public water supply, and electric power and gas facilities, as well as by mass transit. The remaining 0.38 square mile of land proposed to be converted to urban use within the watershed by the year 2000 would be used for commercial, industrial, governmental and institutional, transportation, communication, and utility land uses as required to meet the gross demand for land generated by the anticipated resident population and employment levels within the watershed.

Agricultural and Other Open Land Use: As noted above, the recommended watershed land use plan would require the conversion to urban use of 1.1 square miles of land presently devoted to agricultural and other open land uses within the watershed. The existing stock of such land within the watershed could, therefore, be expected to decrease from 2.14 square miles in 1975 to 1.04 square miles in the year 2000, a decrease of more than 50 percent.

Park and Open Space Plan: As discussed earlier in this report, a regional park and open space plan was recently completed and adopted by the Commission, and includes recommendations for the Kinnickinnic River watershed. The regional park and open space plan is composed of two principal elements—an open space preservation plan element and an outdoor recreation plan element.

The open space preservation plan element recommends the continued maintenance and preservation in essentially natural open uses of all remaining primary environmental corridor lands within the Region and the watershed. The preservation of the primary environmental corridor in essentially natural open uses—and thereby the preservation of the attendant recreational, aesthetic, ecologic, and cultural values in accordance with regional and watershed development objectives—is essential to the maintenance of a wholesome environment within the watershed. As shown on Map 45 in Chapter XI of this report, these corridor lands consist of about 327 gross acres located along the Kinnickinnic River from S. 16th Street to S. 69th Street. Also recommended is the protection through public land use regulation of that portion of the Lake Michigan shoreline primary environmental corridor, about 232 gross acres, in the harbor area of the watershed.

The outdoor recreation plan element is composed of: 1) a resource-oriented outdoor recreation component containing recommendations as to the number and location of large parks, proposed recreation corridors to accommodate trail-oriented activities, and water access facilities; and 2) an urban-oriented outdoor recreation component containing recommendations to guide the public provision of needed local parks and nonresource-oriented recreation facilities within urban areas. More specifically, with respect to the watershed, and as shown on Map 45, the outdoor recreation plan element recommends:

- Continued maintenance of Jackson Park—a large, general use, outdoor recreation site;
- Development of the four-mile segment of a recommended recreation corridor passing across the eastern end of the watershed in a generally north-south direction, relying primarily on existing streets;
- Continued use of 16 existing community and neighborhood parks located partially or wholly within the watershed, and the completion of two acquired but fully developed neighborhood parks, as well as the acquisition and development of three new neighborhood parks;
- Development of urban outdoor recreation facilities for community and neighborhood parks, the type and quantity of which would be determined through a joint effort by county, school districts, and local community recreation agencies; and
- Conduct of preliminary engineering and attendant environmental impact assessment studies leading to the possible location of boat launching ramps and mooring facilities in the estuary portion of the watershed.

The estimated costs for the development and acquisition of the proposed neighborhood parks, and the development of urban outdoor recreation facilities for the watershed, are reflected in the total cost of the regional park and open space plan and are not, therefore, included in the implementation cost of the Kinnickinnic River watershed plan.

The park and open space plan for the Kinnickinnic River watershed, as extracted from the adopted regional park and open space plan, sets forth recommended means for:

- Achieving regional and watershed open space preservation objectives;

- Meeting existing and anticipated future needs for resource-oriented outdoor recreation sites and facilities; and,

- Meeting the existing and anticipated future needs for nonresource-oriented urban outdoor recreation sites and facilities.

Recommended Floodland Management Plan Element

Committed Channel Modifications: The prospectus prepared in 1974 for the Kinnickinnic River watershed study indicated that a severe flooding problem existed in that reach of the Kinnickinnic River between S. 6th Street and S. 16th Street. The prospectus, moreover, indicated that this historic flood problem existed despite extensive improvements made to the channel in this reach as recently as the early Sixties. Due to the severe and urgent nature of this problem, early in the Kinnickinnic River watershed planning program the Watershed Committee considered and discussed the results of a 1975 reconnaissance report on the problem prepared by the U.S. Army Corps of Engineers[3] and asked that the staffs of the Regional Planning Commission and the Milwaukee-Metropolitan Sewerage Commissions evaluate the technical aspects of two of the alternative solutions advanced for consideration therein. Both of the alternatives included the possible removal of 14 bridges, with replacement of four; and one alternative, in addition, included channel alteration and widening between S. 5th Street extended and S. 6th Street, and between S. 8th Street and S. 12th Street. The alternatives were evaluated early under the watershed study, and the bridge alteration and channel modification alternative was found to be adequate to contain the 100-year recurrence interval flood flows within the channel for the entire S. 6th to S. 16th Street reach. Accordingly, early in 1976 the Watershed Committee recommended that the Milwaukee-Metropolitan Sewerage Commissions and the City of Milwaukee proceed immediately to carry out these channel improvements.

The floodland management plan element recommended for inclusion in the comprehensive Kinnickinnic River watershed plan assumes that these bridge removals, reconstructions, and attendant channel modifications will be carried out expeditiously. More specifically, as shown on Map 47 in Chapter XII, the assumed modifications consist of the removal without replacement of 10 bridges and the removal and replacement of four bridges, and the construction of attendant earthen dikes and concrete floodwalls and channel improvements as necessary to provide two feet of freeboard in that reach of the Kinnickinnic River between S. 5th Street extended and S. 16th Street. Responsibility for the implementation of these modifications would rest with the City of Milwaukee for the bridge removal and replacement; with the Milwaukee County Department of Public Works for removal of the abandoned North Shore Railroad crossing; and with the Milwaukee-Metropolitan Sewerage Commissions for the construction of necessary attendant earthen dikes, concrete floodwalls, and channel improvements. In addition, channel improvements along Wilson Park Creek from W. Euclid Avenue to S. 6th Street were assumed to be committed. Under year 2000 planned land use conditions and implementation of these committed channel modifications, only one area—along Wilson Park Creek-Edgerton Channel in the City of Cudahy—would be expected to incur flood damages, the flood problems which presently exist in other areas of the watershed having been abated by the committed bridge removals and reconstruction and attendant channel improvements.

[3]*U.S. Army Corps of Engineers, Reconnaissance Report on Flood Problems on the Kinnickinnic River at Milwaukee, Wisconsin Under Section 205 of the 1948 Flood Control Act as Amended, June 1975.*

Structural Measures for Flood Damage Abatement in the City of Cudahy: The recommended floodland management plan element for the Kinnickinnic River watershed includes the application of primarily structural measures for the abatement of damages in the flood-prone area along Wilson Park Creek—Edgerton Channel—in the City of Cudahy. More specifically, the plan recommends that the detention storage-channel enclosure-bridge alteration alternative be adopted to resolve existing and probable future flood problems along the Wilson Park Creek—Edgerton Channel—in the City of Cudahy. Based upon comments by officials of the City of Cudahy at the Watershed Committee meetings, this recommended alternative as initially presented in Chapter XII of this report was revised to include the realignment of the Edgerton Channel along that reach between the outlet of the proposed channel enclosure and the western limits of the City of Cudahy in order to make the proposed improvement fully consistent with established local planning and with easements previously acquired for this purpose by the City. The recommended alternative consists, as shown on Map 56, of the following three components: 1) a 65-acre-foot detention storage reservoir occupying approximately 13 acres immediately east of Whitnall Avenue in the City of Cudahy; 2) enclosure of the channel in a 10-foot-wide by 6-foot-deep concrete box conduit starting at Nicholson Avenue and extending downstream 0.3 mile; 3) and straightening of the alignment of the channel from a point immediately downstream of the box conduit to the western city limits and attendant reconstruction of the Pennsylvania Avenue crossing. The average annual cost of this detention channel enclosure-channel realignment alternative, computed using an interest rate of 6 percent and a project life and amortization period of 50 years, is estimated at about $64,000 consisting of the following: amortization of the $329,600 capital cost for land acquisition, amortization of the $140,600 capital cost for reservoir construction, amortization of the $475,000 capital cost for channel enclosure, amortization of the $27,600 capital cost for channel realignment, and $2,300 annual operation and maintenance costs.

Bridge Replacement: It is recommended that bridges and culverts on the major stream system of the Kinnickinnic River watershed which have inadequate hydrologic-

Map 56

DETENTION STORAGE-CHANNEL ENCLOSURE-CHANNEL REALIGNMENT ALONG THE EDGERTON CHANNEL IN THE CITY OF CUDAHY

LEGEND

PROPOSED EARTHEN EMBANKMENT

PROPOSED DETENTION STORAGE RESERVOIR

PROPOSED OUTLET CONTROL STRUCTURE

PROPOSED CONDUIT

PROPOSED BRIDGE REPLACEMENT (COST ASSIGNED TO PREVIOUSLY ADOPTED PLAN)

PROPOSED REALIGNED CHANNEL

EXISTING FLOODLAND CONDITIONS

NOTE: A DETENTION RESERVOIR IS NORMALLY EMPTY AND MAY BE USED FOR RECREATIONAL ACTIVITIES BUT IS DESIGNED TO DETAIN WATER DURING FLOOD EVENTS TO ATTENUATE THE DOWNSTREAM DISCHARGE

GRAPHIC SCALE 0 400 800 FEET

In order to make proposed structural floodland management measures fully consistent with established local planning and with easements previously acquired for this purpose by the city, as expressed by the officials of the City of Cudahy at the Watershed Committee meetings, the alternative initially recommended in Chapter XII of this report was revised to include the realignment of the Edgerton Channel along that reach between the outlet of the proposed channel enclosure and the western limits of the city.

Source: SEWRPC.

hydraulic capacity as manifested by historic or potential overtopping of the approach roads or of the structure be eventually modified or replaced so as to eliminate their interference with the desirable operation of the highway and railroad transportation system. More specifically, the analyses conducted under the watershed study indicate that two crossings of the Kinnickinnic River—Chase Avenue and S. 43rd Street—and two crossings of Wilson Park Creek—Pennsylvania Avenue and Nicholson Avenue—were found to be hydraulically inadequate under year 2000 planned land use and committed channel conditions. Such replacement or modification, however, is recommended to be carried out only when required for traffic safety or other transportation purposes.

The design of all new or replacement bridges within the watershed should be based upon the applicable objectives and standards set forth in Chapter X. Of particular importance is the standard which requires that all new and replacement bridges and culverts be designed so as to accommodate the 100-year recurrence interval flood event under year 2000 plan conditions without raising the peak stage more than 0.1 foot above the peak stage for the 100-year recurrence interval flood, as established in the adopted comprehensive watershed plan.

Floodland Regulations: It is recommended that the City of Milwaukee revise its floodland and floodland related land use regulations so as to be fully consistent with the flood hazard data developed under the study for existing land use channel conditions. It is further recommended, based on the identification of existing or potential flood hazards under the watershed planning program, that the Cities of West Allis and Cudahy utilize the flood hazard data generated by the planning program in the preparation and adoption of new floodland and floodland related regulations. More specifically, it is recommended that the floodland and floodland related land use regulations be designed so as to accommodate the existing development, preserve sufficient conveyance capacity for the 100-year flood flow through delineation and preservation in open use of a floodway, and acquire the floodproofing of all new urban development permitted in the floodplain fringe. Upon completion of the committed channel modifications along the Kinnickinnic River and Wilson Park Creek, the floodland regulations should be revised to be fully consistent with flood hazard data developed under the study for these anticipated conditions.

Channel Maintenance: It is recommended that the responsible governmental units and agencies establish a regular channel maintenance program, including the periodic removal of sediment deposits, heavy vegetation, and debris from all watercourses in the watershed.

Flood Insurance: All of the communities located wholly or partly in the watershed have taken the necessary affirmative steps to make their residents eligible to participate in the federal flood insurance program. Furthermore, the U.S. Department of Housing and Urban Development has authorized insurance rate studies for the Cities of Greenfield and Milwaukee. It is recommended that the U.S. Department of Housing and Urban Development, in conjunction with the Wisconsin Department of Natural Resources, also authorize the conduct of such insurance rate studies in the Cities of West Aliis and Cudahy. It is further recommended that contractors retained by the U.S. Department of Housing and Urban Development to conduct the flood insurance studies base those studies on the flood hazard data developed under the watershed program. Finally, it is recommended that owners of property in flood-prone areas purchase flood insurance to provide some financial relief for losses sustained in floods which may occur prior to the completion of committed and recommended flood control works. Subsequent to the completion of these structural floodland management measures, property owners who elect to continue the purchase of flood insurance may do so at much reduced rates, and thereby guard against losses from extraordinary floods having a magnitude in excess of that of the design flood.

Lending Institution and Realtor Policies: It is recommended that lending institutions continue to determine the flood-prone status of properties prior to granting of a mortgage, and that the principal source of flood hazard information be that developed under the watershed planning program. It is also recommended that real estate brokers and salesmen and their agents continue to inform potential purchasers of property of any flood hazard which may exist at the site being traded in accordance with the 1973 Executive Order of the governor of Wisconsin.

Community Utility Policies and Emergency Programs: It is recommended that the policies of governmental units and agencies having responsibility for the design, construction, operation, and maintenance of public utilities and facilities—such as water supply, sewerage, and streets and highways—within the watershed carry out those functions in a manner fully consistent with the land use and floodland regulation recommendations for the Kinnickinnic River watershed. Although the hydrologically "flashy" and unpredictable nature of flooding within the Kinnickinnic River watershed renders a flood forecasting system impractical, it is recommended that until committed and recommended flood control works are completed, each watershed community develop procedures to provide floodland residents and other property owners with timely information about floods in progress. The flood information procedures for a particular community might be selected as appropriate from the following: monitoring of National Weather Service broadcasts during periods when rainfall or snowmelt are occurring or anticipated, patrolling riverine areas to detect rising stages and bankfull conditions, emergency messages broadcast over local radio and television stations, use of police patrol cars or other vehicles equipped with public address systems, and use of warning sirens particularly during nighttime hours.

Land Use Controls Outside of the Floodlands: It is recommended that in preparing plans for the development of remaining small areas throughout the watershed and the redevelopment of local areas, the hydrologic impact of the plans be considered in addition to their relationship to soil capabilities, long established and planned utilities systems, and the natural resource base.

Maintenance of Stream Gaging Network: The continuous recording stream gaging station, partial record stations, and crest stations located throughout the Kinnickinnic River watershed can provide critical data essential to the future rational management of the surface waters of the basin. It is recommended that the continuous recorder gage installed at the S. 7th Street crossing of the Kinnickinnic River in the City of Milwaukee for purposes of the Kinnickinnic River watershed study continue to be operated in the vicinity subsequent to completion of the committed channel modifications. It is also recommended that the partial record station operated in the basin by the U.S. Geological Survey at S. 27th Street on the Kinnickinnic River continue to be operated, and that the City of Milwaukee and the Milwaukee-Metropolitan Sewerage Commissions continue to maintain crest stage or staff gage networks.

Flood Protection Elevations for the Kinnickinnic River Estuary Area: It is recommended that a new flood protection elevation of at least two feet above the 100-year recurrence interval peak flood stage profile for the year 2000 land use plan conditions with the committed channel modifications be established along the Kinnickinnic River downstream of Chase Avenue, superseding the flood protection elevation presently established for that reach by the Milwaukee-Metropolitan Sewerage Commissions.

Recommended Water Quality Management Plan Element

Abatement of Combined Sewer Overflows: A preliminary engineering study currently underway and scheduled for completion in 1978 will provide recommendations for the abatement of pollution from the 22 combined sewer overflow devices located within the 4.5-square-mile combined sewer service area in the lower reaches of the Kinnickinnic River watershed. That study, being conducted by the Milwaukee-Metropolitan Sewerage Commissions, grew out of recommendations contained in the adopted Milwaukee River watershed plan of the Regional Planning Commission. Insofar as the recommendations forthcoming from the preliminary engineering study are consistent with the water use objectives and standards established under the Kinnickinnic River watershed planning program, it is proposed that the findings and recommendations of that preliminary engineering study be considered as an integral part of the comprehensive watershed plan; and that, more specifically, the construction of the necessary transmission, storage, and treatment facilities needed to abate the combined sewer overflow pollution problem in the Kinnickinnic River watershed, as well as in the neighboring Milwaukee and Menomonee River watersheds be implemented as soon as practicable.

Elimination of Flow Relief Devices: The recommended water quality management plan element for the Kinnickinnic River watershed incorporates the recommendation contained in the adopted regional sanitary sewerage system plan for southeastern Wisconsin that the 30 flow relief devices--20 crossovers, 4 bypasses, and 6 relief pumping stations--discharging raw sewage directly or indirectly to the Kinnickinnic River and tributaries be eliminated through trunk and relief sewer construction. Furthermore, it is recommended that the Wisconsin Pollutant Discharge Elimination System (WPDES), which requires a permit and a pollution abatement schedule for each device, be used as the mechanism for elimination of these flow relief devices in the Kinnickinnic River watershed.

Abatement of Industrial Discharges: The recommended water quality management plan element of the Kinnickinnic River watershed plan proposes that the direct or indirect discharge of industrial wastes to the Kinnickinnic River and its tributaries be eliminated while allowing the continued discharge of clear water containing no substances hazardous to recommended water use objectives. It is recognized that such abatement can be achieved under the Wisconsin Pollutant Discharge Elimination System, which requires a permit and pollution abatement schedule for each industrial discharge device.

Control of Diffuse Source Pollution: It is recommended that the communities within the watershed use a judicious blend of education and regulation to encourage citizens to apply low-cost measures such as control of litter and pet waste; proper applicaton of chemical and organic fertilizers and pesticides to lawns and shrubbery; critical area protection; and, for remaining rural land uses, minimum conservation practices. It is also recommended that soil erosion be strictly controlled during demolition and construction activities and along stream banks, and that proper storage and runoff control be provided for facilities handling materials which may be hazardous to the environment. It is further recommended that communities examine the manner in which municipal services such as street and storm sewer system cleaning and maintenance and garbage collection are performed to determine if the amount of dust, dirt, and litter that accumulates on the road surfaces and adjacent areas and that is, therefore, subject to washoff to the stream system can be significantly reduced with marginal increases in cost. It is also recommended that proper application and control of street deicing materials be practiced throughout the entire watershed to reduce the chloride loadings to surface waters. In the combined sewer portion of the watershed, the plan recommends, no urban nonpoint source control if the deep tunnel conveyance, storage, and treatment alternative is selected, since all storm water runoff would be treated.

Development of a Water Quality Monitoring Program: It is recommended that a water quality monitoring program be developed by the Milwaukee-Metropolitan Sewerage Commissions for the watershed to demonstrate and document the changes in surface water quality attendant to plan implementation, and to help detect and locate future illegal sources of pollution.

COST ANALYSIS

In order to assist public officials in evaluating the recommended comprehensive Kinnickinnic River watershed plan in conjunction with the applicable plan elements of adopted regional plans pertaining directly to the Kinnickinnic River watershed, a summary of the costs associated with these plan elements was prepared. In addition, a preliminary capital improvement program with attendant operation and maintenance costs for recommended plan elements attributable solely to the Kinnickinnic River watershed program was prepared which, if followed, would result in complete implementation of these elements by the plan design year 2000. Finally, an analysis was made of recent public expenditures for major channel modifications within the watershed in order to determine if sufficient monies were likely to be available to implement the recommended floodland management plan element.

Applicable Regional and Recommended
Watershed Plan Element Costs

The estimated capital costs for the necessary land acquisition and facility construction, and the attendant operation and maintenance expenditures associated with implementation of other adopted regional plan elements directly applicable to the Kinnickinnic River watershed, and having important implications for attainment of the agreed-upon watershed development objectives, are presented in Table 82. Such adopted plan elements include the sewage treatment plant improvements, intercommunity trunk sewer construction, and combined sewer overflow abatement measures recommended in the adopted regional sanitary sewerage system plan; and the resource-oriented park and related open space acquisition and development recommendations of the adopted regional park and open space plan.

Table 82

CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE APPLICABLE REGIONAL PLANS' ELEMENTS AND THE RECOMMENDED PLAN FOR THE KINNICKINNIC RIVER WATERSHED

Plan	Element or Subelement	Costs[a] (dollars)	
		Capital	Annual Operation and Maintenance
Regional Sanitary Sewerage[b] System Plan	Sewage Treatment Plants Intercommunity Trunk Sewers Abatement of Combined Sewer Overflows	3,700,000 15,530,000 49,500,000	811,800 10,600 429,000
Total		$68,730,000	1,251,400
Regional Park and Open Space Plan	Resource-Oriented Outdoor Recreation Sites Park and Outdoor Recreation Facilities Development	—[c] 711,600	—[c] 21,800[d]
Total		711,600	21,800
Kinnickinnic River Watershed Plan	Floodland Management Element Committed Channel Modifications in the City of Milwaukee Flood Control Measures in the City of Cudahy Streamflow Recordation	3,524,000 972,800 —	3,000 2,300 3,200
Subtotal		4,496,800	8,500
	Water Quality Management Element Diffuse Source Pollution Control Measures	1,359,000	14,000
Total		5,855,800	22,500
Total		75,297,400	1,295,700

[a] *Values shown for the regional sanitary sewerage system plan are based on 1970 costs and the values shown for the regional park and open space plan are based on 1975 costs. These costs were adjusted to 1977 costs using ratios of the Engineering News Record construction cost indices (1.65 and 1.15, respectively) for comparison with the watershed plan costs.*

[b] *These costs are estimated by proration on an area basis to the watershed of total costs for the metropolitan service area determined under the regional sanitary sewerage system study. A combined sewer overflow abatement study currently being conducted by the Milwaukee-Metropolitan Sewerage Commissions may result in more correct as well as more referred cost estimates.*

[c] *Since this element includes in the Kinnickinnic River watershed only the maintenance of an existing recreation facility, no capital costs or incremental operation and maintenance costs are included.*

[d] *Incremental cost based on an estimated average cost of $500 per acre.*

Source: SEWRPC

Those elements of the recommended Kinnickinnic River watershed plan having implementation costs directly assignable to the watershed plan consist of the committed channel modifications in the City of Milwaukee, the recommended structural flood control measures for the City of Cudahy, and continuous streamflow gage subelements of the floodland management plan element; and the diffuse source pollution control measures subelement of the water quality management plan element.

Table 82 indicates that the major capital costs associated with the regional sanitary sewerage system plan including combined sewer overflow abatement, comprise about 91 percent of the total capital costs for recommended plan elements in the Kinnickinnic River watershed. The plan elements of the regional park and open space plan and of the comprehensive watershed plan constitute the remaining 9 percent of the total capital costs, being about 1 and 8 percent of the total capital costs, respectively.

Preliminary Capital Improvement Program

The preliminary capital improvement program includes the staging of the necessary land acquisition and facility construction and the distribution of the attendant costs, including operation and maintenance expenditures, over a 22-year plan implementation period. An expenditure program for the floodland management and water quality management plan elements is presented in summary form for the watershed as a whole in Table 83. This table sets forth the land acquisition and construction costs and estimated operation and maintenance expenditures by year associated with implementation of the recommended plan elements of the Kinnickinnic River watershed planning program, consisting of the floodland management element and one water quality management subelement. The ultimate adoption of capital improvement programs for implementation of the watershed plan will require determination by the responsible public officials not only of those plan subelements which are to be implemented and the timing of such implementation but of the principal beneficiaries and best available means of financing.

The preliminary schedule of capital and operation and maintenance costs set forth in Table 83 is based on 1977 costs for land acquisition, facility construction, and operation and maintenance. The use of present land acquisition, facility construction, and operation and maintenance costs in the schedule of future expenditures is sound since, in the event that costs increase or decrease as a result of general price inflation or deflation, the corresponding revenues available to units of government should also increase or decrease in an approximately proportional manner and thus the relative magnitude of scheduled costs and anticipated revenues is likely to be maintained. That is, if the schedule of capital and operation and maintenance costs, as set forth in Table 83, appears reasonable and achievable in the light of the present cost and revenue situation, it is likely to be equally reasonable and achievable under future cost and revenue situations.

The full capital investment and operation and maintenance costs of implementing the recommended comprehensive plan for the Kinnickinnic River watershed are estimated at $9.1 million over the 22-year plan implementation period. Of this full cost, about $3.9 million, or about 42 percent, is required for implementation of the recommended floodland management element including recommended detention storage, channel realignment channel enclosure, and the operation of a stream gaging network. The remaining $5.2 million, or about 58 percent, of the implementation cost is required for implementation of the recommended diffuse source pollution control measures.

The average annual cost of the total capital investment and operation and maintenance cost required for plan implementation may be expected to approximate $413,500, or about $2.54 per capita per year, over the 22-year plan implementation period. This per capita cost is based on a resident watershed population of 162,500 persons, equal to the anticipated average resident population of the watershed between the 1975 population level of 165,000 persons and the anticipated year 2000 population level of 160,000 persons. The average annual costs of implementation of the floodland management plan element and the water quality management plan element are estimated to total, respectively, about $175,700, or $1.08 per capita per year; and $237,800, or $1.46 per capita per year.

Comparison of Plan Costs to Selected Recent Public Expenditures

In order to assess the possible impact of implementation of the watershed plan on the public financial resources of local units of government within the watershed, recent public expenditures for major channel works by the Milwaukee-Metropolitan Sewerage Commissions and the City of Milwaukee were used as an index of the ability of local units of government to expend the funds necessary to implement the structural flood control measures contained with the recommended floodland management plan element of the watershed plan.

Analysis of Recent Channel Improvement Expenditures:

Capital expenditures for channel modifications within the Kinnickinnic River watershed for the 18-year period from 1960 through 1977 were obtained from the Milwaukee-Metropolitan Sewerage Commissions and the City of Milwaukee. These public capital expenditures relate to major channel modifications carried out on portions of Lyons Park Creek, Wilson Park Creek, and the main stem of the Kinnickinnic River during that 18-year period, and were considered to be a good index of recent flood control expenditures within the watershed. The channel modification expenditures for the watershed as set forth in Table 84 indicate that over the 18-year period, a total of approximately $8.0 million was expended on channel improvements in the watershed, or an average of approximaterly $450,000 per year.

Table 83

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE PRELIMINARY RECOMMENDED FLOODLAND MANAGEMENT AND WATER QUALITY MANAGEMENT PLAN ELEMENTS BY YEAR: 1979-2000

		Floodland Management Element						Water Quality Management Element			
		Committed Channel Modifications[a]		Recommended Structural Flood Damage Abatement Measures for the City of Cudahy				Diffuse Source Pollution Control Measures			
Calendar Year	Project Year	Construction	Operation and Maintenance	Construction	Operation and Maintenance	Operation and Maintenance of Continuous Recorder Gage	Subtotal	Capital	Operation and Maintenance	Subtotal	Total
1978[b]	0	$ 813,000[c]	$ –	$ –	$ –	$ –	$ –	$ –	$ –	$ –	$ –
1979	1	1,213,000	750	486,400	1,150	3,200	1,704,500	42,000	232,500	274,500	1,979,000
1980	2	578,000	1,500	486,400	2,300	3,200	1,071,400	42,000	232,500	274,500	1,345,900
1981	3	460,000	2,250	–	2,300	3,200	467,750	42,000	232,500	274,500	742,250
1982	4	460,000	3,000	–	2,300	3,200	468,500	42,000	232,500	274,500	743,000
1983	5	–	3,000	–	2,300	3,200	8,500	42,000	232,500	274,500	283,000
1984	6	–	3,000	–	2,300	3,200	8,500	42,000	232,500	274,500	283,000
1985	7	–	3,000	–	2,300	3,200	8,500	42,000	232,500	274,500	283,000
1986	8	–	3,000	–	2,300	3,200	8,500	71,000	237,600	308,600	317,100
1987	9	–	3,000	–	2,300	3,200	8,500	71,000	237,600	308,600	317,100
1988	10	–	3,000	–	2,300	3,200	8,500	71,000	237,600	308,600	317,100
1989	11	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1990	12	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1991	13	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1992	14	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1993	15	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1994	16	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1995	17	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1996	18	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1997	19	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1998	20	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
1999	21	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
2000	22	–	3,000	–	2,300	3,200	8,500	71,000	127,600	198,600	207,100
Total		$2,711,000	$61,500	$972,800	$49,450	$70,400	$3,865,150	$1,359,000	$3,871,500	$5,230,500	$9,095,650
22-Year Annual Average		$ 123,200	$ 2,800	$ 44,220	$ 2,250	$ 3,200	$ 175,700	$ 61,750	$ 176,000	$ 237,800	$ 413,500

[a] *Schedule based on completion of the modifications on the Kinnickinnic River between S. 5th Street extended to S. 16th Street by the year 1980, and completion of the ultimate improvements on Wilson Park Creek between W. Euclid Avenue and S. 6th Street within a three-year period ending in 1982.*

[b] *Included to show costs already incurred.*

[c] *Not included in totals.*

Source: SEWRPC

As shown in Table 83, the estimated total capital cost of implementing the floodland management element of the Kinnickinnic River watershed plan is $3.9 million with the entire capital cost being assigned to structural measures such as channel enclosure, detention storage, and channel realignment. The $3.9 million capital cost for structural measures is recommended to be expended during an intensive four-year implementation phase, or about $920,000 per year. Therefore it may be anticipated that sufficient funds should be available to construct the recommended structural flood control works.

Concluding Statement: The cost analysis conducted under the Kinnickinnic River watershed program does not include a comparison of costs associated with implementing the land use plan element and recent park and outdoor recreation expenditures, nor does it include a comparison of costs associated with implementing the water quality management plan element and recent public expenditures for pollution abatement. The land use plan subelements recommended under the Kinnickinnic River watershed planning program are contained within the adopted land use plan and the adopted regional park and open space plan and, under those planning programs, analyses of recent expenditures for public park and outdoor recreation pruposes were conducted which demonstrated that sufficient funds may be expected to be available for plan implementation. Most of the water quality management subelements recommended under this watershed planning program

Table 84

CHANNEL MODIFICATION CAPITAL EXPENDITURES BY THE MILWAUKEE-METROPOLITAN SEWERAGE COMMISSIONS AND THE CITY OF MILWAUKEE IN THE KINNICKINNIC RIVER WATERSHED: 1960-1977

Year	Expenditures in Thousands of Dollars			
	Lyons Park Creek	Wilson Park Creek	Kinnickinnic River	Total
1960	–	351	128	479
1961	–	4	434	438
1962	–	(5)[a]	287	282
1963	–	4	566	570
1964	36	7	801	844
1965	82	192	136	410
1966	–	210	415	625
1967	6	43	177	226
1968	–	7	14	21
1969	52	35	–	87
1970	–	36	–	36
1971	27	701	–	728
1972	–	82	–	82
1973	–	183	–	183
1974	–	2,656	–	2,656
1975	–	344	–	344
1976	–	2	7	9
1977	N/A	–	24	24
Total	203	4,852	2,989	8,044
Annual Average	11	270	166	447

NOTE: N/A indicates data not available.

[a] *Reflects a negative expense since reimbursement results when more work was completed than contract required.*

Source: Milwaukee-Metropolitan Sewerage Commissions and City of Milwaukee

were previously recommended under the adopted regional sanitary sewerage system plan and, under that planning program, analyses were conducted which demonstrated that sufficient funds would be available to implement the recommended pollution abatement measures.

From the foregoing discussion, it is fair to conclude that sufficient monies to implement substantially the recommended land use plan element, the floodland management plan element, and the water quality management plan element of the comprehensive Kinnickinnic River watershed plan should become available within the watershed under continuation of the historic rate of expenditures. The cost of implementing the watershed plan over the 22-year plan implementation period would be reasonably achievable by continuing the approximate current public expenditure patterns for park and outdoor recreation purposes, flood control, and pollution abatement.[4] It is clear that if the adopted watershed development objectives and standards are to be met, and if the associated desired environmental quality within the watershed is to be achieved and maintained, the level of expenditures needed to implement the recommended watershed plan is necessary and fully warranted.

THE ABILITY OF THE RECOMMENDED COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED TO MEET ADOPTED OBJECTIVES AND STANDARDS

The watershed development objectives and supporting standards were formulated early in the Kinnickinnic River watershed study as the second step in a seven-step planning process, and constitute the overall goals of the comprehensive plan. The objectives and standards established for the Kinnickinnic River watershed planning program consist of objectives and standards adopted under related areawide land use and water pollution abatement planning programs, supplemented with objectives and standards developed under the Kinnickinnic River watershed planning program. The adopted watershed development objectives have been translated into adopted detailed design standards in order to provide the basis for plan preparation, test, and evaluation. It is appropriate to determine how well the recommended comprehensive plan for the watershed meets these adopted objectives and standards. Accordingly, an evaluation of the comprehensive plan was made on the basis of its ability to meet the watershed development objectives and standards. The results of that evaluation are presented in summary form in Table 85.

The relatively small number of standards that could not be met or would be only partially met under the recommended comprehensive plan for the Kinnickinnic River watershed, as indicated in Table 85, support objectives that are inextricably related to the underlying natural base. The failure to meet those standards reflects the already deteriorated condition of the natural resource base of this highly urbanized watershed. As discussed in detail in Chapter III, it appears impractical to fully achieve some of the standards because the necessary natural resource base elements are no longer present in sufficient quantity and quality. Adoption and implementation of the recommended watershed plan could, however, result in substantial attainment of the adopted watershed development objectives and standards and,

[4]*It should be noted that this evaluation does not take into account the outcome of the judgment and appeal pending in Federal Courts against the City of Milwaukee, the Sewerage Commission of the City of Milwaukee, and the Metropolitan Sewerage Commission of the County of Milwaukee as a result of the lawsuit brought by the State of Illinois, which could significantly affect the costs associated with the recommended abatement of combined and separate sewer overflows.*

Table 85

ABILITY OF THE RECOMMENDED COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED TO MEET ADOPTED OBJECTIVES AND STANDARDS

Land Use Objectives

Objective Number	Objective Description	Standard		Degree to Which Standard is Met	Comments
1	A balanced allocation of space to the various land use categories which meets the social, physical, and economic needs of the regional population	Residential land allocation			Although a net decrease in population occurs, some migratory movement into as well as within the watershed can be expected to occur. This standard is met where population increases occur
			Suburban—429 net acres/1,000 added persons	Met[a]	
			Low-density urban—238 net acres/1,000 added persons	Met[a]	
			Medium-density—65 net acres/1,000 added persons	Met[a]	
			High-density—25 net acres/1,000 added persons	Met[a]	
		Park and recreation land allocation	14 gross acres/1,000 added population	Met[a]	Planning Report No. 27 presents an in-depth study of park objectives
		Industrial land allocation	7 net acres/100 added employees	Partially met	Future employees will occupy some existing land
		Commercial land allocation	3 net acres/100 added employees	Partially met	
		Government and institutional land allocation	9 net acres/1,000 added population	Met[a]	–
2	A spatial distribution of the various land uses which will result in a compatible arrangement of land uses	Neighborhood units for urban high-, medium-, and low-density residential development		Could be met[b]	–
		Suburban and rural residential land location		Met	–
		Industrial land location		Met	–
		Regional commercial land location		Met	–
3	A spatial distribution of the various land uses which will result in the protection and wise use of the natural resources of the Region, including its soils, inland lakes and streams, wetlands, woodlands, and wildlife	Soils	Sewered urban development	Met[a]	–
			Unsewered suburban development	Met[a]	–
			Rural development	Met[a]	–
		Inland lakes and streams	25 percent of shoreline of major inland lakes in natural state	Not applicable	The watershed does, however, contain seven artificial ponds ranging from 0.33-8.82 acres. These are not considered inland lakes
			50 percent of shoreline of major inland lakes in nonurban use	Not applicable	
			10 percent of shoreline of major inland lakes in public use	Not applicable	
			25 percent of shoreline of minor inland lakes in natural state	Not applicable	
			25 percent of shoreline of perennial streams in natural state	Not met	Requires 4.5 miles natural; only about 2 miles
			50 percent of shoreline of perennial streams in nonurban use	Not met	Requires 9 miles; only about seven existing
			Floodlands free from new incompatible urban development	Met	–
			Restrict encroachments in channels and floodways	Met	–
		Wetlands	Protect wetlands over 50 acres and those with high resource values	Not applicable	–
		Woodlands	Protect 10 percent of watershed	Met	–
			Preserve 40 acres each per county of four forest types	Could be met[b]	–
			Maintain five acres/1,000 regional population	Partially met	–
		Wildlife	Maintain a wholesome habitat	Met	–

Table 85 (continued)

Land Use Objectives

Objective Number	Objective Description	Standard	Degree to Which Standard is Met	Comments
4	A spatial distribution of the various land uses which is properly related to the supporting transportation, utility, and public facility systems in in order to assure the economical provision of transportation, utility, and municipal services	Maximize use of existing transportation and utility facilities	Met[a]	–
		Transportation systems to provide access to urban areas	Could be met	–
		Sewer service to residential areas	Met[a]	–
		Water supply to residential areas	Met[a]	–
		Residential land serviceable by mass transit facilities	Met	–
		Minimize penetration by major transportation routes of residential neighborhood units	Could be met[b]	–
		Locate transportation terminal facilities near principal land uses served	Could be met[b]	–
5	The development and conservation of residential areas within a physical environment that is healthy, safe, convenient, and attractive	Locate residential development in physically self-contained neighborhood units	Could be met[b]	–
		Locate appropriate land uses within neighborhood units	Could be met[b]	–
		Locate suburban and rural residential development properly to environment	Met	–
6	The preservation, development, and redevelopment of a variety of suitable industrial and commercial sites both in terms of physical characteristics and location	Regional industrial site requirements	Not applicable	No new regional sites proposed for Kinnickinnic River watershed
		Regional commercial site requirements	Not applicable	
		Local industrial site requirements	Could be met[b]	
		Local commercial site requirements	Could be met[b]	
7	The preservation and provision of open space to enhance the total quality of the regional environment, maximize essential natural resource availability, give form and structure to urban development, and facilitate the ultimate attainment of a balanced year-round outdoor recreational program providing a full range of facilities for all age groups	Local park spacial location	Could be met[b]	–
		Regional park spacial location	Met	–
		Areas of scientific, cultural scientific, and educational value	Met	–

Sanitary Sewerage System Objectives

Objective Number	Objective Description	Standard	Degree to Which Standard is Met	Comments
1	The development of sanitary sewerage systems which will effectively serve the existing regional urban development pattern and promote implementation of the regional land use plan, meeting the anticipated sanitary waste disposal demand generated by the existing proposed land uses	Sanitary sewer service to medium- and high-density urban development	Met[a]	Entire watershed presently served by public sanitary sewer facilities
		Sanitary sewer service to low-density urban development	Not applicable	Plan does not contain significant low-density area
		Sanitary sewer service in poor soil areas	Met[a]	–
		Sanitary sewer service not provided to undeveloped primary environmental corridor lands	Met[a]	–
		Sanitary sewer service not provided to floodlands	Met[a]	–
		Sanitary sewer service restricted in areas of soils with very severe limitations for urban development	Not applicable	Entire watershed presently served by public sanitary sewer facilities
		Orderly extension of sanitary sewerage facilities	Not applicable	
		Sizing of sewerage facility components in accordance with land use plan	Met	–
		Treatment and disposal of industrial wastes	Met	–
2	The development of sanitary sewerage systems that meet established water use objectives and supporting water quality standards	Level of treatment at sewage treatment plant	Not applicable	–
		Sewage treatment plant discharges	Not applicable	–
		Standards for sewage treatment at plants	Not applicable	–
		Existing sewage treatment plants scheduled to be abandoned	Not applicable	–
		Interim sewage treatment plants to be constructed	Not applicable	–
		Bypassing sewage to storm sewer systems, stream, and so forth	Could be met	–
		Combined sewer overflows	Could be met	–
		The design of sewage treatment plants	Not applicable	–

Table 85 (continued)

Sanitary Sewer System Objectives

Objective Number	Objective Description	Standard	Degree to Which Standard is Met	Comments
3	The development of sanitary sewerage systems that are properly related to, and enhance the overall quality of the natural and man-made environments	New and replacement location of sewage treatment plants outside of 100-year floodplain	Not applicable	–
		Floodproofing sewage treatment plants located in 100-year floodplain	Not applicable	–
		Location of new and replacement sewage treatment plants relating to proposed urban development	Not applicable	–
		Sewage treatment plant sites to supply adequate open space	Not applicable	–
		Disposal of sludge from sewage treatment plants	Not applicable	–
4	The development of sanitary sewerage systems that are both economical and efficient, meeting all other objectives at the lowest cost possible	Minimize investment and operating costs of sanitary sewerage systems	Could be met	–
		Minimize number of sanitary sewerage systems and sewage treatment facilities	Met	–
		Maximize feasible use of sanitary sewerage facilities	Met	–
		Use of new and improved materials and management practices	Could be met	–
		Staged or incremental construction of sanitary sewerage facilities	Not applicable	–
		Minimize land acquisition costs for new sewer construction	Not applicable	–
		Minimize clear water inflows and infiltrated into sanitary sewerage system	Could be met	–
		Integrated design of sanitary and storm sewer systems	Could be met	–

Park and Open Space Objectives

Objective Number	Objective Description	Standard	Degree to Which Standard is Met	Comments
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	Sufficient recreation sites to meet the recreation demand of population: Regional	Not applicable	–
		Multi-Community, Community, Neighborhood	Partially met	Maximum service radius standard met, minimum per capita public requirement partially met
		Recreation sites located within corridors	Met	–
		Linear recreation corridor requirement	Not applicable	Regional basis only
		Recreation corridor dimensions	Partially met	–
		Travel distance to recreation corridors	Met	–
		Resource-oriented recreation corridors	Met	–
2	The preservation of sufficient high-quality open space lands for protection of the underlying and sustaining natural resource base and enhancement of the social and economic well being and environmental quality of the Region	Preserve all remaining nonurban lands within corridors	Met	Corridor contains all urban lands
		Preserve all prime agricultural lands	Not applicable	No prime agricultural lands in watershed
		Preserve agricultural lands adjoining recreation or educational sites	Not applicable	Insignificant agricultural lands remaining
3	The efficient and economical satisfaction of outdoor recreation and related open space needs, meeting all other objectives at the lowest possible cost	Minimize the total of all expenditures required to meet park demands and open space needs	Met	–

Table 85 (continued)

Water Control Objectives

Objective		Standard	Degree to Which Standard is Met	Comments
Number	Description			
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 watershed land use plan, meeting the anticipated runoff loadings generated by the existing and proposed land uses	New and replacement bridges and culverts: Minor streets—pass the 10-year flood	Met	–
		Arterial streets and highways—pass the 50-year flood	Met	–
		Freeways and expressways—pass the 100-year flood	Met	–
		Railroads—pass the 100-year flood	Met	–
		New or replacement bridges and culverts shall pass the 100-year flood without reaching the peak stage more than 0.1 foot	Met	–
		Structure design shall maximize passage of ice flow and debris	Met	–
		Certain new and replacement bridges and culverts shall pass the 100-year flood with 2.0 feet of free board	Met	–
		Existing bridges and culverts to meet standards 1, 3, and 4 above	Met	
		Channel improvements should be restricted to the absolute minimum necessary	Met	–
		The height of dikes and floodwalls shall pass the 100-year flood with 2.0 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 shall accommodate the 100-year flood	Met	–
		Public land acquisition to eliminate water control facilities shall encompass the entire 100-year floodplain	Met	–
		Regulatory floodways shall 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 concept	Could be met	–
2	An integrated system of land management and water quality control facilities and pollution abatement devices adequate to assure a quality of surface water necessary to meet the desired uses	Satisfy established water quality standards	Could be met	–
		Low flow criteria are basis for evaluating conformance with water quality standards	Not applicable	–

[a] *This standard has been met under the recommended land use and/or regional sanitary sewerage system plan because it served as an input to the plan design process.*

[b] *This standard could be met only by local community action.*

thus, implementation of the plan may be expected to provide a safer, more healthful, and more pleasant as well as a more orderly and efficient, environment for all life within the watershed.

CONSEQUENCES OF NOT IMPLEMENTING THE RECOMMENDED COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED

Within the framework of the overriding goals of the Kinnickinnic River watershed planning program—that is, the adopted objectives and standards—it is likely that the recommended comprehensive plan for the basin approaches the optimum or best combination of measures for: 1) resolving the water resource and water resource-related problems such as flooding, water pollution, diminishing quality of the natural resource base, and changing land use that presently plague the Kinnickinnic River watershed; and 2) preventing aggravation of the existing problems or the development of new environmental problems within the basin. This is believed to be so because preparation of the recommended comprehensive plan for the Kinnickinnic River watershed involved the conduct of extensive inventories; application of state-of-the-art analytic tools; exhaustive examination of alternative subelements and careful evaluation of the technical, economic, and environmental impacts of each; preparation of a plan implementation strategy and capital and operation and maintenance expenditure schedule; careful consideration of public views and concerns through public informational meetings and hearings; and several years of deliberation by the Kinnickinnic River Watershed Committee, a Committee comprised of knowledgeable and concerned citizens and public officials.

In the absence of a sound comprehensive watershed plan, a multitude of incorrect decisions are likely to be made and courses of action are likely to be followed that will lead to the aggravation of existing water resource and water resource-related problems as well as to the development of new problems. Because the comprehensive plan for the Kinnickinnic River watershed seeks to identify those courses of action most likely to result in the rational, most cost-effective, and lasting solutions to the water resource and water resource-related problems of the watershed and the prevention of future problems, it is appropriate to identify and, where feasible, to quantify the consequence of not adopting and implementing the recommendations contained within the comprehensive plan for the Kinnickinnic River watershed. The analysis of the consequences of not adopting and implementing the watershed plan has a negative aspect in that it identifies water resource and water resource-related problems that may be expected to occur or be aggravated within the watershed in the absence of watershed plan implementation. The analysis is positive or constructive, however, in that it is intended to support and reinforce the need for implementation of the recommended rational, long-range, comprehensive plan for the urban watershed.

The analysis of the likely consequences of not implementing the recommended comprehensive plan for the Kinnickinnic River watershed is based primarily on two sources of information: 1) the data collected and the analyses conducted under the Kinnickinnic River watershed planning program, and 2) empirical information derived from observation of water resource and water resource-related problems that already exist within the seven-county planning Region and which have been the subject of other Commission plan and plan implementation activities. The likely consequences of not implementing the recommended comprehensive plan for the Kinnickinnic River watershed are summarized in Table 86. Within the overall framework of the three basic plan elements—the land use plan element, the floodland management plan element, and the water quality plan element—Table 86 identifies each plan subelement and some likely negative consequences of failure to implement those subelements.

Land Use Plan Element

By the year 2000, about 25 square miles, or about 96 percent, of the total area of the watershed are expected to be urbanized. This new development would be located within public utility service areas, since the entire watershed is already served by public sanitary sewerage facilities and by public water supply facilities, as well as by electric power and gas facilities. Thus, in the absence of implementation of an overall land use plan, there is not the problem of uncontrolled urbanization as in certain other watersheds of the Region. However, if the park and open space subelement of preservation, acquisition, and development of open spaces is not implemented, those natural resource amenities remaining within the watershed and affecting the quality of life in this basin would be lost. In addition, the quantity of outdoor recreation facilities and related park and recreation areas would not meet the probable future demand for recreational activities.

Floodland Management Element

The primary floodland management element of the Kinnickinnic River watershed plan consists of structural flood control measures recommended to be constructed in the Cities of Cudahy and Milwaukee. Failure to implement the recommended measures in the City of Cudahy would mean continuation of average flood damage risks of $47,000 per year, and as a result of a 100-year recurrence interval flood event occurring under existing land use-floodland development conditions, about $240,000 of flood damages could be expected to be incurred in the City of Cudahy. Failure to construct those channel improvements and bridge alterations described above as committed channel modifications would mean the continuation of average annual flood damage risks on the order of $660,000 along the Kinnickinnic River between S. 6th Street and S. 16th Street, and on the order of $20,000 along Wilson Park Creek between W. Euclid Avenue and W. Layton Avenue in the City of Milwaukee. In addition, flooding resulting from failure to construct

Table 86

PROBABLE CONSEQUENCES OF NOT IMPLEMENTING THE RECOMMENDED COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED

Plan Element	Plan Subelement	Probable Negative Consequences of Failure to Implement Plan Recommendations
Land Use	Overall Land Use Plan	Essentially all of the negative consequences discussed below, since most are inextricably related to the land use plan
	Park and Open Space Plan	Loss of recreational, aesthetic, and cultural values found in park and open space lands Lack of recreation land to meet the demand which will result as leisure time increases, as well as, environmental awareness of residents
Floodland Management	Committed Flood Control Measures for the Kinnickinnic River and Wilson Park Creek in the City of Milwaukee	Continuation of average annual flood damage risk of about $700,000 or more under existing conditions Accumulation of about $8.8 million damages during a 100-year recurrence interval flood event under existing conditions
	Flood Control Measures for Wilson Park Creek—Edgerton Channel in the City of Cudahy	Continuation of average annual flood damage risk of $47,000 or more under existing conditions Accumulation of about $240,000 worth of damages during a 100-year recurrence interval flood event under existing conditions Continuation of aesthetic and health hazard problems associated with a portion of the channel
	Bridge Replacement for Transportation Purposes	Interference with operation of highway and railroad facilities during flood events
	Floodland Regulations	Increased flood losses due to construction of new flood-prone structures Aggravation of flood problems due to loss of conveyance and storage Loss of portions of the environmental corridor
	Channel Maintenance	Serious flooding or storm water inundation problems
	Flood Insurance	Large monetary losses absorbed by owners of flood-prone structures and property
	Lending Institution and Realtor Policies	Aquisition of flood-prone lands and structures by unwary buyers
	Community Utility Policies	Tacit approval of urban development in flood-prone lands and in primary environmental corridors
	Emergency Procedures	Damage to property and risk to property owners due to inadequate information about floods already in progress
	Stream Gaging Network	Lack of critical flow data on actual flood events for use in monitoring the effects of changes in the watershed and in eventually refining simulation models
Water Quality Management	Combined Sewer Overflow Abatement[a]	Continuation of combined sewer overflows to the 4.9-mile-long portion of the Kinnickinnic River downstream of S. 27th Street with resultant inorganic, organic, nutrient, pathogenic, and aesthetic pollution
	Sanitary Sewer Flow Relief Device Abatement[a]	Localized public health hazards and objectionable instream aesthetic conditions
	Industrial Discharge Abatement	Localized pollution problems
	Urban and Rural Diffuse Source Pollution Control Measures	Continued watershedwide surface water quality degradation during and immediately after runoff events

[a] *Recommended in the adopted regional sanitary sewerage system planning program and endorsed under the Kinnickinnic River watershed planning program.*

Source: SEWRPC

the committed modifications would constitute a widespread problem especially aggravating to the flood-prone residents, since solutions had been identified but not implemented.

If the bridge replacement recommendations—for transportation purposes—are not carried out during the plan design period, a continued and increased interference with the safe and efficient operation of highway and railroad facilities during flood events may be expected. Failure to implement the recommended floodland regulations and other land use controls may be expected to cause increased monetary flood losses due to construction of flood-prone structures; aggravation of upstream and downstream flood problems due to loss of conveyance and storage; and loss of portions of the primary environmental corridors.

If watershed residents do not avail themselves of the opportunity to acquire flood insurance available under the federal program, the monetary losses resulting from future floods will have to be absorbed entirely by owners of flood-prone structures and property, particularly since one of the objectives of the insurance program is to eliminate federally funded disaster relief in the event of flooding. Failure to continue the desirable lending institution and realtor policies concerning informing prospective purchasers of the flood vulnerability of riverine area land and structures will result in acquisition of flood-prone lands and structures by unwary buyers.

The failure of the individual communities to adopt utility policies in conformance with the floodland management element of the watershed plan may be expected to be interpreted as tacit public approval of urban development in flood-prone lands and in primary environmental corridors. If watershed communities with serious flood problems do not adopt emergency procedures to be invoked during such floods, the likely consequences are unnecessary damage to property as well as unnecessary risk to the safety and well being of property owners.

Failure to implement the stream gaging recommendations contained within the plan will forego the opportunity to monitor the effects of future changes in the watershed on the stream flow regimen and to ultimately refine the simulation modeling for future design applications of various kinds within the watershed. Long-term stream gaging records provide the best possible basis for water resources management efforts which require definitive knowledge of stream flows and the variations of those flows over time.

Water Quality Management Element

The principal negative effect of failure to implement the recommended combined sewer overflow abatement measures will be to continue to subject the lower approximately five-mile reach of the Kinnickinnic River to combined sewer overflows and the resultant inorganic, organic, nutrient, pathogenic, and aesthetic pollution. Failure to resolve the sanitary sewer flow relief device problem within the Kinnickinnic River watershed will present localized public health hazards and objectionable instream aesthetic conditions. Similarly, failure to mitigate the discharge of industrial waste directly or indirectly to the surface water system within the watershed may result in localized pollution problems. Watershedwide surface water quality degradation will continue during and immediately after runoff events if the recommended measures for the control of diffuse source pollution are not implemented.

PUBLIC REACTION TO THE RECOMMENDED PLAN AND SUBSEQUENT ACTION OF THE KINNICKINNIC RIVER WATERSHED COMMITTEE

As an integral part of the watershed planning program, a formal public hearing was held upon the completion of a preliminary plan for the watershed.[5] The hearing was conducted on behalf of the Regional Planning Commission by the Kinnickinnic River Watershed Committee with the Chairman of the Watershed Committee presiding. The purpose of the hearing was to present the preliminary findings and recommendations of the watershed planning program for review and consideration by public officials and interested citizens. The hearing was announced through news releases sent to all local radio and television stations and to all daily and weekly newspapers in circulation within the watershed, through the mailing of a notification of the hearing to a list of interested officials and citizens, and through publication and widespread distribution of a Commission Newsletter summarizing the preliminary findings and recommendations of the watershed study.[6] The hearing was held at 7:30 p.m. on October 12, 1978 at the Pulaski Senior High School, a central location in the watershed well served by public transit as well as by highway transportation facilities.

Minutes of the public hearing were published by the Commission and provided to both the Kinnickinnic River Watershed Committee and the Regional Planning Commission for review and consideration prior to final adoption of the recommended plan[7]. The minutes of the public hearing contain a complete record of all comments made at the hearing by the public officials and interested private citizens on the recommended preliminary plan, together with any written comments submitted at or after the hearing.

The record of the proceedings of the public hearing indicates that public reaction was generally quite favorable to the recommended preliminary plan, although opposition to the specific flood control alternatives initially selected for the Edgerton Channel in the City of Cudahy was expressed. This opposition centered on the inclusion in the plan of a flood detention reservoir located east of Whitnall Avenue on lands committed by the City of Cudahy to industrial development and the provision of attendant open drainage channel as well as closed drainage conduit facilities. The Mayor of the City of Cudahy had arranged to have the Commission staff brief the Board of Public Works on the preliminary plan recommendations at a meeting of the Committee held on October 2, 1978. Based on the lengthy discussion and deliberations at that meeting, the City formulated its formal position for presentation at the hearing. More

[5]*On March 9, 1977, prior to initiation of the watershed planning program, a public hearing was held by the Watershed Committee to elicit public opinions concerning the need for, objectives of, and scope and content of the proposed study. Testimony presented at that hearing was published by the Commission as Minutes of Initial Public Hearing on the Kinnickinnic River Watershed Study. This testimony reinforced the findings of the Watershed Committee that flooding and pollution were the two problems of greatest concern to the residents of the watershed. With respect to flooding, testimony by City of Cudahy officials and citizens directed attention to the Edgerton Channel as well as to Wilson Park Creek and the main stem of the Kinnickinnic River. In response to the testimony, the scope of the study was broadened to include consideration of the flood problems existing along the Edgerton Ditch.*

[6]*See SEWRPC Newsletter, Vol. 18, No. 4, July-August 1978.*

[7]*See Minutes of Public Hearing on the Comprehensive Plan for the Kinnickinnic River Watershed.*

specifically, as documented in the proceedings of the hearing and as discussed at the October 2, 1978 meeting of the City of Cudahy Board of Public Works, the City objected to the recommended use for floodwater detention reservoir purposes of land proposed for industrial use in local plans and zoning with attendant potential loss of property tax base, property and other tax revenues, and jobs; objected to the provision of open drainage channels in areas where such channels had proven to be a hazard to the health and safety of residents, particularly children, as well as an aesthetic nuisance; and noted that because of the industrial character of the area in which the reservoir was proposed to be located, no significant park and recreation benefits nor land value enhancement could be expected to be attendant to the reservoir. Finally, the City questioned the practicality of constructing unlined open channels. In response to these comments by the City of Cudahy, the Commission staff proposed an additional alternative plan for the abatement of the flooding problems which exist along the Edgerton Channel for presentation to the Watershed Committee together with an evaluation of the technical, economic and financial aspects of that alternative. As described below, the additional alternative eliminated the detention reservoir and placed the entire Channel from S. Whitnall Avenue to General Mitchell Field in a box culvert.

Reconsideration of Flood Control Recommendations for the Edgerton Channel in the City of Cudahy

As described in Chapter XII of this report, nine alternative proposals were originally evaluated as possible means of resolving existing and probable future flood problems along that reach of Wilson Park Creek between S. Whitnall Avenue and the Chicago & North Western Railway right-of-way, locally known as the Edgerton Channel. These alternative solutions were no action, floodwater diversion, structure floodproofing and elevating, major channelization, major channelization-channel enclosure composite, dikes and floodwalls, detention storage, detention storage-channel enclosure-bridge alteration composite, and bridge and culvert alteration or replacement. Based on evaluation of these nine alternatives, it was initially recommended that flood damage relief be achieved by the detention storage-channel enclosure-bridge alteration composite shown on Map 56. As described earlier in this chapter, this alternative was revised at the request of the City of Cudahy to include realignment of the channel between the outlet of the proposed channel enclosure and the western city limits. The estimated capital cost of the recommended alternative was $945,200 and the equivalent average annual cost, utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, was estimated at $62,000. The recommended solution to the existing and forecast flood problems thus had a benefit cost ratio of 1.5 and an excess of benefits over cost of $31,500.

Channel Enclosure Alternative: Based on comments by City officials and citizens at the public hearing, it was the consensus that any additional flood control alternative should consist primarily of channel enclosure. Therefore, the Commission staff and Watershed Committee conducted a technical, economic, and financial evaluation of an additional floodland management alternative for the Edgerton Channel consisting of about 0.8 mile of channel enclosure from S. Whitnall Avenue through the Chicago & North Western Railway right-of-way to the existing improved channel in General Mitchell Field near the westerly limits of the City, as shown on Map 57.

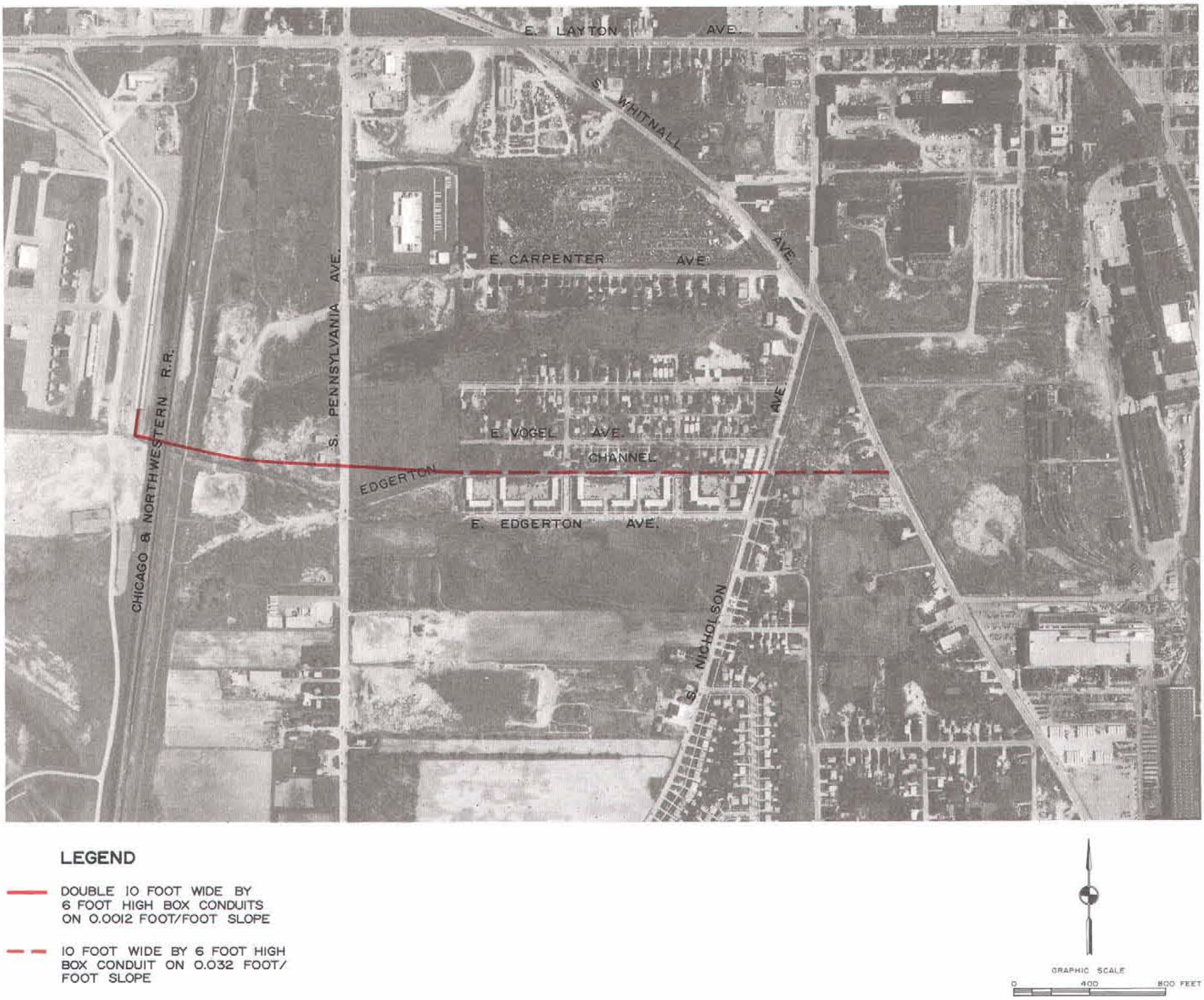
The channel enclosure alternative would consist of a single reinforced concrete box culvert approximately 10 feet wide and 6 feet deep constructed between S. Whitnall Avenue and a point approximately 1,600 feet downstream from S. Nicholson Avenue. At that point, a transition would be made to a double concrete box culvert, each box being approximately 10 feet wide and 6 feet deep, which would extend downstream to join the existing improved channel in General Mitchell Field. The final sizes of these conduits would be determined by the Milwaukee-Metropolitan Sewerage Commission, which would be responsible for the design, construction, and maintenance of the improvements included in this alternative in accordance with its established policies and practices.

Utilizing an interest rate of 6 percent and a project life and amortization period of 50 years, the equivalent average annual cost of this alternative is estimated at about $133,300 consisting of $132,800 per year for amortization of the $2,094,000 capital cost for channel enclosure and $500 per year for operation and maintenance. The average annual flood abatement benefit along the Edgerton Channel in the City of Cudahy is estimated at $93,500, yielding a benefit cost ratio of 0.7 and an excess of annual costs over benefits of about $39,800.

Additional Considerations Concerning the Recommended Detention Storage-Channel Enclosure-Channel Realignment Alternative: It should be noted that under the channel design policy as indicated by past practice of the Milwaukee-Metropolitan Sewerage Commissions, open earth-lined channels would not be constructed. For erosion control and maintenance reasons, the Sewerage Commissions' design policy calls for concrete lining of the bottom and lower portion of channel sidewalls for all channels constructed under their jurisdicition. As much as the originally recommended alternative includes the construction of the new channel downstream of the channel enclosure along an alignment consistent with local planning and zoning and past land acquisition, the construction of such a channel by the Milwaukee-Metropolitan Sewerage Commissions would necessitate the use of a concrete lining. In addition, it may be expected that the reach upstream of S. Nicholson Avenue to S. Whitnall Avenue would also be improved by the Sewerage Commissions with paving of the channel bottom and sidewalls. The additional capital cost for construction of a concrete lining in these reaches is estimated at about $232,000, thus increasing the total capital cost of the originally recommended alternative to about $1,177,200, and reducing the benefit cost ratio to 1.2 with an excess of annual benefits over cost of about $16,800.

Map 57

CHANNEL ENCLOSURE ALONG THE EDGERTON CHANNEL IN THE CITY OF CUDAHY



In response to suggestions made at the public hearing, enclosure of the Edgerton Channel along the entire length from S. Whitnall Avenue to General Mitchell Field was evaluated as another potential means of resolving flood problems in this reach. Based on the considerable intangible benefits associated with this alternative in addition to the technical and economic aspects, the Watershed Committee recommended that this channel enclosure alternative be incorporated into the comprehensive watershed plans.

Source: SEWRPC.

Action of the Kinnickinnic River Watershed Committee: After due consideration of the various technical and economic features and other aspects of the 10 alternatives considered, including the channel enclosure alternative prepared as a result of the public hearing on the preliminary plan, the Kinnickinnic River Watershed Committee recommended that the channel enclosure alternative be incorporated, as described above, into the recommended comprehensive watershed plan to resolve existing and probable future flood problems along the Edgerton Channel in the City of Cudahy. In making this recommendation, the Watershed Committee acknowledged that 1) because of the industrial character of the area in which the originally recommended detention reservoir was to be located, no significant park and recreation benefits nor land value enhancement would be incurred; 2) under the originally recommended alternative, there would be loss of property tax base and property and other tax revenues and a potential for lost jobs by the taking of land proposed in local plans and zoning for industrial use; and 3) there was a potential for health and aesthetic problems which currently exist in a portion of the channel to recur in those portions which would, under the initially recommended alternative, remain as open channels. This decision was also influenced by the testimony of city officials that an agreement between the City and the Milwaukee-Metropolitan Sewerage Commissions, perhaps informal, to enclose the Edgerton Channel through the City of Cudahy has existed for a number of years, dating back to at least 1965.

Revisions to the Cost Analysis

The changes made to the floodland management plan element by the Kinnickinnic River Watershed Committee subsequent to the public hearing resulted in some modest changes in the construction and operation and maintenance costs, presented in Table 83, associated with the structural flood damage abatement measures recommended for the Edgerton Channel in the City of Cudahy, and, hence, in the total cost of implementing the comprehensive plan for the Kinnickinnic River watershed. As shown in Table 87, the resulting revised cost of implementing the recommended comprehensive plan for the Kinnickinnic River watershed is estimated at $10.2

Table 87

SCHEDULE OF CAPITAL AND OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED BY YEAR: 1979-2000

		Floodland Management Element						Water Quality Management Element			
		Committed Channel Modifications[a]		Recommended Structural Flood Damage Abatement Measures for the City of Cudahy				Diffuse Source Pollution Control Measures			
Calendar Year	Project Year	Construction	Operation and Maintenance	Construction	Operation and Maintenance	Operation and Maintenance of Continuous Recorder Gage	Subtotal	Capital	Operation and Maintenance	Subtotal	Total
1978[b]	0	$ 813,000[c]	$ –	$ –	$ –	$ –	$ –	$ –	$ –	$ –	$ –
1979	1	1,213,000	750	–	–	3,200	1,216,950	42,000	232,500	274,500	1,491,450
1980	2	578,000	1,500	1,047,000	250	3,200	1,629,950	42,000	232,500	274,500	1,904,450
1981	3	460,000	2,250	1,047,000	500	3,200	1,512,950	42,000	232,500	274,500	1,787,450
1982	4	460,000	3,000	–	500	3,200	466,700	42,000	232,500	274,500	741,200
1983	5	–	3,000	–	500	3,200	6,700	42,000	232,500	274,500	281,200
1984	6	–	3,000	–	500	3,200	6,700	42,000	232,500	274,500	281,200
1985	7	–	3,000	–	500	3,200	6,700	42,000	232,500	274,500	281,200
1986	8	–	3,000	–	500	3,200	6,700	71,000	237,600	308,600	315,300
1987	9	–	3,000	–	500	3,200	6,700	71,000	237,600	308,600	315,300
1988	10	–	3,000	–	500	3,200	6,700	71,000	237,600	308,600	315,300
1989	11	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1990	12	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1991	13	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1992	14	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1993	15	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1994	16	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1995	17	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1996	18	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1997	19	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1998	20	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
1999	21	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
2000	22	–	3,000	–	500	3,200	6,700	71,000	127,600	198,600	205,300
Total		$2,711,000	$61,500	$2,094,000	$10,250	$70,400	$4,947,150	$1,359,000	$3,871,500	$5,230,500	$10,177,650
22-Year Annual Average		$ 123,200	$ 2,800	$ 95,180	$ 470	$ 3,200	$ 224,850	$ 61,750	$ 176,000	$ 237,800	$ 462,650

[a] Schedule based on completion of the modifications on the Kinnickinnic River between S. 5th Street extended to S. 16th Street by the year 1980, and completion of the ultimate improvements on Wilson Park Creek between W. Euclid Avenue and S. 6th Street within a three-year period ending in 1982.

[b] Included to show costs already incurred.

[c] Not included in totals.

Source: SEWRPC

million over the 22-year period, a $1,080,000, or 12 percent, increase relative to the full cost of the preliminary plan as presented for public review and comment. Of this total cost, about $5.0 million, or about 49 percent, is now required for implementation of the floodland management plan element including the committed bridge alterations and channel improvements, and the recommended channel enclosure and the operation of a stream gaging network. The remaining $5.2 million, or about 51 percent, of the implementation cost is required for implementation of the recommended diffuse source pollution control measures.

The revised average annual costs of the total capital investment and operation and maintenance cost required for plan implementation may be expected to approximate $462,600, or about $2.84 per capita per year, over the 22-year plan implementation period. This per capita cost is based on a resident watershed population of 162,500 persons, equal to the anticipated average resident population of the watershed between the 1975 population level of 165,000 persons and the anticipated year 2000 population level of 160,000. The average annual costs of implementation of the floodland management plan element and the water quality management plan element are estimated to total, respectively, about $224,800, or $1.38 per capita per year, and $237,800, or $1.46 per capita per year.

Final Action of the Kinnickinnic River Watershed Committee

After careful consideration of the information presented at the public hearing held on the preliminary watershed plan, the Kinnickinnic River Watershed Committee, at a meeting held on October 27, 1978, voted unanimously to recommend to the Regional Planning Commission adoption of the final watershed plan, shown in graphic summary form on Map 58. That plan, as adopted, consisted of the preliminary plan presented at the public hearing, as described earlier in this chapter, with the original recommendation of detention storage-channel enclosure-channel realignment along the Edgerton Channel in the City of Cudahy changed to a recommendation to enclose the entire length of the Edgerton Channel through the City of Cudahy. The Committee also noted that the representatives of the City of Milwaukee had, at the October 27, 1978 meeting, indicated that there was some sentiment on the part of local residents to replace some of the vehicular bridges proposed in the plan to be removed in the reach from S. 6th Street to S. 16th Street with pedestrian bridges. The Committee directed that the final planning report explicitly indicate that the construction of such pedestrian bridge would be in conformance with the recommended watershed plan, provided that the waterway openings be designed to meet the standards set forth in Chapter X of this report.

SUMMARY

The various plan subelements recommended as integral parts of the comprehensive plan for the Kinnickinnic River watershed have all been described separately and in considerable detail in the preceding chapters of the report. This chapter presents a concise description of the overall recommended comprehensive plan of the Kinnickinnic River watershed intended, in part, to show how each of the three elements—land use, floodland management, and water quality management—complement and strengthen each other.

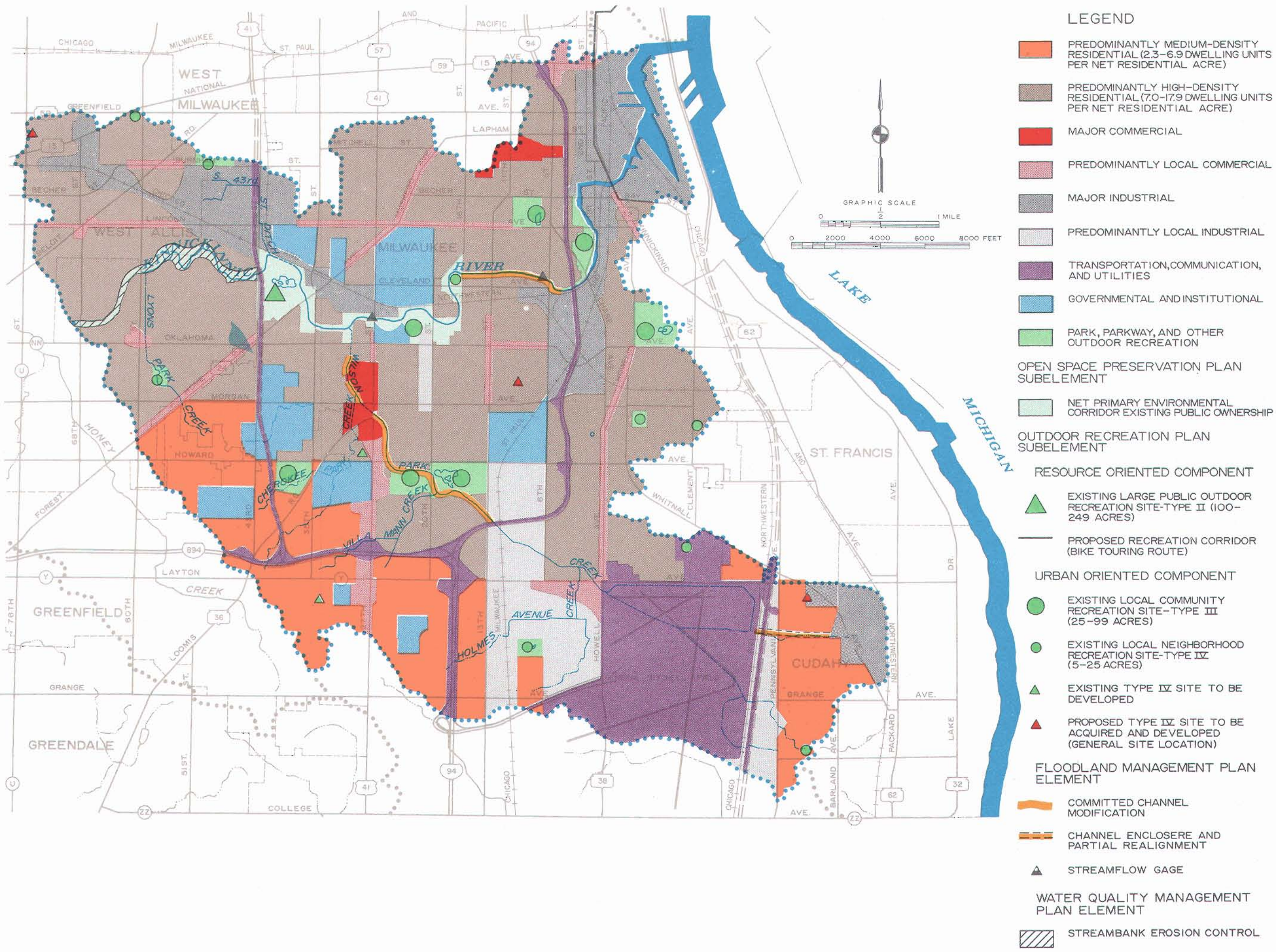
Under the comprehensive watershed plan recommended herein, future urban development within the watershed would be guided through locally exercised land use controls into a more orderly and economical land use pattern, and intensification of existing and the creation of new developmental and environmental problems would thus be avoided. The primary environmental corridors of the watershed, together with the remaining undeveloped floodlands, would be protected from incompatible urban development, thereby assuring continued enjoyment of the recreational, aesthetic, ecological, and cultural values associated with the riverine areas while avoiding intensification of flood damage and water pollution problems. Primary environmental corridor preservation would be accomplished through continued maintenance in such use of riverine area lands presently used for recreation and related open space, and by judicious use of floodland and conservancy zoning. Currently, the primary environmental corridor lands along the Kinnickinnic River lie largely within the public parks and parkways of the Milwaukee County park system and are available for general recreational use.

The watershed plan encourages expeditious implementation of the committed channel improvements on the Kinnickinnic River and Wilson Park Creek in the City of Milwaukee. Flood control measures are recommended to abate serious existing and forecast flood problems in the City of Cudahy. Bridge replacement recommendations are included in the plan to assure that major streets, highways, and railroads remain operable during major flood events. Various supplementary measures intended to minimize the monetary losses associated with flooding are recommended, including: participation in the federal flood insurance program, continuation of desirable lending institution and realtor policies concerning the sale of riverine area properties, supportive community utility policies, and the establishment of emergency flood warning programs. Maintenance of a basic stream gaging network is also recommended.

The recommended Kinnickinnic River watershed plan incorporates those water quality management measures recommended in other adopted commission plans which are directly applicable to the Kinnickinnic River watershed, including: abatement of the combined sewer overflow pollution and elimination of separate sewer flow relief devices. In addition, industrial discharges to the stream system would be controlled, and diffuse source pollution control measures would be invoked to reduce the surface water pollution associated with washoff from rural and urban land surfaces.

Map 58

RECOMMENDED COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED: 2000



The recommended Kinnickinnic River watershed plan consists of a land use plan element, a floodland management plan element, and a water quality management plan element. The land use plan element would efficiently meet future needs for various land uses within the watershed through the conversion to urban use of about one square mile of existing "unused" open lands and renewal and redevelopment of existing urban areas; continued maintenance and preservation in park and open space uses of the 325 acres of existing new primary environmental corridor; and protection through public land use regulations of that portion of the primary environmental corridor along the Lake Michigan shoreline. In addition, the land use plan called for development of the four-mile segment of the recommended recreational corridor across the eastern end of the watershed; continued maintenance of Jackson Park as a large general-use outdoor recreation site; continued use of the 16 existing community and neighborhood parks; completion of the development of two existing neighborhood parks; acquisition and development of three new neighborhood parks; and the development of boat launching ramps and mooring facilities in the estuary portion of the watershed. The floodland management plan element of the Kinnickinnic River watershed plan includes the completion of committed flood control works on the Kinnickinnic River and Wilson Park Creek consisting of the removal without replacement of 10 bridges, the removal and replacement with adequate waterway openings of four bridges; the construction of earthen berms, concrete floodwalls, and channel improvements as necessary to provide two feet of freeboard in that reach of the Kinnickinnic River between S. 5th Street extended and S. 16th Street; and channel improvements with concrete linings along that portion of Wilson Park Creek from W. Euclid Avenue to S. 6th Street. As presented at the public hearing, this plan element included structural flood control measures consisting of a 13-acre detention reservoir, 0.3 mile of channel enclosure, and 0.3 mile of channel realignment. Based upon testimony given at the public hearing, enclosure of the Edgerton Channel along the entire length in the City of Cudahy was recommended. Also included in this plan element are: the establishment of a program of periodic cleaning and maintenance of stream channels and of bridge and culverts waterway openings and the establishment of a new flood protection elevation along the lower Kinnickinnic River. The water quality management plan element of the Kinnickinnic River watershed plan incorporates those water quality management measures recommended in other adopted SEWRPC plans which are directly applicable to the watershed including the abatement of the combined sewer overflows and the elimination of separate sanitary sewer flow relief devices. The plan element also includes the abatement of direct or indirect discharges of industrial wastes to the Kinnickinnic River and its tributaries; the application of measures designed to control sources of toxic and hazardous substances; and a reduction in diffuse source pollution through the implementation of land management measures throughout the watershed such as proper material storage and runoff control on industrial and commercial sites, stream bank erosion control, control of sediment and debris during demolition and construction activities, street deicing material control, public education programs, pet waste and litter control ordinances, and proper application of chemical and organic fertilizers and pesticides to lawns.

Source: SEWRPC.

A preliminary schedule of capital costs and operation and maintenance expenditures was prepared which, if followed, would result in total watershed plan implementation by the year 2000. An analysis of recent actual public expenditures for public works and facilities indicated that the cost of implementing the watershed plan is such as to be reasonably obtainable through continuing the current public expenditures patterns in the basin.

An evaluation was made of the comprehensive plan relative to its ability to meet the adopted watershed development objectives and standards. In spite of the highly urbanized nature of this watershed and the associated serious deterioration in the underlying natural resource base, the analysis indicates that the watershed plan could result in achievement of most of the standards established in support of the adopted watershed development objectives. Implementation of the plan may be expected to provide a safer, healthful, more pleasant, as well as a more orderly and efficient, environment within the watershed.

An evaluation was also conducted of the probable consequences of not implementing the recommended comprehensive plan for the Kinnickinnic River watershed based on analyses carried out under the watershed planning program and on empirical evidence gathered from other portions of the Planning Region. This evaluation indicates that, in the absence of a vigorous and prompt watershed plan implementation program, the Kinnickinnic River watershed will be susceptible to aggravation of the costly existing water resource and water resource-related problems and to the development of new problems.

A formal public hearing was held subsequent to the completion of the preliminary comprehensive watershed plan for the purpose of allowing public officials and interested citizens the opportunity to review and comment on the preliminary plan. Public reaction generally was quite favorable to the recommended preliminary plan, although opposition to the specific flood control alternatives initially selected for the Edgerton Channel in the City of Cudahy were expressed. This opposition centered on the inclusion in the plan of a flood detention reservoir and the provision of attendant open drainage channels. After careful consideration of the results of the public hearing, the Kinnickinnic River Watershed Committee voted to recommend to the Regional Planning Commission adoption of the plan as originally presented at the public hearing, with the initial recommendation of detention storage-channel enclosure-channel realignment along the Edgerton Channel in the City of Cudahy changed to a recommendation to enclose the entire length of the Edgerton Channel through the City of Cudahy.

The full capital investment and operation and maintenance costs of implementing the comprehensive plan for the Kinnickinnic River watershed, based on 1977 costs, are estimated at $10.2 million over the 22-year plan implementation period. This total of $10.2 million is a $1.1 million, or 12 percent, increase relative to the total cost of the preliminary plan as originally presented for public review and comment. Of the total $10.2 million cost of the plan, about $5.0 million, or about 49 percent, is required for implementation of the floodland management plan element, including the committed bridge alterations and channel improvements and the recommended channel enclosure and the operation of a stream gaging network. The remaining $5.2 million, or about 51 percent, of the implementation cost is required for implementation of the recommended diffuse source pollution control measures.

Chapter XV

PLAN IMPLEMENTATION

INTRODUCTION

The recommended comprehensive plan for the Kinnickinnic River watershed, as described in Chapter XIV of this report, provides a design for the attainment of the specific watershed development objectives formulated under the Kinnickinnic River watershed study. The final watershed plan consists of three major elements: 1) a land use element, including open space preservation and outdoor recreation subelements, 2) a supporting floodland management element composed of various structural and nonstructural subelements; and 3) a supporting water quality management element composed of various point and diffuse source pollution abatement subelements.[1]

While the recommended comprehensive plan for the Kinnickinnic River watershed is designed to attain, to the extent practicable, the agreed-upon watershed development 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 accordingly intended as a guide for use in the implementation of the Kinnickinnic River watershed plan. Basically, it outlines the actions which must be taken by the various levels and agencies of government concerned if the recommended comprehensive watershed plan is to be fully carried out by the design year 2000. Those units and agencies of government which have plan adoption and plan implementation powers applicable to the Kinnickinnic River watershed 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 with respect to the land use, floodland management, and water quality management plan elements of the comprehensive watershed plan. In addition, financial and technical assistance programs available to such units and agencies of government in the implementation of the watershed plan are discussed.

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[1]*The recommended land use plan element as well as the process used to arrive at that element is described in Chapter XI of this report. The various alternatives that were considered and the process used to arrive at the recommended floodland management plan element and the water quality management plan element are described in Chapters XII and XIII, respectively. The recommended comprehensive plan for the Kinnickinnic River watershed is described in Chapter XIV of this report.*

PRINCIPLES OF PLAN IMPLEMENTATION

The plan implementation recommendations contained in this chapter are, to the maximum extent possible, based upon and related to existing governmental programs and are predicated upon existing enabling legislation. Because of the ever-present possibility of unforeseen changes in economic conditions, state and federal legislation, case law decisions, governmental organization, and tax and fiscal policies, it is not possible to declare once and for all time exactly how a process as complex as watershed plan implementation should be administered and financed. In the continuing regional planning program for southeastern Wisconsin it will, therefore, be necessary to periodically update not only the watershed plan elements and the data and forecasts on which these plan elements are based, but the recommendations contained herein for plan implementation.

It is important to recognize that plan implementation measures must not only grow out of formally adopted plans, but must be based upon a full understanding of the findings and recommendations contained in those plans. Thus, action policies and programs must not only be preceded by formal plan adoption and, following such adoption, be consistent with the adopted plans, but must emphasize implementation of the most important and essential elements of the comprehensive watershed plan and those areas of action which will have the greatest impact on guiding and shaping development in accordance with those elements. Of particular importance in this regard are those plan implementation efforts which are most directly related to achieving the basic watershed development objectives, especially those objectives concerned with the protection of the underlying and sustaining natural resource base; flood control and flood damage abatement; and water quality control and pollution abatement.

Principal Means of Plan Implementation

There are three principal ways through which the necessary watershed plan implementation may be achieved—ways which parallel the three functions of the Regional Planning Commission: 1) inventory, or the collection, analysis, and dissemination of basic planning data on a uniform, areawide basis; 2) plan design, or the preparation of a framework of long-range plans for the physical development of the Region; and 3) plan implementation, or the provision of a center for the coordination of planning and plan implementation activities. All require a receptive attitude and active planning and plan implementation programs at the local, county, and state levels of government.

A great deal can be achieved in guiding watershed development into a more desirable pattern through the simple task of collecting, analyzing, and disseminating basic planning and engineering data on a continuing, uniform, areawide basis. Experience within the Southeastern Wisconsin Region to date has shown that if this important inventory function is properly carried out, the resulting information will be used and acted upon both by local and state agencies of government and by private investors. A wealth of definitive information about the natural and man-made features of the watershed, the hydrology and hydraulics of the watershed and the water-related problems of the watershed, particularly flood damage and water pollution, was assembled under the Kinnickinnic River watershed study. The use of this information base in arriving at development decisions on a day-to-day basis by the public and private interests involved contributes substantially toward implementation of the recommended watershed plan.

With respect to the function of plan preparation or design, it is essential that some of the watershed plan elements be carried into greater depth and detail for sound plan implementation. Specifically, the plan recommendations dealing with structural flood control measures and pollution abatement facilities must be carried through preliminary engineering to the final design stages. Further study must be given to the acquisition and development of proposed neighborhood parks and the development of urban outdoor recreation facilities. The preparation of such detailed plans will require the continuing development of close working relationships between the Commission, the Milwaukee County Board, and its agencies, the Milwaukee Metropolitan Sewerage District, the local units of government concerned, and certain other agencies—in particular, the Wisconsin Department of Natural Resources.

To achieve a high degree of watershed plan implementation it will be essential to effectively carry out the Commission's function as a center for the coordination of local, areawide, state, and federal planning and plan implementation activities within the watershed. The community assistance program, through which the Commission, upon request, actively assists the local municipalities in the preparation of local plans and plan implementation devices, is an important factor in this function. If properly utilized, this program should help make possible the full integration of watershed and local plans, adjusting the details of the latter to the broader framework of the former.

Distinction Between the Systems Planning, Preliminary Engineering, and Final Design Phases of the Public Works Development Process

The planning process used to prepare the Kinnickinnic River watershed plan constituted the first, or systems planning phase of what may be regarded as a three-phase public works development process. Preliminary engineering is the second phase in this sequential process, with final design being the third and last phase. Because effective implementation of the Kinnickinnic River watershed plan requires an understanding of this three-phased process, that process is briefly described below. Although emphasis is placed on use of the process in preparing a comprehensive plan for the Kinnickinnic River watershed and in the subsequent steps needed to advance that plan toward implementation, it is important to note that the three-phased process is applicable to any regional or subregional plan containing recommendations for the development of public works for flood control, pollution abatement, water supply, sanitary sewerage, transportation, parks and open spaces, or other public facilities and services.

Systems Planning: The systems planning phase concentrates on the precise definition of the problems to be addressed and on the development and evaluation of alternative measures for resolution of these problems on a sound areawide basis. Systems planning is intended to permit the selection, from among the alternative measures considered, of the most effective measure to resolve the identified problems in accordance with agreed-upon objectives and supporting standards. In this first or systems planning phase, each alternative plan element is developed to sufficient detail to permit a sound consistent comparison of the technical practicality and economic feasibility of each alternative and a proper evaluation of its nontechnical and noneconomic characteristics.

Properly conducted, systems planning is comprehensive in three ways. First, it is comprehensive in that it takes into consideration the entire system and attendant rational planning area most likely to significantly influence the environmental and developmental problems of concern and the proper resolution of those problems. Water and water resource-related problems, for example, should be approached on a watershed basis because the watershed system is the most rational planning area for such problems. Man's use of the land and changes in such use in one portion of a watershed can markedly influence environmental problems in other areas of the watershed, as illustrated in Chapter XII of this report, through, for example, the impact of urban development and channel modifications on downstream flood discharges and stages.

Second, properly conducted systems planning is comprehensive in that it considers not only the immediate problem but the relationship of the problem to broad land use, socioeconomic, and environmental considerations. For example, comprehensive watershed planning recognizes that the quantity and quality of the surface waters in the watershed system are determined in part by existing and planned land use in the watershed system and that land use is, in turn, determined by socioeconomic conditions within as well as outside of the watershed. Therefore, the regional land use plan is taken as a "given" in the preparation of the watershed plan so as to reflect regional land use, socioeconomic, and environmental conditions likely to influence the cause of and solution to water resource problems within the watershed.

Third, the systems planning phase of the three-phase public works development process is comprehensive in that a full spectrum of potential solutions to the water resource and water resource-related problems are considered during the process. Because of the many measures, variations on measures, and combinations of measures that are available, it is recognized in the systems planning phase that there are an almost unlimited number of solutions to a given problem that, in effect, form a continuum of possible solutions. The key to efficient systems planning is not examining each of the many possible alternative measures but rather examining alternatives that define the boundaries of the continuum and that are truly representative of the full range of available measures within the continuum.

Preliminary Engineering

Although systems planning requires considerable effort, it is not normally carried to the level of detail needed to permit immediate implementation of the recommended measures. In general, it is essential that the analysis of the technical, economic, environmental features and other features of the plan elements be carried into great detail and depth as the first step toward implementation of the system plan. The second phase of the three-phase public works development process is referred to as preliminary engineering and is most properly carried out, subsequent to the adoption of the areawide systems plan, by the implementing units and agencies of government concerned.

The preliminary engineering phase begins where the systems planning phase ends, and the analysis is no longer comprehensive. Emphasis is now placed on function in that the preliminary engineering phase concentrates on the basic solution to the problem at hand as that problem and its solution have been identified in the systems planning phase. The preliminary engineering phase of the three-phase public works development process presumes that the optimum solution in terms of technical practicality, economic feasibility, and environmental consequences and other considerations has been identified under the previous systems planning phase. Preliminary engineering concentrates on examining variations on the recommended solution and on examining the technical, economic, environmental features, and other features of those variations in depth in order to determine the best way to carry out the recommended solution.

Final Design: Upon acceptance of the findings and recommendations of the preliminary engineering phase by the governmental units and agencies affected, the third or final design phase of the public works development process is initiated. This work should also be carried out by the implementing units and agencies of government concerned. Starting with the solution to the problem at hand as set forth in the final, approved version of the preliminary engineering report, the final design phase should move toward the development of the detailed construction plans and specifications needed to completely implement the recommended solution. In the case of a public works project involving construction, the plans and specifications should provide sufficient detail to permit potential contractors to submit bids for the project and to actually construct the recommended works. Engineers responsible for carrying out the final phase should also have responsibility for securing the necessary permits and other approvals from regulatory and review agencies, for providing supervisory and inspection services during the actual construction process, and for certifying to the governmental units and agencies involved that the construction is carried out in accordance with the design provisions and specifications.

Other Considerations: For many reasons, the three-phased public works development process does not always proceed in the simple three-step fashion as described above. In some situations an iterative process is set in motion whereby a reexamination of an earlier step is required. For example, during the preliminary engineering phase a new alternative, based on additional information, may be developed that must be subjected to systems analysis.

Ever-changing federal and state regulations and guidelines can disrupt the three-phased public works development 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 back to the systems planning phase to reconsider measures considered during that phase or to analyze additional measures as may be necessitated by the regulation and guideline changes. As a result of the passage of time between the systems planning phase and the preliminary 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, because of changing values and objectives, be rejected or encounter considerable opposition, necessitating an iteration back to the systems planning phase.

The effective functioning of the three-phase public works development process is highly dependent on close cooperation among governmental units and agencies. For example, the systems level planning conducted by the Southeastern Wisconsin Regional Planning Commission must be acceptable to local governmental units and agencies in order to prompt them to undertake the necessary second or preliminary engineering phase and to make full use of the recommendations resulting from the first or systems planning phase of the public works development process.

In some special situations, the public works development process can be carried out without proceeding through the above three phases. For example, systems planning in the area of floodland management may lead to the recommendation that structure floodproofing and removal be used to resolve flood problems. In this instance, assuming adoption of the plan recommendations by the governmental units and agencies concerned, the preliminary engineering phase can be combined with the final design phase, the goal of which would be to provide a precise identification of structures requiring floodproofing and those requiring removal and of the manner in which floodproofing and removal should be carried out.

In carrying out the three-phase process, there is a tendency to circumvent a critical step, usually the systems planning phase, in response to intense public concern and controversy over a pressing environmental or developmental problem. This approach sometimes achieves short-term gains in that it leads to prompt problem-solving activity—for example, minor channel work to "solve" a flood problem—thereby satisfying the immediate public concern. Unfortunately, circumvention of key steps in the public works development process often leads to long-term losses as a result of the failure to fully identify and quantify the problem at hand and to determine the most effective solution to that problem in terms of technical practicality, economic feasibility, and environmental impact. Superposition of man's works and activities on the natural resource base produces an urban ecosystem that is complicated in terms of its many and varied components and processes and the interrelationships between those components and processes—an ecosystem that usually defies simple solutions to the environmental and developmental problems that arise.

Review Responsibility of the
Regional Planning Commission

Under the provisions of recently enacted federal legislation and subsequent federal administrative determinations,[2] applications by state and local units of government for federal grants in partial support of the planning, acquisition of land for, and construction of public works facilities such as sewerage and water supply systems, parks, waste treatment facilities, and soil and water conservation projects must be submitted to an officially designated areawide planning agency for review, comment, and recommendation before consideration by the administering federal agency. The comments and recommendations of the areawide planning agency must include information concerning the extent to which the proposed project is consistent with the comprehensive planning program for the region, including, in southeastern Wisconsin, the Kinnickinnic River watershed planning program, and the extent to which such a project contributes to the fulfillment of such planning programs. The review comments and recommendations by the areawide planning agency are entirely advisory to the local, state, and federal agencies of government concerned and are intended to provide a basis for achieving the necessary coordination of public development programs in urbanizing regions of the United States on a voluntary, cooperative basis. If used properly, such review can be of material assistance in achieving implementation of the recommended Kinnickinnic River watershed plan.

In this respect, it should be noted that the Regional Planning Commission has formally adopted a policy statement on the review of applications submitted to the Commission for federal grants-in-aid. This policy requires that adopted plan elements, such as a comprehensive watershed plan, form the basis for review and comment of applications by the Commission. All projects that are the subject of applications are thus either certified as being in conformance with and serving to implement, not in conflict with, or in conflict with adopted regional plan elements. In considering the Regional Planning Commission's findings in this respect, it is important that local public officials and concerned citizens recognize that the failure to implement any major element of the recommended comprehensive watershed plan will proportionately reduce the capability of the watershed to provide a pleasant, safe, and healthful place in which to live and work. In addition, it is essential that the state and federal implementing agencies recognize that the watersheds of southeastern Wisconsin, in particular the Kinnickinnic River watershed, are located in that part of the State where the concentration of people is the largest, where the degree of natural resource base destruction has been greatest, and where existing demands on the resource base are highest.

PLAN IMPLEMENTATION ORGANIZATIONS

Although the Regional Planning Commission can promote and encourage watershed plan implementation in various ways, the complete advisory role of the Commission makes actual implementation of the recommended Kinnickinnic River watershed plan entirely dependent upon action by certain local, areawide, state, and federal agencies of government. Examination of the various agencies that are available under existing enabling legislation to implement the recommended watershed plan reveals an array of departments, commissions, committees, boards, and districts at all levels of government. These agencies range from general-purpose local units of government, such as cities and villages, to special-purpose districts, such as metropolitan sewerage districts; to state regulatory bodies, such as the Wisconsin Department of Natural Resources; and to federal agencies that provide financial and technical assistance for plan implementation, such as the U.S. Soil Conservation Service.

Because of the many and varied agencies in existence, it becomes exceedingly important to identify those agencies having the legal authority and financial capability to most effectively implement the recommended watershed plan elements. Accordingly, those agencies whose actions will have significant effect either directly or indirectly upon the successful implementation of the recommended comprehensive watershed plan and whose full cooperation in plan implementation will be essential are listed and discussed below.[3] The agencies are, for convenience,

[2] *Section 204 of the Demonstration Cities and Development Act of 1966; Title IV of the Intergovernmental Cooperation Act of 1968; and U.S. Office of Management and Budget Circular No. A-94 (Revised), January 13, 1976.*

[3] *A more detailed discussion of the duties and functions of local, areawide, and state agencies as they relate to plan implementation may be found in SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin, 2nd Edition, April 1977, and SEWRPC Technical Report No. 6, Planning Law in Southeastern Wisconsin, 2nd Edition, April 1977.*

discussed by level of government; however, the interdependence between the various levels as well as between agencies of government and the need for close intergovernmental cooperation cannot be overemphasized. The creation of new agencies for watershed plan implementation should be considered only if the existing agencies fail to carry out the plan in a timely manner; and, if found necessary, new agencies should be created in such form as to effectively complement and supplement the plan implementation activities of the agencies already in existence.

Watershed Committee

Since planning at its best is a continuing function, a public body should remain on the scene to coordinate and advise on the execution of the watershed plan and to undertake plan updating and renovation as necessitated by changing events. Although the Regional Planning Commission is charged with, and will perform, this continuing areawide planning function, it cannot do so properly without the active participation and support of local governmental officials through an appropriate advisory committee structure. It is, therefore, recommended that the Kinnickinnic River Watershed Committee be reconstituted as a continuing intergovernmental advisory committee to provide a focus for the coordination of all levels of government in the execution of the Kinnickinnic River watershed plan. The Kinnickinnic River Watershed Committee would thus continue to be a creation of the Southeastern Wisconsin Regional Planning Commission, pursuant to Section 66.945 (7) of the Wisconsin Statutes, and would report directly to the Commission. It is recommended that all agency representatives and individuals currently serving on the Kinnickinnic River Watershed Committee remain as members of the continuing committee and that the question of committee membership be left open so that additional members could be added to the Committee as appropriate.

Local Level Agencies

Statutory provisions exist for the creation at the county and municipal level of the following agencies having planning and plan implementation powers, including police powers and acquisition, condemnation (eminent domain), and construction (tax appropriation) powers, important to comprehensive watershed plan implementation.

County Park and Planning Agencies: County government has a great deal of flexibility available in forming agencies to perform the park and outdoor recreation and zoning and planning functions within the county. Counties may organize park commissions or park and planning commissions pursuant to Section 27.02 of the Wisconsin Statutes. In addition, instead of organizing such commissions counties may elect to utilize committees of the county board to perform the park and outdoor recreation and zoning and planning functions. The powers are essentially the same no matter how an individual county chooses to organize these functions. If, however, a county elects to establish a county park or county park and planning commission, these commissions have the obligation to prepare a county park system plan and a county street and highway system plan. There is no similar mandate for plan preparation when a county elects to handle these functions with committees of the county board.

In Milwaukee County there is a County Park Commission with full authority and responsibility for park and parkway planning, acquisition, development, operation, and maintenance. Because Milwaukee County contains no unincorporated area, there is no county zoning authority. The Milwaukee County Park Commission, however, does perform a limited subdivision review function with respect to subdivision plats lying in, or adjacent to, proposed park and parkway developments outside of the Cities of Milwaukee, Wauwatosa, and West Allis. Milwaukee County has also created a County Planning Commission to perform, essentially, a capital budgeting and programming function. This planning Commission reviews all requests for capital improvements by Milwaukee County agencies.

County Highway Committees: County highway committees of the county board are required in every county of Wisconsin pursuant to Section 83.015 of the Wisconsin Statutes. In Milwaukee County, this requirement is met through the Transportation and Public Works Committee. Each county highway committee is responsible for laying out, constructing, and maintaining all county highways as authorized by the county board of supervisors. County highway committees work in close cooperation with the Wisconsin Department of Transportation. The Transportation and Public Works Committee for Milwaukee County can play an important role in implementation of the Kinnickinnic River watershed plan with respect to the construction and reconstruction of certain bridges and other highway facilities within the watershed.

Municipal Planning Agencies: Municipal planning agencies include city and village plan commissions created pursuant to Sections 62.23 (1) and 61.35 of the Wisconsin Statutes. Such agencies are important to watershed plan implementation at the local level. All six communities within the watershed have established plan commissions in accordance with Section 62.23 or 61.35 of the Wisconsin Statutes.

Soil and Water Conservation Districts: The importance of good soil and water conservation and management practices to the full implementation of the floodland and water quality management elements of the Kinnickinnic River watershed plan cannot be overemphasized. Lack of such practices will have a critical adverse effect upon water quality, drainage and flood control, and recreational pursuits within the watershed. Soil and water conservation districts, as authorized under Section 92.05 of the Wisconsin Statutes, have the authority to develop plans for the conservation of soil and water resources, prevention of soil erosion, and prevention of floods. Technical and educational services can be provided to aid in the establishment both urban and rural land management practices. Soil and water conservation districts have the authority to acquire through eminent domain any property or rights therein for watershed protection, soil and water conservation, flood prevention works, and fish and wildlife conservation and recreational works.

Soil and water conservation districts are by law in Wisconsin made geographically coterminous with counties and Milwaukee County, which contains the Kinnickinnic River watershed, consists of such a district. This district has entered into a basic and supplemental memoranda of understanding with the U.S. Department of Agriculture, Soil Conservation Service, for technical assistance. Thus, there exists within the watershed a duly constituted body required to represent the county in agricultural, conservation, and land management programs which are administered by state and federal agencies. Because all of Milwaukee County lies within incorporated units of government, the soil and water conservation district can provide educational, financial, and technical assistance but cannot exercise any regulatory powers, as it may in unincorporated areas.

Harbor Commissions: The authority to develop and operate harbors and make harbor improvements is granted by Section 30.30 through 30.38 of the Wisconsin Statutes to every municipality in Wisconsin having navigable waters within or adjoining its boundaries. Such authority may be exercised directly by the governing body of the municipality or by a board of harbor commissioners created for that purpose. The boards of harbor commissioners are authorized by these sections to create or improve inner or outer harbor turning basins, slips, canals, and other waterways; to construct, maintain, or repair dock walls and shore protection walls; and to plan, construct, operate, and maintain docks, wharves, warehouses, piers, and related port facilities. A board of harbor commissioners also may serve as a regulatory enforcement agency for the municipality for dock wall construction and shoreline encroachment. The City of Milwaukee Common Council has created a Board of Harbor Commissioners to exercise such authority. The geographic jurisdiction of the Milwaukee Board of Harbor Commissioners within the Kinnickinnic River watershed implicitly extends along the Kinnickinnic River from its confluence with the Milwaukee River upstream to the fixed bridge at Becher Street.

Areawide Agencies

Statutory provisions exist for the creation of the following areawide agencies having both general and specific planning and plan implementation powers potentially applicable to the implementation of the Kinnickinnic River watershed plan.

Milwaukee Metropolitan Sewerage District: The Metropolitan Sewerage Commission of the County of Milwaukee, which operates and exists pursuant to the provisions of Section 59.96 of the Wisconsin Statutes, has the power to project, plan, and construct main sewers and pumping and temporary disposal works for the collection and transmission of domestic, industrial, and other sanitary sewage to and into the intercepting sewer system of the Milwaukee Metropolitan Sewerage District. The District consists of all of Milwaukee County except the City of South Milwaukee and includes the Kinnickinnic River watershed. The Metropolitan Sewerage Commission, furthermore, may improve any watercourse within the District by deepening, widening, or otherwise changing same where it may be necessary in order to carry off surface waters or drainage waters. The Metropolitan Sewerage Commission, however, may only exercise its powers outside the City of Milwaukee. The Sewerage Commission of the City of Milwaukee, on the other hand, may build treatment plants and build main and intercepting sewers and may improve watercourses in its area of operation, which is within the City of Milwaukee.

Flood Control Boards: Chapter 87 of the Wisconsin Statutes provides that property owners living in a single drainage area may petition the Wisconsin Department of Natural Resources for the formation of a flood control board for the sole purpose of effecting flood control measures. The flood control boards are empowered to straighten, widen, deepen, and otherwise alter watercourses and build flood control works, all activities being subject to review by, and approval of, the Wisconsin Department of Natural Resources.

Comprehensive River Basin District: Areawide flood control, water quality, and land use plan implementation can be achieved through the establishment of a special comprehensive river basin district embracing the entire watershed and capable of raising revenues through taxation and bonding; land acquisition; construction and operation of any necessary facilities; and otherwise dealing with the wide range of problems, alternatives, and projects inherent in comprehensive watershed planning. Such a district might be specifically charged in the enabling legislation by which it is created with carrying out the plans formulated under the Kinnickinnic River watershed study. Although enabling legislation to permit the creation of such districts has been proposed to the Wisconsin Legislature in the past, such legislation has not, to date, been adopted, and thus is not presently available as a means of dealing with the watershed plan implementation problem.

Cooperative Contract Commissions: Section 66.30 of the Wisconsin Statutes provides that municipalities[4] may contract with each other to form cooperative service commissions for the joint provision of any services or joint exercise of any powers that each municipality may be authorized to exercise separately. Such commissions have been given bonding powers for the purposes of acquiring, developing, and equipping land, buildings, and facilities for areawide projects. Significant economies can often be effected through providing governmental

[4]*The term municipality under this section of the statutes is defined to include the state, any agency thereof, cities, villages, towns, counties, school districts, and regional planning commissions.*

services and facilities on a cooperative, areawide basis. Moreover, the nature of certain developmental and environmental problems often requires that solutions be approached on an areawide basis. Such an approach may be efficiently and economically provided through the use of a cooperative contract commission.

Intergovernmental cooperation under such cooperative contract commissions may range from the sharing of expensive public works equipment to the construction, operation, and maintenance of major public works facilities on an areawide basis. A cooperative contract commission may be created for the purpose of watershed plan implementation and may be utilized in lieu of and of the aforementioned areawide organizations for such implementation.

Regional Planning Commission: Although not a plan implementation agency itself, one other areawide agency warrants comment: the Regional Planning Commission. As already noted, the Commission has no statutory plan implementation powers. In its role, however, as a coordinating agency for planning and development activities within the Southeastern Wisconsin Region, the Commission may play an important role in plan implementation through community planning assistance services and through the review of federal and state grant-in-aid applications, using adopted plan elements as a basis for this review. In addition, the Commission provides a basis for the creation and continued functioning of the Kinnickinnic River Watershed Committee, which should remain as an important continuing public planning organization in the watershed.

State Level Agencies

In existence at the state level are the following agencies that have either general or specific planning authority and hold certain plan implementation powers important to the adoption and implementation of the comprehensive Kinnickinnic River watershed plan.

Wisconsin Department of Natural Resources: This Department has broad authority and responsibility in the areas of park development, natural resources protection, water quality control, and water regulation. As such, it combines the park development and land-based natural resource protection functions of the former State Conservation Commission and the water regulatory functions formerly assigned to the State Public Service Commission. The Department has the obligation to prepare a comprehensive statewide plan for outdoor recreation; and to develop long-range, statewide conservation and water resource plans. In addition, it has the authority to designate such sites, as necessary to protect, develop, and regulate the use of state parks, forests, fish, game, lakes, streams, certain plant life, and other outdoor resources; to acquire conservation and scenic easements; and to administer the federal grant program known as the Land and Water Conservation (Lawcon) Fund within the State, as well as the park and open space grant funds available under the state Outdoor Resource Action Plan (ORAP) program. The Secretary of the Department has, pursuant to federal planning guidelines, the responsibility of certifying to the U.S. Environmental Protection Agency (EPA) river basin, regional, and metropolitan plans for water quality management. Without such certification and subsequent acceptance by the EPA, local units of government within the watershed would lose their eligibility for federal grants-in-aid for the construction of sewerage facilities.

As discussed in Chapter IX, of this report, the responsibility for water pollution control in Wisconsin is centered in the Wisconsin Department of Natural Resources. The basic authority and accompanying responsibilities relating to the water pollution control function 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 recent legislation[5] 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 recent legislation establishes a new waste discharge permit system and provides that no permit may be issued by the Department for any discharge from a point source of pollution which is in conflict with any areawide waste treatment management plan approved by the Department. Also under this new legislation, the Department is given rule-making authority to establish effluent limitations, water quality-related 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 waste discharges must meet, as applicable, and 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. It is anticipated that this new legislation

[5] *See Chapter 74, Wisconsin Laws of 1973. This law created Chapter 147 of the Wisconsin Statutes.*

and accompanying procedures will become the primary enforcement tool of the Wisconsin Department of Natural Resources in achieving the established water use objectives and supporting water quality standards.

The Department also has the obligation to establish standards for floodplain and shoreland zoning and the authority to adopt, in the absence of satisfactory local action, shoreland and floodplain zoning ordinances. In addition, the Department has authority to prohibit the installation or use of onsite soil absorption sewage disposal systems and to approve the regulation of such systems as promulgated by the Wisconsin Department of Health and Social Services. The Department also has authority to regulate the following: 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 lake bed materials. Finally, the Department has authority to require abatement of water pollution, to administer state financial aid programs for water resource protection; to assign priority for federal aid applications for sewage treatment plans; to review and approve water supply and sewerage systems; and to license well drillers and issue permits for high-capacity wells. With such broad authority for the protection of the natural resources of the State and the Region, this Department will be extremely important to implementation of nearly all of the major elements of the comprehensive Kinnickinnic River watershed plan.

Wisconsin Department of Transportation: This Department is broadly empowered to provide the State with an integrated transportation system. The Department is responsible for administering all state and federal aid and highway and airport improvement; for planning, designing, constructing, and maintaining all state highways; and for planning, laying out, revising, constructing, reconstructing, and maintaining the national interstate and defense highway system, the federal aid primary system, the federal aid secondary system, the forest highway system, and the airport aid system, all subject to federal regulation and control. The Department is also responsible for reviewing and approving changes in county trunk highway systems. As such, the Department, along with the respective county highway committees of the county boards of supervisors concerned, can play a role in full implementation of the Kinnickinnic River watershed plan with respect to the construction and reconstruction of certain bridges and highway and airport facilities within the watershed.

Wisconsin Board of Soil and Water Conservation Districts: This Board, on behalf of the State, coordinates and assists the programs of the county soil and water conservation districts concerned with the proper development, use, and protection of soil, water, and related natural resources; apportions among the districts any funds allotted from state or federal sources; approves district sponsorship of federally assisted watershed projects authorized under Public Law 566; and approves the participation of drainage boards in federally assisted water management projects.

University of Wisconsin-Extension: A University of Wisconsin-Extension office is located within each county. Although the Extension has no statutory plan implementation powers, the Extension can aid communities in solving environmental problems by providing educational and information programs to the general public, and by offering advice to local decision makers and community leaders. The Extension carries out these responsibilities by conducting meetings, tours, and consultations, and by providing newsletters, bulletins, and research information.

Federal Level Agencies

There exist at the federal level the following agencies which administer federal aid and assistance programs that can have important implications for implementation of the recommended Kinnickinnic River watershed plan because of their potential impact on the financing of both actual land acquisition and construction of specific facilities.

U.S. Department of Housing and Urban Development: This agency administers urban planning grants, flood insurance, and community development block grant programs. The community development block grants are available as entitlement grants to cities of more than 50,000 persons and are available as discretionary grants to communities of less than 50,000 persons. The community development block grant program and the flood insurance program can be important to implementation of the land use, floodland management, and water quality management elements of the Kinnickinnic River watershed plan.

U.S. Environmental Protection Agency: The U.S. Environmental Protection Agency administers water quality management planning grants and sanitary sewage treatment plant and pollution control facility construction grants. The latter grants can be particularly important to implementation of the water quality management element of the Kinnickinnic River watershed plan. In addition, this agency 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 Agency has delegated authority over the National Pollutant Discharge Elimination System (NPDES) permit issuance process whereby the Wisconsin Department of Natural Resources issues discharge permits under both state and federal authorities. Under guidelines promulgated by the Environmental Protection Agency, river basin, areawide water quality management, and sanitary sewerage facilities plans must be prepared as prerequisites to the receipt of federal capital grants in support of sewerage works construction. As a designated areawide water quality management planning agency under Section 208 of the Federal Water Pollution Control Act, the Regional Planning Commission is engaged in an areawide water quality management planning program for southeastern

Wisconsin intended to refine the previous related studies and plans completed by the Commission, to extend those plans to encompass nonpoint as well as point sources of water pollution, and, in so doing, to fully meet the requirements of Section 208 of the Federal Water Pollution Act.

U.S. Department of the Interior, Heritage, Conservation and Recreation Service: The U.S. Department of the Interior, Heritage, Conservation and Recreation Service, formerly the Bureau of Outdoor Recreation, administers park and open space acquisition and development grants through the Federal Land and Water Conservation (Lawcon) Fund program. The program is administered in Wisconsin through the Wisconsin Department of Natural Resources. Grants under this program can be important to implementation of the outdoor recreation and open space and natural resource protection subelements of the Kinnickinnic River watershed plan.

U.S. Department of the Interior, Geological Survey: This agency conducts continuing programs on water resource appraisal and monitoring. The programs of the U.S. Geological Survey are important to the implementation of the continuous stream gaging program recommended in the Kinnickinnic River watershed plan.

U.S. Department of Agriculture, Soil Conservation Service: This agency administers resource conservation and development projects and watershed projects under federal Public Law 566 and provides technical and financial assistance through county soil and water conservation districts to landowners in the planning and construction of measures for land treatment, agricultural water management, and flood prevention and for public fish, wildlife, and recreational development. This agency also conducts detailed soil surveys and provides interpretations as a guide to utilizing soil survey data in local planning and development. Certain programs administered by this agency can be of importance to implementation of the land management and treatment measures recommended in the Kinnickinnic River watershed plan.

U.S. Department of the Army, Corps of Engineers: This agency can conduct planning studies and construct flood control facilities as authorized by the U.S. Congress. In addition, under Section 205 of the Flood Control Act of 1948, as amended, the Corps is authorized to contribute to the review, design, and construction phases of selected projects, provided that the maximum Corps of Engineers first cost is one million dollars or less.[6] In the event a project is authorized by the Chief of Engineers within five years of the project area being declared a federal flood disaster area by the President, the Corps of Engineers contribution to the project may be increased to a maximum first cost of two million dollars. While the structural flood control subelements contained in the recommended Kinnickinnic River watershed plan can be implemented largely through existing local agencies and units of government, the potential exists for the Corps of Engineers to play a role in the implementation of the floodland management element of the recommended Kinnickinnic River watershed plan, provided that responsible local agencies or units of government request the Corps or Congress to fund a review of the flood control subelements contained in the recommended plan by the Corps of Engineers.[7]

[6] *The Office of Management and Budget has blocked funding of Section 205, Flood Control Act of 1948, as amended, for federal fiscal year 1977.*

PLAN ADOPTION AND INTEGRATION

Upon adoption of the Kinnickinnic River watershed plan by formal resolution of the Southeastern Wisconsin Regional Planning Commission, in accordance with Section 66.945(10) of the Wisconsin Statutes, the Commission will transmit a certified copy of the resolution adopting the watershed plan, together with the plan itself, to all local legislative bodies within the Kinnickinnic River watershed and to all of the existing federal, state, areawide, and local units and agencies of government that have potential plan implementation functions. Adoption, endorsement, or formal acknowledgment of the comprehensive watershed plan by the local legislative bodies and the existing local, areawide, state, and federal level agencies 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. This acceptance or acknowledgment is, in some cases, required by the Wisconsin Statutes before certain planning actions can proceed; such a requirement holds in the case of city and village plan commissions created pursuant to Section 62.23 of the Wisconsin Statutes. In addition, formal plan adoption may also be required for state and federal financial aid eligibility. A model resolution for adoption of the comprehensive plan for the Kinnickinnic River watershed is included in Appendix G.

It is extremely important to understand that adoption of the recommended Kinnickinnic River watershed plan by any unit or agency of government pertains only to the statutory duties and functions of the adopting agencies, and such adoption does not and cannot in any way preempt or commit action by another unit or agency of government acting within its own area of functional and geographic jurisdiction.

Upon adoption or endorsement of the Kinnickinnic River watershed plan by a unit or agency of government, it is recommended that the policymaking body of the unit or

[7] *The authorization for the Corps of Engineers to conduct such reviews for the Milwaukee River and its tributaries—which includes the Kinnickinnic River watershed—is provided in Section 205, Flood Control Act of 1950, (Title II, Public Law 516-81st Congress), Milwaukee River and Tributaries, Wisconsin.*

agency direct its staff to review in detail the plan elements of the comprehensive watershed plan. Once such review is completed, the staff can propose to the policymaking body for its consideration and approval the steps necessary to fully integrate the watershed plan elements into the plans and programs of the unit or agency of government.

Local Level Agencies

1. It is recommended that the Milwaukee County Board formally adopt the Kinnickinnic River watershed plan, including the land use elements, the floodland management element, and the water quality management element, by resolution pursuant to Sections 27.04(2) and 66.945(12) of the Wisconsin Statutes after a report and recommendation by the County Park Commission, County Planning Commission, and County Transportation and Public Works Committee.

2. It is recommended that the plan commissions of the five cities and one village in the watershed adopt the recommended Kinnickinnic River watershed plan as it affects them, by resolution pursuant to Section 62.23(3)(b) of the Wisconsin Statutes and certify such adoption to their respective governing bodies, and that such governing bodies also adopt the recommended plan.

3. It is recommended that the Soil and Water Conservation District of Milwaukee County adopt those portions of the recommended Kinnickinnic River watershed plan affecting it so as to establish a basis for the provision of technical services in the abatement of nonpoint sources of water pollution.

Areawide Agencies

1. It is recommended that the Metropolitan Sewerage Commission of the County of Milwaukee and the Sewerage Commission of the City of Milwaukee, acting jointly, adopt the recommended Kinnickinnic River watershed plan as such plan affects the work of those bodies.

State Level Agencies

1. It is recommended that the Wisconsin Natural Resources Board endorse the comprehensive Kinnickinnic River watershed plan, certify the plan as an official river basin plan to the U.S. Environmental Protection Agency, and direct the staff of the Wisconsin Department of Natural Resources to integrate the recommended watershed plan elements into its broad range of agency responsibilities, as well as to assist in coordinating plan implementation activities over the next 20 years. In particular, it is recommended that the Natural Resources Board endorse the recommended open space preservation and outdoor recreation plan subelements and direct its staff to integrate these plan elements into the long-range conservation and comprehensive outdoor recreation plans authorized by Section 23.09(7) of the Wisconsin Statutes and required by the Federal Land and Water Conservation Act. It is further recommended that the Board, through its staff, coordinate the recommended Kinnickinnic River watershed plan with its activities relating to floodland and shoreland zoning. It is also recommended that the Board and its staff consider and give due weight to the recommended watershed plan in the exercise of their various water regulatory powers. It is further recommended that the Board endorse the water quality management plan recommendations of the Kinnickinnic River watershed plan and direct its staff to integrate these plan recommendations into its water quality control activities, including the issuance of amended pollution abatement orders to require local units of government to implement the recommendations contained in the Kinnickinnic River watershed plan.

2. It is recommended that the Secretary of the Wisconsin Department of Transportatation endorse the recommended Kinnickinnic River watershed plan and direct the Department staff to consider and give due weight to the plan in the exercise of its various responsibilities governing the construction and reconstruction of highway facilities in the watershed.

3. It is recommended that the Wisconsin Board of Soil and Water Conservation Districts endorse the recommended Kinnickinnic River watershed plan so as to provide a basis for the coordination of the county soil and water conservation district programs and projects affecting the watershed.

Federal Level Agencies

1. It is recommended that the U.S. Department of Housing and Urban Development endorse the Kinnickinnic River watershed plan and utilize this plan in its administration and granting of federal aids for community development and in the administration of its flood insurance program.

2. It is recommended that the U.S. Environmental Protection Agency formally accept and endorse the recommended Kinnickinnic River watershed plan upon State of Wisconsin certification and utilize plan recommendations in the administration and granting of federal aids for water quality management.

3. It is recommended that the U.S. Department of the Interior, Heritage, Conservation and Recreation Service formally acknowledge the Kinnickinnic River watershed plan and utilize the plan recommendations in its administration and granting of federal aids under the Land and Water Conservation Act.

4. It is recommended that the U.S. Department of the Interior, Geological Survey, endorse the Kinnickinnic River watershed plan and con-

tinue, in cooperation with Milwaukee County, its water resources investigation program including the maintenance of its stream gaging program within the watershed.

5. It is recommended that the U.S. Department of Agriculture, Soil Conservation Service, formally acknowledge the Kinnickinnic River watershed plan and utilize the plan recommendations in its administration and granting of federal aids for resource conservation and development, multipurpose watershed projects, and best management practices design and implementation, and in its provision of technical assistance to landowners and operators for land and water conservation practices in urban and rural areas.

6. It is recommended that the U.S. Department of the Army, Corps of Engineers, formally acknowledge the Kinnickinnic River watershed plan. It is further recommended that the Corps of Engineers cooperate with any local or state units and agencies of government in any requests for assistance in the review, design, and construction phases of the floodland management plan elements of the recommended Kinnickinnic River watershed 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 an areawide plan, such as a comprehensive watershed plan, to be viable and of use to local, state, and federal units and agencies of government, be continually adjusted through formal amendments, extensions, additions, and refinements to reflect changing conditions. The Wisconsin Legislature clearly foresaw this when it gave to regional planning commissions the power to " . . . amend, extend, or add to the master plan or carry any part or subject matter into greater detail . . . " in Section 66.945(9) of the Wisconsin Statutes.

Amendments, extensions, and additions to the Kinnickinnic River watershed plan will be forthcoming not only from the work of the 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 watershed plan. This is particularly true of the land use element of the watershed plan. Areawide adjustments may come from subsequent regional or state planning programs, which may include additional comprehensive or special-purpose planning efforts, such as the preparation of regional sanitary sewerage service plans, regional water supply plans, and regional or county park and open space plans.

All of these adjustments and refinements will require the utmost cooperation by the local, areawide, state, and federal agencies of government, as well as coordination by the Southeastern Wisconsin Regional Planning Commission, which has been empowered under Section 66.945(8) of the Wisconsin Statutes to act as a coordinating agency for programs and activities of the local units of government. To achieve this coordination between local, state, and federal programs most effectively and efficiently and, therefore, to assure the timely adjustments of the watershed plan, it is recommended that all of the aforesaid state, areawide, and local agencies having various plan and plan implementation powers advise and transmit all subsequent planning studies, plan proposals and amendments, and plan implementation devices to the Southeastern Wisconsin Regional Planning Commission for consideration as to integration into, and adjustment of, the watershed plan. Of particular importance in this respect will be the continuing role of the Kinnickinnic River Watershed Committee in intergovernmental coordination.

LAND USE PLAN ELEMENT IMPLEMENTATION

The implementation of the land use plan element—including the overall land use plan, open space preservation plan, and outdoor recreation plan subelements—of the comprehensive Kinnickinnic River watershed plan is of central importance to the realization of the overall watershed plan. This element, moreover, requires the most intricate implementation actions and utmost cooperation between the local units of government and the areawide, state, and federal agencies concerned if the watershed development objectives are to be fully achieved. This is true not only because the land use plan subelements are closely interrelated in nature and support and complement one another, but because they are closely related to the floodland management and water quality management elements of the plan. If, for example, urban residential, commercial, and industrial growth is properly located within the watershed and is not allowed to further preempt the natural floodland areas, a great deal will be achieved with respect to flood damage mitigation. Similarly, the maintenance and preservation of primary environmental corridors for natural resource protection and conservancy purposes will, in turn, assure the preservation of many of the best park sites remaining within the watershed. Although all of the plan implementation recommendations are closely interrelated, this section has been divided for convenience in presentation and use into the following major subject areas: overall land use plan subelement, open space preservation plan subelement, and outdoor recreation plan subelement. The recommended implementation actions discussed under this plan element are summarized in Table 88.

Overall Land Use Plan Subelement

The overall land use plan subelement of the Kinnickinnic River watershed plan was developed from the land use pattern established in the preparation of the revised and

Table 88

MATRIX OF KINNICKINNIC RIVER WATERSHED PLAN ELEMENTS AND IMPLEMENTING GOVERNMENTAL UNITS AND AGENCIES

Plan Elements	Kinnickinnic River Watershed Committee	City of Cudahy	City of Greenfield	City of Milwaukee	City of St. Francis	City of West Allis	Village of West Milwaukee	Milwaukee County	Milwaukee County Soil and Water Conservation District	Milwaukee-Metropolitan Sewerage Commissions	Regional Planning Commission	Wisconsin Department of Natural Resources	Wisconsin Department of Transportation	Wisconsin Department of Health and Social Services	Wisconsin Board of Soil and Water Conservation Districts	U.S. Department of Housing and Urban Development	U.S. Environmental Protection Agency	U.S. Department of the Interior, Heritage, Conservation and Recreation	U.S. Department of the Interior Geological Survey	U.S. Department of Agriculture, Soil Conservation Service	U.S. Department of the Army, Corps of Engineers
	Implementing Governmental Units and Agencies: Local Level Agencies and Units of Government									Implementing Governmental Units and Agencies: Areawide Agencies		State Level Agencies				Federal Level Agencies					
I. Kinnickinnic River Watershed Plan																					
A. Plan Adoption	X	X	X	X	X	X	X	X	X	X	X										
B. Plan Endorsement												X		X	X	X	X		X		
C. Plan Acknowledgment													X					X		X	X
II. Land Use Plan Element																					
A. Overall Land Use Plan Subelement		X	X	X	X	X	X	X	X												
B. Open Space Preservation Plan Subelement																					
C. Outdoor Recreation Plan Subelement																					
III. Floodland Management Plan Element																					
A. Floodland Regulations Preparation Subelement		X	X	X	X	X	X	X													
B. Committed Channel Modifications Subelement				X				X		X		X									
C. Recommended Structural Measures for Flood Damage Abatement Subelement																					
1. Construction and maintenance of a flood detention reservoir		X								X		X									
2. Stream channel modifications		X								X		X									
D. Bridge Replacement Subelement		X	X	X	X	X	X	X				X	X								
E. Flood Insurance Subelement		X		X		X						X				X					
F. Lending Institution Realtor Policies Subelement[a]																					
G. Community Utility Policies and Emergency Programs Subelement		X		X		X		X		X		X	X	X		X	X				
H. Streamflow Recordation Subelement				X						X		X							X		
I. Flood Protection Elevations for the Kinnickinnic River Estuary Area Subelement				X						X											
J. Channel Maintenance Subelement		X	X	X	X	X	X	X		X		X	X								
IV. Water Quality Management Plan Element																					
A. Combined Sewer Overflow Abatement Subelement				X						X		X					X				
B. Flow Relief Device Abatement Subelement				X		X				X		X					X				
C. Industrial Discharge Abatement Subelement[a]												X					X				
D. Diffuse Source Pollution Control Measures Subelement		X	X	X	X	X	X	X	X			X					X			X	
E. Water Quality Monitoring Subelement										X							X				

[a]This subelement can be implemented wholly or in part by the private sector.

Source: SEWRPC

updated regional land use plan for the year 2000[8]. The overall land use plan subelement deals with land use within and outside of the riverline areas of the watershed.

The implementation of the overall land use plan subelement can best be accomplished through the adoption of the recommended regional land use plan and the implementation of that plan through local land use regulations. It is recommended that all five cities and the one village within the watershed, as well as Milwaukee County, adopt the recommended regional land use plan for the year 2000 as refined under the Kinnickinnic River watershed study. It is further recommended that the following methods be used in the implementation of the overall land use plan subelement.

Zoning Ordinances: Of all the land use plan implementation devices, the most readily available, most important, and most versatile are zoning ordinances, including zoning district regulations and zoning district delineations. It should be noted that Milwaukee County has no zoning powers because the total land area of the County lies within incorporated municipalities. The following zoning ordinances or amendments to existing zoning ordinances should be adopted by the appropriate local units of government within the watershed so as to provide a clear indication of the intent to implement the overall land use plan subelement of the Kinnickinnic River watershed plan, and thereby to provide a framework for other planning and plan implementation efforts.

It is recommended that the plan commissions of all five cities and of the one village in the watershed formulate and recommend to their respective governing bodies new zoning ordinances or amendments to existing zoning ordinances in accordance with Section 60.74 or 62.23(7) of the Wisconsin Statutes, as necessary. These new zoning measures would serve to provide district regulations, including the exclusive use district and floodlands and shoreland regulations similar to those provided in the Commission model zoning ordinance, together with appropriate zoning district map changes to reflect the recommended watershed land use pattern. It is recommended that the respective municipal governing bodies then adopt such zoning ordinances, or amendments thereto, including such zoning district map changes, pursuant to Section 60.74 or 62.23(7) of the Wisconsin Statutes.

The task of delineating zoning district boundaries to reflect the land use plan recommendations in the comprehensive Kinnickinnic River watershed plan is as difficult as it is important. Proper delineation of the boundaries of the various zoning districts to achieve the general land use pattern recommended in the watershed plan will require careful study and a thorough understanding not only of the local community plan recommendations by the local zoning agencies but of the watershed plan recommendations and their relationships to the local plans. It is accordingly recommended that each local plan commission review its local zoning ordinances for conformity with the recommended land use plan, drawing upon the assistance of the Regional Planning Commission staff as may be necessary.

Floodlands: It is recommended that the five cities and one village within the watershed amend their zoning ordinances, as appropriate, to include special floodland regulations similar to those set forth in Appendix I of SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, as amended and improved through application throughout the Region. Such regulations, if properly adopted and enforced, will ensure the substantial maintenance in open uses of all undeveloped floodways and floodplains in the watershed. It should be noted that such floodland regulations are required in addition to any basic zoning district regulations, such as agricultural districts, park districts, and conservancy districts. At the present time, of the three communities in the watershed which have existing or potential flood hazard areas, only the City of Milwaukee has formulated and adopted a floodland zoning ordinance. The remaining two communities, the Cities of Cudahy and West Allis, must, pursuant to Section 87.30 of the Wisconsin Statutes, formulate and adopt an effective and reasonable floodland zoning ordinance as soon as the necessary flood hazard data, such as those provided by the Kinnickinnic River watershed study, become available. Failure to do so may result in the Wisconsin Department of Natural Resources acting to exercise state floodplain zoning powers, pursuant to Section 87.30 of the Wisconsin Statutes. Floodland regulations in those communities having substantial amounts of urban development already in the floodlands will require special attention and should be so constructed as to carry out the floodland management plan elements as discussed later in this chapter.

Conservation and Renewal: As noted in Chapter XI of this report, the Kinnickinnic River watershed is a heavily urbanized basin, with little potential for significant additional urban development. Thus, the focus of land use planning in the watershed should be on the preservation, revitalization, and enhancement of the existing urban development. Care should be taken in such planning, however, to adjust the land uses and, particularly, the location and the intensities of the uses to the watershed plan so that the water resource-related problems of the watershed are not aggravated. Specific growth management policies should be developed by the local units of government concerned relating to conservation and renewal, and such policies should include the delineation of existing neighborhood boundaries and the development of policies and programs to conserve and rehabilitate not only the residential portions but the commercial, industrial, and recreational components of neighborhoods. For example, a private organization, Historic

[8] *See SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000. Additional refinement of the land use pattern for the watershed was accomplished under the watershed study using the data provided by the 1975 regional land use inventory.*

Walker's Point, Inc., has been active in neighborhood preservation planning for the area bounded by 16th Street, Greenfield Avenue, Lake Michigan, and the Menomonee River Valley, and has received special foundation and private grants to work toward restoration of the historically significant area. The objectives of the organization are to revitalize the 19th Century workingman's neighborhood, stabilize the economy of the neighborhood, and rejuvenate the commercial area of the neighborhood. Among its projects to date are completion of an architectural survey with sites specifically marked and recognized by the National Registrar of Historic Places and the development of a park for the elderly.

Another example of redevelopment within the watershed is the Mitchell Street Project. The City of Milwaukee has recently been involved in the redevelopment of the W. Mitchell Street-W. Forest Home Avenue area into a public use district with a pedestrian mall. The objective of the redevelopment plan was to eliminate blight and obsolescence, prevent the development and spread of slums or blight, and foster redevelopment activities within the project area which are consistent with the sound needs and objectives of the community and surrounding area. The general renewal activities included acquisition of real property, demolition and removal of buildings; installation, construction, or reconstruction of site and project improvements; disposition (including sale or lease) of real property for redevelopment; and provision of land or easements for needed public and private improvements and utilities.

The land use plan contained a pedestrian mall, including pedestrian sidewalks, landscaped park and plaza areas, landscaped boulevard permitting one lane of traffic in each direction, and functional and/or ornamental fixtures, equipment, and facilities such as benches, shelters, kiosks, and lighting. Primary funding for both the Mitchell Street Project and Walker's Point redevelopment activities has been from the Community Development Block Grant Program.

In other areas of the watershed, neighborhood renewal site improvements, including sewer, water, paving, electrical, and forestry improvements, as well as the rehabilitation of neighborhood and community facilities, have also been undertaken.

It is recommended that these types of growth management policies be encouraged to continue to provide for the development of those physical improvements which are necessary for a safe, healthful, efficient, stable and aesthetically pleasing environment, especially in a "fully developed" area such as the Kinnickinnic River watershed. Actual plan implementation will be largely dependent upon the actions of local, county, state, and federal agencies and units of government concerned with redevelopment. In addition to these public agencies, certain quasi-public organizations and elements of the private sector can effect implementation of the plan.

Open Space Preservation Plan Subelement

The recommended open space preservation plan subelement of the Kinnickinnic River watershed plan is intended to protect all of the remaining net primary environmental corridor lands in the watershed. The net primary environmental corridor lands, as shown on Map 58 in Chapter XIV of this report are largely coincident with the public parks and parkways of the Milwaukee County Park System. Thus, these lands are considered permanently preserved. It is recommended that the Milwaukee County Park Commission continue to maintain and preserve these county-owned lands which comprise the net primary environmental corridor.

Outdoor Recreation Plan Subelement

The recommended outdoor recreation plan subelement of the Kinnickinnic River watershed plan addresses a broad range of outdoor recreation needs within the watershed. This subelement consists of a recreation corridor, large parks, small parks, nonresource-oriented recreation facilities, and water access facilities.

Recreation Corridor: The recreation corridor network proposed under the outdoor recreation plan subelement connects many of the existing major parks and would accommodate trails for such activities as hiking and biking. A four-mile segment of a recommended recreation corridor passes across the eastern end of the watershed a generally north-south direction. Since this corridor exists within an urbanized area, implementation of the proposed recreation corridor would rely heavily on the use of the Milwaukee County Park Commission's designated bicycle tour route over existing streets.

Large Parks: Under the outdoor recreation plan subelement, Type I and Type II parks are defined by the Commission as large, general-use, outdoor recreation sites which generally provide opportunities for such activities as camping, golfing, picnicking, and swimming and have a large area containing significant natural resource amenities. Within the watershed, Jackson Park is the only large park that meets these requirements. It is recommended that Jackson Park, presently publicly owned by Milwaukee County, continue to be maintained as a large park by the Milwaukee County Park Commission.

Small Parks: Type III and Type IV general-use outdoor recreation sites depend more upon the developmental characteristics of the area to be served than on the underlying natural resource base and amenities. It is recommended that all seven of the Type III parks existing within the watershed continue to be maintained by Milwaukee County. Of the nine existing Type IV parks, seven are presently owned by Milwaukee County, and it is recommended that the responsibility for the maintenance of those parks continue to be assumed by the County. For the remaining two Type IV parks—Adams playfield and Washington playground—which are owned and operated by the City of Milwaukee, it is recommended that they continue to be maintained by the City.

The outdoor recreation plan subelement also recommends the completion of two acquired but not fully developed Type IV neighborhood parks. One of these is a playlot located at S. 30th Street and W. Fordale Avenue in the City of Milwaukee, owned and operated by the City, and the other is Barnard Park in the City of Greenfield, owned and operated by Milwaukee County. It is recommended that this park development be completed by the appropriate agencies involved.

Three new Type IV neighborhood park lands within the urban area of the watershed, as shown on Map 58, are proposed to be acquired and developed by the plan design year 2000.[9] It is recommended that the County Park Commission, which has responsibilities for the provision of local parks as well as major parks and parkways, identify the exact location of these sites. As soon as the boundaries of these proposed parks have been determined, the sites should be appropriately zoned and located on local offical maps to ensure their preservation and availability for future acquisition by Milwaukee County.

Nonresource-Oriented Recreation Facilities: Implementation of the outdoor recreation plan subelement would result in the provision of additional intensive nonresource-oriented recreation facilities on existing or proposed Type III and Type IV park lands. The type and quantity of these facilities proposed for the watershed should be determined through a joint effort by the County, school districts, and the local community recreation agencies.

Water Access Facilities: The outdoor recreation plan subelement recommends the development of detailed engineering and environmental studies concerning the location of boat launching ramps and mooring facilities in the estuary portion of the watershed. It is recommended that the local units of government in the watershed, expecially Milwaukee County, undertake detailed planning and engineering studies and actual construction of harbor facilities. A possible location for such boat landing ramps and mooring facilities in the Kinnickinnic River watershed is the Chesapeake & Ohio Railroad land located on the west side of the Kinnickinnic River, south of E. Greenfield Avenue in the harbor area.

FLOODLAND MANAGEMENT PLAN ELEMENT IMPLEMENTATION

The major floodland management recommendation contained in the Kinnickinnic River watershed plan is the application of structural flood control measures to those riverine areas experiencing the most severe flood problems to abate existing and future flood problems. The floodland management plan element is divided into the following subelements: committed channel modifications, structural measures for flood damage abatement, bridge replacement, land use controls, flood insurance, lending institution and realtor policies, community utility policies and emergency programs, streamflow recordation, flood protection elevators for the Kinnickinnic River estuary area, and maintenance of stream channels and hydraulic structure waterway openings. The recommended implementation actions discussed under this plan element are summarized in Table 88, and a schedule of capital and operation and maintenance costs for this plan element are set forth in Table 83 in Chapter XIV of this report.

Committed Channel Modifications Subelement

It is recommended that the implementation of the committed channel modification subelement continue expeditiously through the cooperative efforts of the City of Milwaukee, the Milwaukee County Department of Public Works, and the Milwaukee-Metropolitan Sewerage Commissions. More specifically, it is recommended that: the City of Milwaukee carry out the necessary removal and replacement of bridges between S. 6th Street to S. 16th Street on the Kinnickinnic River inclusive; that the Milwaukee County Department of Public Works be responsible for the removal of the abandoned North Shore Railroad crossing; that the Milwaukee-Metropolitan Sewerage Commissions design and construct channel improvements on the Kinnickinnic River from S. 5th Street extended to S. 16th Street, including the low dikes and floodwalls necessary to provide two feet of freeboard under 100-year recurrence interval flood conditions; and that the Milwaukee-Metropolitan Sewerage Commissions design and construct channel improvements from S. 6th Street to W. Euclid Avenue on Wilson Park Creek.

It is further recommended that the Milwaukee County Department of Public Works and the Milwaukee County Park Commission cooperate fully in these channel improvements through the acquisition of necessary lands and the provision of attendant construction easements and rights-of-way.

Structural Measures for Flood Damage Abatement Subelement

It is recommended that the City of Cudahy request the Milwaukee-Metropolitan Sewerage Commissions to exercise their authority to deal with the storm and floodwater problems within the watershed affecting the community. In particular, it is recommended that the Milwaukee-Metropolitan Sewerage Commissions be authorized to construct and maintain the necessary works for enclosure of the Edgerton Channel in the City of Cudahy for approximately 0.8 mile from S. Whitnall Avenue downstream to the existing improved channel in General Mitchell Field.

Bridge Replacement Subelement

It is recommended that any public or private body constructing or financing new bridges or replacing existing bridges over the major stream channel system of the Kinnickinnic River watershed design and construct such

[9]*The cost implementation schedule is included in SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000, November 1977.*

bridges in accordance with the water control facility objectives and standards set forth in Chapter X of this report using the accompanying design methodology and criteria. The cost of bridge replacement and construction is not included in the recommended watershed plan since it is assumed that any structures requiring replacement will have served their useful life and will, in any case, require replacement for traffic safety and transportation system construction, operation, and maintenance purposes.

Land Use Controls Subelement

Floodland Regulations: It is recommended that the Cities of Cudahy, Milwaukee, and West Allis modify existing floodland and related regulations or prepare new floodland regulations based upon the flood hazard data and the floodland management concepts and recommendations set forth in this report.

It is further recommended that the floodland and floodland-related land use regulations be designed so as to accommodate existing development and to preserve sufficient conveyance capacity for the 100-year flood flow through delineation and preservation of a floodway, and require the floodproofing of all new urban development committed in the floodplain fringe.

Land Use Controls Outside of the Floodlands: It is recommended that the five cities and one village within the Kinnickinnic River watershed adopt land use controls outside of the floodlands as needed to achieve the recommended watershed land use plan for the year 2000. Such land use controls may take the form of or be incorporated into zoning, land subdivision, and sanitary and building ordinances. Land use controls outside of the floodlands should be viewed as an important floodland management measure for the watershed.

Flood Insurance Subelement

It is recommended that all cities and villages in the watershed continue to participate in the federal flood insurance program. It is further recommended that the U.S. Department of Housing and Urban Development, in cooperation with the Wisconsin Department of Natural Resources, authorize the conduct of insurance rate studies in the Cities of West Allis and Cudahy. It is also recommended that the contractors retained by the U.S. Department of Housing and Urban Development to conduct the flood insurance rate studies base those studies on the flood hazard data developed under this study. Finally, it is recommended that owners of property in flood-prone areas purchase flood insurance for protection against losses sustained in floods which may occur prior to the completion of committed and recommended flood control works.

Lending Institution and Realtor Policies Subelement

It is recommended that lending institutions continue to determine the flood-prone status of properties prior to the granting of a mortgage and that the principal source of flood hazard information be that compiled under the watershed planning program. It is also recommended that real estate brokers and salesmen and their agents continue to inform potential purchasers of property of any flood hazard which may exist at a site in accordance with the 1973 executive order by the Governor of Wisconsin.

Community Utility Policies and Emergency Programs Subelement

It is recommended that the policies of governmental units and agencies having responsibility for public utilities and facilities be designed to complement the floodland management regulations for the Kinnickinnic River watershed and the recommended primary environmental corridor subelement. It is further recommended that each watershed community develop procedures to provide floodland residents and other property owners with information about floods already in progress until flood control works are completed.

Streamflow Recordation Subelement

It is recommended that the U.S. Geological Survey continue to operate the continuous recorder gage temporarily installed at the N. 7th Street crossing of the Kinnickinnic River in Milwaukee. It is further recommended that the partial record station operated by the U.S. Geological Survey at S. 27th Street on the Kinnickinnic River continue to be operated and that the City of Milwaukee and the Milwaukee-Metropolitan Sewerage Commissions continue to maintain crest stage or staff gage networks to provide for the acquisition of high water data during flood events.

Flood Protection Elevations for the Kinnickinnic River Estuary Area Subelement

It is recommended that the Milwaukee-Metropolitan Sewerage Commissions set a new flood protection elevation of at least two feet above the 100-year recurrence interval peak flood stage profile for the year 2000 land use plan with committed channel modification conditions along the Kinnickinnic River in the estuary area downstream of Chase Avenue.

Maintenance of Stream Channels and Hydraulic Structure Waterway Openings Subelement

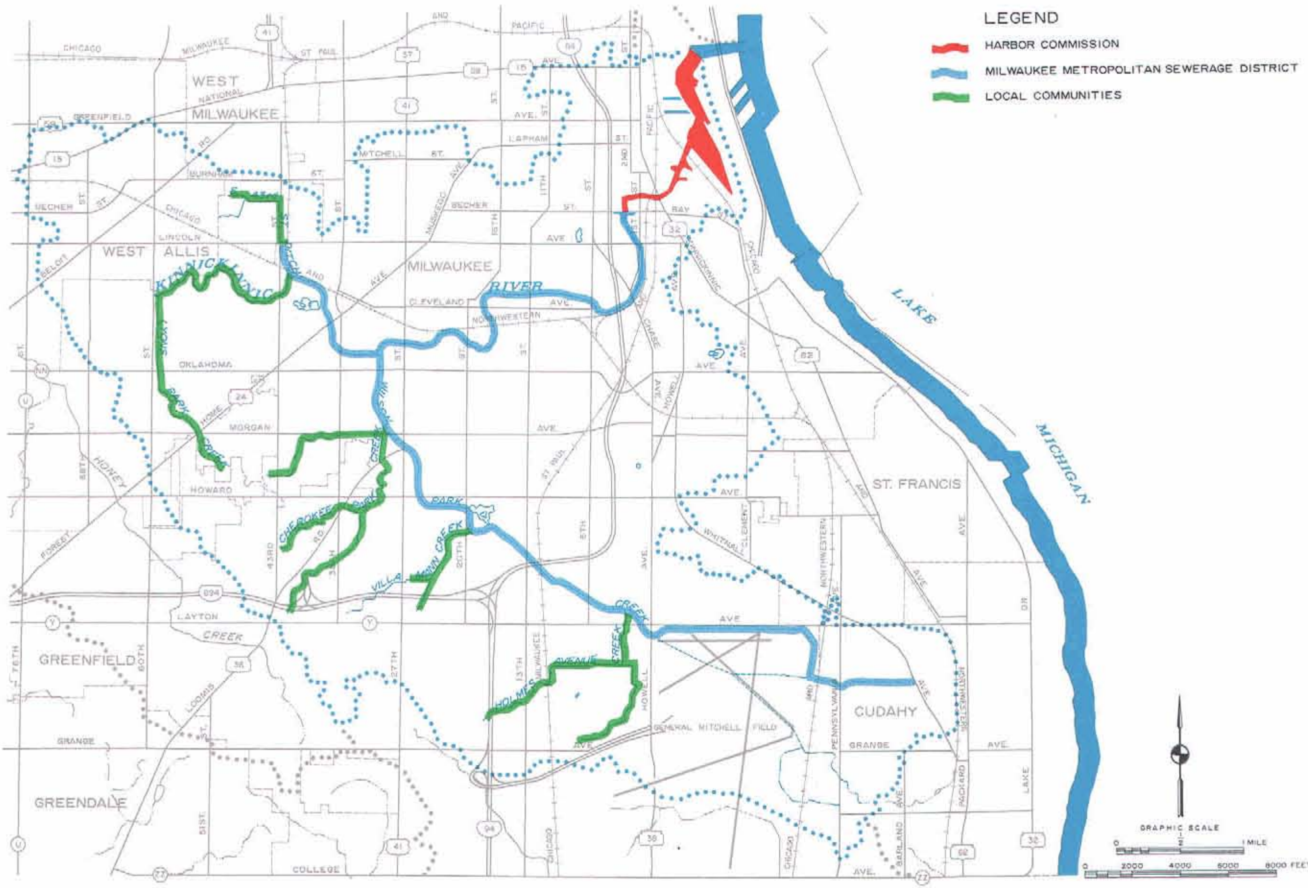
It is recommended that civil divisions and governmental agencies within the watershed affected by or having jurisdiction over the watershed stream system, as indicated on Map 59, carry out periodic cleaning and maintenance of both the stream channels and the bridge and culvert waterway openings.

WATER QUALITY MANAGEMENT PLAN ELEMENT

The water quality management plan element of the recommended comprehensive Kinnickinnic River watershed plan includes the completion of the long-range relief sewer construction program currently being conducted by the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee; implementation of the recommendations for a preliminary engineering study providing recommendations for the elimination of all combined sewer overflows emanating in the 4.5-square-mile combined sewer service area of the Kinnickinnic River water-

Map 59

RECOMMENDED CHANNEL MAINTENANCE JURISDICTIONS IN THE KINNICKINNIC RIVER WATERSHED



The watershed plan recommends the establishment of a program of periodic cleaning and maintenance of stream channels and the bridge and culvert waterway openings by those civil divisions and governmental units within the watershed having jurisdiction over the watershed stream system.

Source: SEWRPC.

shed; and elimination of all separate sanitary sewer flow relief device and industrial wastewater discharges in the watershed. The plan also recommends the institution of sound land management practices to control pollution from washoff from the land surface. Finally, the plan recommends the conduct of a continuing water quality monitoring program in the watershed. The water quality management plan element, for purposes of discussion, is divided into the following subelements: combined sewer overflow abatement, flow relief device elimination, industrial discharge abatement, diffuse source pollution control measures, and continuing water quality monitoring. The recommended water quality management plan element implementation actions are set forth in Table 88, and a schedule of capital and operation and maintenance costs for those subelements of this plan element not previously adopted under regional plans are set forth in Table 83 in Chapter XIV of this report.

Combined Sewer Overflow Abatement Subelement

It is recommended that pollution resulting from the 22 combined sewer overflows discharging to the Kinnickinnic River downstream of S. 27th Street be abated. A preliminary engineering study, called for in the adopted regional sanitary sewer system plan, is underway to provide recommendations for the abatement of the combined sewer overflow problem in the City of Milwaukee. It is proposed that the recommendations of that preliminary engineering study be implemented by the Milwaukee-Metropolitan Sewerage Commissions so as to result in the construction of the necessary facilities needed to abate the combined sewer overflow problem in the Kinnickinnic River watershed as well as in the neighboring Milwaukee and Menomonee River watersheds.

Flow Relief Device Elimination Subelement

It is recommended that the 30 separate sanitary sewer relief devices—crossovers, bypasses, and relief pumping stations—discharging directly or indirectly to the Kinnickinnic River and tributaries be controlled as called for in the adopted regional sanitary sewerage system plan. The watershed plan assumes the gradual elimination of flow relief devices through the Wisconsin Pollutant Discharge Elimination System (WPDES) administered by the Wisconsin Department of Natural Resources. It is anticipated that the Section 201 facilities plan currently under preparation by the Milwaukee-Metropolitan Sewerage Commissions will identify the specific measures required to eliminate these devices, together with the appropriate implementing agencies.

Industrial Discharge Abatement Subelement

It is recommended that the direct or indirect discharge of industrial wastes from 60 outfalls to the Kinnickinnic River and its tributaries be eliminated while allowing the continued discharge of clean waters meeting the recommended water quality standards. The watershed plan recommends that these discharges be controlled by the individual industries involved under the guidance of the Wisconsin Department of Natural Resources through administration of the Wisconsin Pollutant Discharge Elimination System.

Diffuse Source Pollution Control Measures Subelement

It is recommended that the communities within the watershed use a judicious blend of education and regulation to encourage citizens to apply low-cost measures such as control of litter and pet waste; proper application of chemical and organic fertilizers and pesticides to lawns and shrubbery; critical area protection; and, for remaining rural land uses, minimum conservation practices. It is also recommended that, through local building codes and inspection, soil erosion be strictly controlled by contractors during demolition and construction activities and that proper storage and runoff control be provided for facilities handling materials which may be hazardous to the environment. The University of Wisconsin-Extension should provide assistance in the public education process required to control litter and pet wastes and in the application of fertilizers and pesticides. The U.S. Soil Conservation Service should provide technical assistance in the development of specific diffuse source pollution control measures by local communities. It is further recommended that local public works departments examine the manner in which municipal services such as street and storm sewer system cleaning and maintenance and garbage collection are performed to determine if the amount of dust, dirt, and litter than accumulates on the road surfaces and adjacent areas and that is, therefore, subject to washoff to the stream system can be significantly reduced, particularly in advance of major runoff events, with marginal increases in cost. Finally, it is recommended that proper application and control of street deicing materials be practiced by the necessary agencies within the watershed to reduce the chloride loadings to surface waters.

Continuing Water Quality Monitoring Subelement

It is recommended that a water quality monitoring program be developed by the Milwaukee-Metropolitan Sewerage Commissions in coordination with the Wisconsin Department of Natural Resources for the watershed to demonstrate and document the changes in surface water quality attendant to plan implementation and to help detect and locate future alleged sources of pollution.

RELATIONSHIP OF THE WATERSHED PLAN TO ENVIRONMENTAL IMPACT STATEMENTS

Section 102(c) of the National Environmental Policy Act of 1969 requires the preparation by appropriate officials of detailed statements which assess the impact of the environment of nearly all development proposals and projects which in any way involve federal participation. Such statements must include an assessment of 1) the environmental impact of the proposed project, 2) any unavoidable adverse environmental effects, 3) alternatives to the proposed project, 4) the relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity, and 5) any irreversible and irretrievable commitments of natural resources caused by the proposed project. Such environmental impact statements are intended to provide an additional basis for the review of proposed capital improvement projects and are important in assuring that the decisionmaking process for federally aided public works of improvement includes adequate consideration of the potential effect of the project on the environment.

The inventory data, extensive analyses, alternative plan elements, and recommended comprehensive plan for the Kinnickinnic River watershed presented in summary form in this planning report constitute, in effect, a comprehensive environmental impact statement. In particular, positive and negative features of the various alternative subelements considered in synthesis of the comprehensive plan are discussed in Chapter XI, Chapter XII, and Chapter XIII. Furthermore, Chapter XIV contains an evaluation of the ability of the plan to meet the adopted objectives and standards and describes the likely negative consequences of not implementing the recommended plan.

As a comprehensive design for the preservation and protection of the natural resource base and for the maintenance and enhancement of the overall quality of the environment within the Kinnickinnic River watershed, the plan should provide a basis for preparation of future environmental impact statements with respect to specific proposals for land and water resource-related public works construction within the watershed. Moreover, each such future environmental impact statement should be carefully related to the recommended comprehensive watershed plan and should demonstrate how the particular project under consideration would assist in achieving the objectives, principles, and standards which underly and have formed the basis for the recommended comprehensive watershed plan.

FINANCIAL AND TECHNICAL ASSISTANCE

Upon adoption of the various land use, floodland management, and water quality management plan elements and any necessary schedules of capital costs and operation and maintenance expenditures, it becomes necessary for the areawide governmental agencies concerned and the local units of government within the watershed to utilize effectively all sources of financial and technical assistance available for the timely execution of the recommended plan elements. In addition to using current tax revenue sources, such as property taxes, fees, fines, public utility earnings, highway aids, educational aids, and state-collected taxes, the areawide agencies and local units of government can make use of such revenue sources as borrowing, special taxes and assessments, state and federal grants, and gifts. Various types of technical assistance useful in plan implementation are also available from county, state, and federal agencies. The type of assistance available ranges from the technical advice on land and water management practices provided by the U.S. Soil Conservation Service to the educational, advisory, and review services offered by the University of Wisconsin-Extension Service and the Regional Planning Commission itself.

Borrowing

Areawide agencies and local units of government are normally authorized to borrow so as to effectuate their powers and discharge their dutes. Chapter 67 of the Wisconsin Statutes generally empowers counties, cities, villages, and towns to borrow money and to issue municipal obligations not to exceed 5 percent of the equalized assessed valuation of their taxable property, with certain exceptions, including school bonds and revenue bonds. Such borrowing powers, which are related directly to implementation of the comprehensive Kinnickinnic River watershed plan, include the following:

1. Counties may issue bonds for county park and related open space land acquisition and development.

2. Cities and villages may borrow and issue bonds for the construction of water supply and distribution systems, for sewage treatment plants, and for park and related open space land acquisition and development.

3. The Metropolitan Sewerage District of the County of Milwaukee, consisting of the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee, is directed under Sections 59.96(6s) and 59.96(7) of the Wisconsin Statutes to prepare and submit to the Milwaukee County Board of Supervisors annually on or before September 1 a budget which need include only the anticipated expenditures for the coming year reduced by funds on hand and estimated revenues; thereupon, the Board of Supervisors is required and directed to provide for the amount so required. Milwaukee County has in the past provided substantial amounts for capital improvement through the issuance of bonds and may be expected to do so in the future.

Special Taxes and Assessments

Counties and cities have special assessment powers for park and parkway acquisition and improvements under Sections 27.065 and 27.10(4), respectively, of the Wisconsin Statutes. Counties are empowered under Section 27.06 of the Wisconsin Statutes to levy a mill tax to be collected into a separate fund and to be paid out only upon order of the county park commission for the purchase of land and other commission expenses. Most governmental units which have authority to provide for sanitary sewerage facilities have special assessment powers under various provisions of the Wisconsin Statutes. Cities and villages have such special assessment powers under Sections 62.18(16) and 61.39 of the Statutes; and Metropolitan Sewerage Districts have special assessment powers under Sections 59.96(9) and 66.25 of the Statutes.

Park and Open Space Land and Development Grants

Several federal grant programs are available to state and local units of government, and one state grant program is available to local units of government for the financing of park land acquisition and development. In general, the local units of government and agencies in the Region are eligible for these grants; however, the eligibility of individual projects is based upon certain planning and other prerequisites and must be determined for each specific project. The following is a brief description of these programs.

State Outdoor Resource Action Plan (ORAP) Program: This program, administered by the Wisconsin Department of Natural Resources, provides grants to all local units of government in amounts up to 50 percent of the cost of acquiring and developing recreational lands and rights-in-land to be used for local park and open space systems. Such state funds can also be used to help match federal funds.

Federal Land and Water Conservation (LAWCON) Fund Program: This program, administered by the U. S. Department of the Interior, Heritage, Conservation and Recreation Service through the Wisconsin Department of Natural Resources, provides grants to state and local units of government in amounts up to 50 percent of the cost of acquisition and development of outdoor recreation areas and facilities for the general public. These grants may be used for a wide range of outdoor recreation projects, such as picnic areas, inner city parks, campgrounds, tennis courts, boat launching ramps, bike trails, and outdoor swimming pools, and for support facilities such as roads, sewerage, and water supply. Priority consideration generally is given to projects serving urban populations.

Community Development Block Grants Program: This program, authorized under Title I of the Housing and Community Development Act of 1974, Public Law 93-383, and administered by the U.S. Department of Housing and Urban Development, consolidates seven former community development-type categorical programs and provides grants to local units of government for a variety of purposes, including the construction or improvement of public utilities and facilities, economic development activities, and housing rehabilitation. These grants are available as entitlement grants to urban counties as well as to cities with populations in excess of 50,000 and are available as "small city grants" to communities of less than 50,000 persons.

Water Quality Management Grants
One state and one federal grant program are available to local units of government for the financing of water systems, sewerage facilities, storm water drainage systems, and sewage treatment facilities. A brief description of these two programs follows.

State Water Pollution Prevention and Abatement Program: A new state water pollution prevention and abatement program was established in 1978. This program is referred to as the "Wisconsin Fund" and is administered by the Wisconsin Department of Natural Resources pursuant to rules set forth in Chapter NR 128 of the Wisconsin Administrative Code. The program provides financial assistance to local governments for the cost of approved pollution abatement and prevention projects. Eligible projects include waste treatment facilities; trunk, relief, and intercepting sewers; outfall sewers; certain sewage collection systems where new sewage treatment plants are being built in unsewered communities; and other appurtenances, only that portion of the project required to accommodate 10 years of development in the tributary area is eligible for assistance. It is anticipated that significant portions of all facility recommendations included in the water quality management element of the watershed plan would be eligible for state financial assistance. For nonfederally aided projects, the state grant may cover as much as 75 percent of the total cost of facilities planning activities, and up to 60 percent of the eligible costs of construction. For projects receiving federal aid, the state grant may be combined with federal assistance to provide a maximum of 75 percent of the eligible cost of the project.

Federal Waste Treatment Works Construction Program: This program, administered by the U.S. Environmental Protection Agency, provides federal financial assistance in an amount of 75 percent of the total cost of an approved project, or at even higher levels in a few select situations, where "alternative" or "innovative" technology is applied. Projects must be found to be in conformance with an approved facility plan and areawide water quality management or Section 303 basin plan, as applicable. It is anticipated that all facilities to be included in the areawide water quality management plan will be eligible for 75 percent federal assistance under this program.

State Water Quality Nonpoint Control Grants Program: As an element of the Wisconsin Fund, this program is administered by the Wisconsin Department of Natural Resources to provide grants for urban and rural nonpoint source controls. The grant share is not to exceed 50 percent of the cost of implementing the eligible land management practices. However, when combined with federal grant assistance, up to 70 percent grant shares may be provided.

Federal Water Resources Investigation Program
The U.S. Department of the Interior, Geological Survey, administers a cooperative water resources investigation program that provides federal matching funds in amounts up to 50 percent of the cost of projects under the program. This program includes the installation, calibration, operation, and maintenance of stream gage recording stations.

General Works Projects—U.S. Army Corps of Engineers
Substantial federal financial and technical assistance is available for the construction of approved flood control works under the general works projects program carried out by the U.S. Army Corps of Engineers upon U.S. Congressional approval of a particular project. After feasibility studies and public hearings, the U.S. Army Corps of Engineers will undertake the construction of such flood control works as levees, dams, and reservoirs. Costs for all lands, easements, and necessary rights-of-way and all other such costs, however, must be provided by the local unit of government in accordance with established cost-sharing policies. In addition, the local unit of government must agree to maintain and operate all facilities constructed under the program in accordance with regulations prescribed by the Secretary of the Army.

Technical Assistance
Certain federal, state, regional, and county agencies provide various levels and types of technical assistance useful in watershed plan implementation to local units of government upon request. Limited guidance and assistance are usually provided without cost, or such assistance may be provided for a nominal fee. In some cases the local unit of government may contract with the agency for more extensive technical assistance services. A summary of the various levels and types of assistance available by agency follows.

Federal Agencies: The U.S. Department of Agriculture, Soil Conservation Service, provides technical assistance to local units of government and soil and water conservation districts for resource conservation, development, and utilization programs. The Soil Conservation Service also provides technical assistance to local units of government in the adaptation of the detailed operational soil survey and interpretive analyses to urban planning and development problems under a "Memorandum of Understanding" with the Commission.

The U.S. Department of the Interior, Heritage, Conservation and Recreation Service, formerly the Bureau of Outdoor Recreation, provides limited technical assistance and advice to local units of government and private interests in historic preservation, conservation, and recreation resource planning and program.

The U.S. Environmental Protection Agency provides technical assistance and advice on request at no cost to state and local units of government and private firms relative to water quality problems.

State Agencies: The University of Wisconsin-Extension, through the county agents and extension specialists, provides important educational and technical assistance to farmers and to local units of government in public affairs, soil and water conservation, and outdoor recreation. One example of such university assistance having a direct relationship to watershed plan implementation is the educational services on the use and adaptation of the detailed operational soil survey and interpretive analyses being provided under the previously cited "Memorandum of Understanding" between the University and the Commission. Since the work of the Commission is entirely advisory, the importance of organized educational efforts directed at achieving public understanding and acceptance of the regional plans cannot be overestimated. The University Extension can, in this respect, fulfill an indirect, yet most important, plan implementation function.

The Wisconsin Department of Natural Resources provides advice on water problems; fish management; and forest planting, protection, management, and harvesting and will contract with counties to prepare outdoor recreation plans which would establish county eligibility under the Federal Land and Water Conservation program. The Wisconsin Department of Natural Resources also provides plan review services and supervision of the operation of public water supply and sewage treatment facilities and is authorized to provide technical assistance to local units of government and private groups in their efforts to initiate or engage in specific types of development, such as parks, recreation, resource development, water supply, and sewage disposal. The Department was recently authorized to extend assistance to local units of government for the purpose of securing uniformity of water resource protection regulations.

The State Board of Soil and Water Conservation Districts is authorized to provide assistance to landowners and to the county soil and water conservation districts in carrying out soil and water conservation practices.

Areawide Agencies: The Southeastern Wisconsin Regional Planning Commission, through its Community Assistance Division, provides limited educational, advisory, and review services to the local units of government, including participation in educational programs, such as workshops; provision of speakers; sponsorship of regional planning conferences; publication of bimonthly newsletters; selection of staff and consultants; preparation of planning programs; preparation of special base and soil mapping; preparation of suggested zoning, official mapping, and land division ordinances; provision of information regarding federal and state aid programs; and review of local planning programs, plan proposals, ordinances, and most state and federal grant applications. In addition, the Commission is empowered to contract with local units of government under Section 66.30 of the Wisconsin Statutes to make studies and offer advice on land use, transportation, community facilities, and other public improvements.

County Agencies: The county soil and water conservation districts are authorized to cooperate in furnishing technical assistance to landowners or occupiers and any public or private agency in preventing soil erosion and floodwater and sedimentation damage and in furthering water conservation and development.

SUMMARY

This chapter has described the various means available and recommended specific procedures for implementation of the recommended comprehensive Kinnickinnic River watershed plan. The most important recommended plan implementation actions are summarized in the following paragraphs by level of government, responsible agency or unit of government, and plan elements.

Federal Level

U.S. Department of Housing and Urban Development: It is recommended that the U.S. Department of Housing and Urban Development:

1. Endorse the comprehensive Kinnickinnic River watershed plan and use such plan as a guide in the administration and granting of federal aids for community development and in the administration of the national flood insurance program.

2. Assign the highest appropriate priorities to all applications for community development block grants that are in support of the acquisition and development of those park and open space sites recommended for public use in the plan.

U.S. Environmental Protection Agency: It is recommended that the U.S. Environmental Protection Agency accept the comprehensive Kinnickinnic River watershed plan upon state certification therefore, and utilize the plan as a guide in the following:

1. The administration and granting of federal aids for the construction of wastewater treatment facilities within the watershed.

2. The Development of urban storm water management systems programs and general permit issuance.

3. The administration of urban nonpoint source pollution controls and best-management practice identification programs.

4. The review of water quality standards developed by the Wisconsin Department of Natural Resources.

U.S. Department of the Interior, Heritage, Conservation and Recreation Service: It is recommended that the U.S. Department of the Interior, Heritage, Conservation and Recreation Service acknowledge the Kinnickinnic River watershed plan and utilize the plan in its administration and granting of aids under the Land and Water Conservation Fund Act.

U.S. Department of the Interior, Geological Survey: It is recommended that the U.S. Department of the Interior, Geological Survey, endorse the comprehensive Kinnickinnic River watershed plan and continue to maintain a cooperative program of water resources investigation in the watershed, including the continued operation of the one continuous stream gaging station and one low-flow gaging station in the basin.

U.S. Department of Agriculture, Soil Conservation Service: It is recommended that the U.S. Department of Agriculture, Soil Conservation Service, acknowledge the recommended Kinnickinnic River watershed plan and utilize the plan as a guide in the administration and granting of federal aids for resource conservation and development and for construction of multi-purpose watershed projects and best-management practices design and implementation within the Region and in the provision of technical assistance for land and water conservation practices in urban and rural areas.

U.S. Department of the Army, Corps of Engineers: It is recommended that the U.S. Department of the Army, Corps of Engineers, acknowledge the recommended Kinnickinnic River watershed plan and cooperate with any local or state units and agencies of government in any requests for assistance in implementation of the floodland management element of the Kinnickinnic River watershed plan.

State Level

Wisconsin Department of Natural Resources: It is recommended that the State Natural Resources Board and the Department of Natural Resources:

1. Endorse the comprehensive Kinnickinnic River watershed plan and direct its integration into the various conservation, park and outdoor recreation, environmental protection, water control, and technical and financial assistance programs conducted by various divisions of the Department.

2. Certify the Kinnickinnic River watershed plan to the U.S. Environmental Protection Agency as a river basin plan for state and federal planning purposes.

3. Conduct periodic water pollution control surveys of the Kinnickinnic River Basin including surveys for toxic and hazardous substances and reevaluate, amending as necessary, and enforce outstanding pollution control orders in accordance with pollution abatement recommendations, as set forth in the Kinnickinnic River watershed plan.

4. Endorse the recommended water quality management plan element for the Kinnickinnic River watershed, which seeks to abate pollution in the Kinnickinnic River stream system, and reflect such endorsement through the amendment of the water quality standards to those determined to be achievable under the watershed plan and through the continual review and amendment of permits issued under the Wisconsin Pollutant Discharge Elimination System.

5. Give due weight to the recommended Kinnickinnic River watershed plan in the exercise of the Department's various water regulatory functions, including approval of floodland regulations and the issuance of permits dealing with proposed river crossings and channel-floodplain alternatives.

6. Encourage Milwaukee County and local units of government in the watershed to follow the watershed plan recommendations relative to floodland and shoreland zoning when review is made of floodland and shoreland zoning ordinances prepared by such local units of government, pursuant to Sections 59.971 and 87.30 of the Wisconsin Statutes.

7. Assign the highest appropriate priorities to all Federal Land and Water Conservation (LAWCON) Fund and State Outdoor Resource Action Plan (ORAP) program local park aids applications for land located within the primary environmental corridors, or for lands recommended for acquisition by the regional park and open space plan.

8. Approve only such applications for state and federal aids in partial support of the construction and improvement of municipal pollution prevention and abatement facilities that are in general concurrence with the recommended Kinnickinnic River watershed plan.

9. Continue the operation and maintenance of the low-flow streamflow gage in cooperation with the U.S. Geological Survey.

Wisconsin Department of Transportation: It is recommended that the Department of Transportation give due weight to the recommended Kinnickinnic River watershed plan in its transportation facility planning and construction activities, with particular respect to the alignment of rights-of-way and replacement of bridge structures in the stream valleys of the watershed so that the flood control objectives of the watershed plan are achieved.

Wisconsin Board of Soil and Water Conservation Districts: It is recommended that the Wisconsin Board of Soil and Water Conservation Districts endorse the comprehensive Kinnickinnic River watershed plan, with particular respect to the recommended land use plan element, including the environmental corridor recommendations, as a guide in the coordination of county soil and water conservation district projects.

Areawide Level

Metropolitan Sewerage District of the County of Milwaukee: It is recommended that the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee, acting as agents for the Metropolitan Sewerage District of the County of Milwaukee:

1. Adopt the recommended Kinnickinnic River watershed plan, including the land use, floodland management, and water quality management elements.

2. Construct and maintain the recommended structural flood control works.

3. Continue their program of monitoring stream stages in the Kinnickinnic River watershed.

4. Clean and maintain, in cooperation with local units of government, stream channels and hydraulic structure waterway openings.

5. Eliminate overflow from separate and combined sewers under their jurisdiction.

Local Level

Milwaukee County Board of Supervisors: It is recommended that the Milwaukee County Board of Supervisors, upon the recommendation of the appropriate agencies and committees adopt the recommended Kinnickinnic River watershed plan as a guide to the future development of the watershed, which lies entirely within Milwaukee County, and direct its agencies and staff to integrate the plan recommendations into their activities.

County Park and Planning Agencies: It is recommended that the park and planning agencies for Milwaukee County:

1. Recommend to the county board adoption of the land use plan element, with its overall land use, open space preservation, and outdoor recreation plan subelements, of the recommended Kinnickinnic River watershed plan.

2. Refine the recommended regional park and open space plan and integrate the plan into any existing county park plans.

3. Assist in urban redevelopment activities to provide much-needed parks in certain fully developed areas of the watershed.

County Department of Public Works: It is recommended that the Department of Public Works of Milwaukee County participate in the implementation of the recommended structural flood control works.

Soil and Water Conservation District: It is recommended that the Soil and Water Conservation District of Milwaukee County:

1. Adopt the recommended Kinnickinnic River watershed plan as it affects the district and request cooperating federal and state agencies to provide such assistance as would serve to implement the recommended land use, park and open space, and water pollution abatement plan elements.

2. Formulate, as appropriate, soil and water conservation regulations necessary to assist in implementation of the recommended watershed land use and park and open space plan elements.

Common Councils and Village Boards: It is recommended that, upon referral to and recommendation of the local plan commission, each common council and village board within the watershed, as appropriate and as noted:

1. Support the establishment of the Kinnickinnic River watershed committee as a continuing intergovernmental coordinating body concerned with the Kinnickinnic River watershed plan adjustment and implementation.

2. Adopt the recommended Kinnickinnic River watershed plan as a guide to the future development of the community as that plan affects each community.

3. Adopt the regional land use and transportation plan.

4. Amend existing or adopt new local zoning ordinances so as to provide land use regulations similar to those contained in the SEWRPC Model Zoning Ordinance and adopt changes to the zoning district maps, as appropriate, to reflect the recommended land use plan element of the Kinnickinnic River watershed plan. Such regulations should include provisions for the discontinuance of nonconforming uses in the floodways of the watershed.

5. Amend or adopt land division ordinances, as appropriate, prohibiting further land division and development in the floodways and floodplains of the perennial channel system of the Kinnickinnic River watershed and assuring park plan dedication or fees in lieu of dedication.

6. Prepare and adopt or amend official maps showing, as appropriate, park and open space land use plan elements.

7. Include floodway, floodplain, and floodproofing regulations in local building, housing subdivison, and sanitary ordinances.

8. Continue to participate in the federal flood insurance program.

9. Continue to maintain and operate and establish and operate a system of gages for the procurement of high water data throughout the watershed.

10. Work with the Milwaukee-Metropolitan Sewerage Commissions and the Department of Natural Resources in eliminating flow relief devices.

11. Work with the Milwaukee-Metropolitan Sewerage Commissions and the Wisconsin Department of Natural Resources to clean and maintain stream channels and hydraulic structure waterway openings.

Plan Commissions of the Cities and Village: It is recommended that the plan Commissions of the five cities and one village within the watershed:

1. Adopt the watershed plan elements and certify such adoption to the governing body.

2. Formulate and recommend to their governing body amendments to their existing land use control ordinances to effectuate the land use plan elements of the watershed plan.

3. Prepare for submission to the governing body detailed local plans relative to the acquisition of park lands as recommended in the outdoor recreation plan subelement.

Chapter XVI

SUMMARY AND CONCLUSIONS

This report presents the major findings and recommendations of the Southeastern Wisconsin Regional Planning Commission Kinnickinnic River watershed planning program. The report first sets forth the basic concepts underlying the study and the factual findings of the extensive inventories conducted under the study. It identifies and, to the extent possible, quantifies the existing water-related developmental and environmental problems of the watershed, and sets forth forecasts of future economic activity, population growth, and land use and concomitant probable future water-related developmental and environmental problems. The report presents alternative plan elements relating to floodland management, pollution abatement, and land use, and sets forth a recommended plan for the development of the watershed and the resolution of its flood damage and water pollution problems based upon regional and watershed development objectives adopted by the watershed committee and the Commission. In addition, it contains financial analyses related to, and specific recommendations for, plan implementation.

STUDY ORGANIZATION AND PURPOSE

The Kinnickinnic River watershed study, which resulted in the preparation of this report, is the fifth comprehensive watershed planning program to be undertaken by the Southeastern Wisconsin Regional Planning Commission. This watershed study was undertaken within the statutory authority of the Commission and upon the specific request of the City of Milwaukee. The study was guided from its inception by the Kinnickinnic River Watershed Committee, an advisory committee to the Commission composed of 12 public officials, technicians, and citizen leaders from throughout the watershed. The technical work was carried out by the Commission staff with the assistance of cooperating governmental agencies, including the U. S. Department of the Interior, Geological Survey, and the Wisconsin Department of Natural Resources, and private consultants engaged by the Commission, including Hydrocomp, Inc., specialists in hydrologic simulation modeling, and Alster and Associates, Inc., photogrammetric and control survey engineers. The disciplines provided by the cooperating governmental agencies and private consultants included groundwater and surface water hydrology and hydraulics, ecology and natural resource conservation, simulation modeling, and control survey and photogrammetric engineering.

The study was founded upon the recognition by concerned public officials that such water-related resource problems as flooding and water pollution are directly and inextricably interrelated, not only with each other, but also with problems of areawide urbanization which transcend local governmental boundaries and that solutions to such areawide problems must be sought on a watershed basis. Therefore, the primary purpose of the Kinnickinnic River watershed planning program is to help abate the serious water resource and water resource-related problems of the Kinnickinnic River basin by developing a workable plan to guide the staged development of multipurpose water resource facilities and related resource conservation and management programs for the watershed. More specifically, the objectives of the planning program are to:

- Prepare a plan for the management of floodlands along the major waterways of the Kinnickinnic River watershed, including measures for the mitigation of existing flood problems and measures for the minimization of future flood problems.
- Prepare a plan for surface water quality management within the Kinnickinnic River watershed, incorporating measures to abate existing pollution problems and measures intended to prevent future pollution problems;
- Refine and adjust the regional land use and park and open space plans within the watershed to help promote a more rational adjustment of land uses to the surface water resources of the watershed.

The problems to be addressed in the watershed study were articulated by the Watershed Committee in the Prospectus for the study published in November 1974. An initial public hearing on the need for and proposed scope and content of the study held on March 9, 1977 reinforced the findings of the Watershed Committee that flooding and pollution were the two problems of greatest concern to residents of the watershed.

To be effective in abating problems of flooding, water pollution, and improper and changing land use within the watershed, the watershed plan was developed to be amenable to cooperative adoption and joint implementation by all levels and agencies of government concerned.

This report can only summarize briefly the large volume of information assembled in the extensive data collection, analysis, and forecasting phases of the Kinnickinnic River watershed study. However, all of the basic data are on file in the Commission offices and are available to member units and agencies of government and to the general public upon specific request. This report, therefore, serves the additional purpose of indicating the types of data which are available from the Commission and which may be of value in assisting federal, state, and local units of government and private investors in making better decisions about community development within the Region.

INVENTORY, ANALYSIS, AND FORECAST FINDINGS

Geography

The Kinnickinnic River watershed is a surface water drainage unit approximately 25 square miles in areal extent, wholly contained within Milwaukee County. The Kinnickinnic River from its source in the 2600 block of S. 60th Street in the City of Milwaukee flows easterly and northerly to a confluence with the Milwaukee River at a point about 0.3 mile upstream from Lake Michigan. The boundaries of the watershed and its salient hydrographic and cultural features are shown on Map 3 in Chapter III of this report. The watershed contains parts of five cities—Cudahy, Greenfield, Milwaukee, St. Francis, and West Allis—and parts of one village—the Village of West Milwaukee. These local units of government have the basic responsibility for land use control and land cover management within the watershed and for the provision of basic municipal services. The Metropolitan Sewerage District of the County of Milwaukee is responsible for the provision of sanitary trunk sewer service, sewage treatment, water pollution control, and drainage and flood control within the entire Kinnickinnic River watershed. The Milwaukee County Park Commission is responsible for providing park and related open space lands within the watershed. Certain state and federal government agencies, including, importantly, the Wisconsin Department of Natural Resources and the U.S. Environmental Protection Agency, also have important responsibilities for water resource conservation and management within the watershed.

Population and Economic Activity

The 1975 population of the watershed was estimated at about 165,000 persons, or about 16 percent of the population of Milwaukee County, and about 9 percent of the population of the Region. The resident population of the watershed is expected to decrease to about 160,000 persons by the year 2000, a decrease of about 5,000 persons, or 3 percent. Because of changing household size, however, this future resident population may be expected to reside in about 60,800 housing units, or about 7,400 more units than in 1975.

Employment in Milwaukee County and the watershed is expected to increase during the next three decades but at a rate less than that of the Region as a whole, reflecting a continued decentralization of economic activity from the established urban areas of the Region to suburban and rural locations. Employment within the watershed in 1972 totaled about 77,000 jobs and is expected to increase to about 84,000 jobs by the year 2000, an increase of about 7,000 jobs, or about 9 percent, over the 28-year period.

Land Use

The extent ot urban development within the Kinnickinnic River watershed is very high compared to any of the watersheds previously studied by the Commission, with about 24 square miles, or 92 percent of the total area of the watershed, being devoted to urban land uses in 1975. The dominant urban land use categories in the basin are residential and transportation-communication-utility facilities which encompass, respectively, 35 and 36 percent of the watershed area. The overall spatial distribution of land use in the watershed is shown on Map 8 in Chapter III of this report, and is characterized by high-density residential development in the northern three-fourths of the basin and medium-density residential development in the southern one-quarter. Retail sales and service land uses are scattered throughout the watershed, and concentrations of industrial and transportation-communication-utility facilities exist at various locations in the watershed including in the estuary area, in the Village of West Milwaukee, and in the southeastern corner of the watershed near General Mitchell Field.

The amount of land devoted to urban use within the watershed is forecast to increase from the 1975 total of 24 square miles to about 25 square miles, or almost all of the watershed by the year 2000. The increase of about one square mile of land in urban use will be satisfied primarily through conversion to urban use of existing "unused" open lands.

Public Utility Service and Transportation Facilities

The public utility base of the watershed is well developed. Electric power is supplied throughout the watershed by the Wisconsin Electric Power Company, natural gas service by the Wisconsin Gas Company and the Wisconsin Natural Gas Company, and sanitary sewerage service by the Metropolitan Sewerage District of the County of Milwaukee in cooperation with the local units of government. Public water supply utilizing Lake Michigan as the source is also available essentially throughout the watershed.

The Kinnickinnic River watershed is served by a well-developed surface transportation system consisting of a particularly good network of all weather streets and highways, including 8.3 lineal miles of freeway and extensive urban mass transit service. The watershed is traversed by a network of railway lines which provide freight service; one line also provides scheduled Amtrak passenger service between Milwaukee and Chicago. Commercial shipping operations, handling bulk material such as coal, salt, liquid cargoes, and scrap metals, utilize the Kinnickinnic River downstream of W. Becher Street in the City of Milwaukee. General Mitchell Field, the only air carrier airport in the seven-county planning Region, lies mostly within the watershed and was in 1978 served by eight major airlines—North Central, United, Eastern, Northwest Orient, Ozark, Hughes Airwest, Southern and Braniff.

Climate

The Kinnickinnic River watershed has a climate characterized by a progression of markedly different season because of its mid-continental location, far removed from the moderating effect of the oceans. An essentially continuous pattern of distinct weather changes occurring at about three-day intervals is superimposed on the seasonal pattern. Air temperatures in the watershed range from a daily average of about 20°F in January to 72°F in July, while the extremes range from a low of about -25°F to a high of approximately 105°F.

The average annual precipitation within the watershed is 30.1 inches, and the average total monthly precipitation ranges from a low of 1.25 inches in February to a high of 3.64 inches in June. The watershed receives, on the average, 44.3 inches of snow and sleet per year, which, when converted to its water equivalent, constitutes 15 percent of the total annual precipitation. The average annual snowfall ranges from a low of five inches to a high of approximately 109 inches. As a result of its proximity to Lake Michigan, the eastern part of the watershed experiences an average of about 10.7 inches more seasonal snow and sleet accumulation than does the western part of the watershed.

Prevailing winds follow a clockwise pattern over the seasons of the year, being generally northwesterly in the late fall and in winter, northeasterly in the spring, and southwesterly in the summer and early fall. Daylight hours in the basin range from a minimum of about nine hours on about December 22, to a maximum of about 15 hours on about June 21. During the summer months, about one-third of the days may be expected to be categorized as clear, one-third as partly cloudy, and one-third as cloudy. Greater sky cover occurs in the winter, when more than one-half of the days are classified as cloudy, with the remainder being approximately equally divided between partly cloudy and clear.

Physiography and Geology

The Kinnickinnic River watershed, which lies entirely within the Milwaukee urbanized area, is an irregularly shaped drainage basin, with its major axis lying in an approximately northeast-southwest direction. The watershed, which lies entirely within Milwaukee County, has a total area of approximately 25 square miles, with a length—measured from the northwest to the southwest extremity of the basin—of approximately 8.5 miles and a maximum width of about 5.5 miles. The Kinnickinnic River watershed is bounded on the north and west by the Menomonee River watershed, on the south by the Oak Creek watershed, and on the east by lands that drain directly to Lake Michigan.

The Kinnickinnic River has its source at the junction of a piped storm water drain and Lyons Park Creek in the 2600 block of S. 60th Street in the City of Milwaukee. The headwater areas of the watershed lie in the City of Milwaukee, the City of West Allis, and the City of Greenfield. From its source the river flows easterly through the Cities of West Allis and Milwaukee. Near S. 43rd Street in Jackson Park in the City of Milwaukee the Kinnickinnic River is joined by the S. 43rd Street ditch tributary, which drains an industrial area located in the southern part of the Village of West Milwaukee. From its junction with the S. 43rd Street ditch tributary, the Kinnickinnic River flows south and then east through the City of Milwaukee to be joined by the Wilson Park Creek tributary near S. 30th Street and the Kinnickinnic River Parkway in the City of Milwaukee. Wilson Park Creek drains portions of the Cities of Cudahy, Milwaukee, Greenfield, and St. Francis.

There are three streams tributary to Wilson Park Creek: Cherokee Park Creek, Villa Mann Creek, and Holmes Avenue Creek. The Cherokee Park Creek tributary drains the Cherokee Park area located in the northeastern portion of the City of Greenfield and joins the Wilson Park Creek near the 2900 block of W. Morgan Avenue. The Villa Mann Creek tributary drains part of the southern portion of the City of Milwaukee and joins the Wilson Park Creek near the 1800 block of W. Plainfield Avenue. The Holmes Avenue Creek tributary, which also drains the southern portion of the City of Milwaukee, joins Wilson Park Creek near the 200 block of W. Armour Avenue, just to the northwest of General Mitchell Field.

From its junction with the Wilson Park Creek tributary, the Kinnickinnic River continues to flow easterly through the City of Milwaukee to a point near Chase Avenue, and then flows northeasterly through the City of Milwaukee, joining the Milwaukee River-Lake Michigan estuary near W. Bruce Street extended and S. Jefferson Street extended. The river actually becomes part of the Lake Michigan estuary near the Kinnickinnic River flushing tunnel pumping station at S. Chase Avenue in the City of Milwaukee. The main channel of the Kinnickinnic River is navigable by large commercial vessels from its junction with the Milwaukee River to approximately W. Becher Street in the City of Milwaukee. The lower estuary portion of the Kinnickinnic River includes a number of slips in the area known as the municipal mooring basin, serving the industrial-commercial complex located in this area near the mouth of the Kinnickinnic River.

Watershed topography and physiographic features have been largely determined by the underlying bedrock and overlying glacial deposits. The Niagara Cuesta, on which the watershed lies, is a gently eastward sloping bedrock surface. Glacial deposits overlying the bedrock formations from the surface topography of the watershed consist primarily of gently sloping ground moraine—heterogeneous material deposited by the glacial ice. Surface elevations within the watershed range from a high of approximately 800 feet above National Geodetic Vertical Datum (Mean Sea Level Datum) in the City of Greenfield to approximately 580 feet above National Geodetic Vertical Datum in the harbor area, a maximum relief of 220 feet.

Wildlife and Wildlife Habitat

As a result of urban activity and the associated decrease in woodlands, wetlands, and other natural areas, wildlife habitat has been almost eliminated in the Kinnickinnic River watershed. The habitat that remains consists primarily of Milwaukee County parklands and other scattered small, open space areas. The remaining wildlife resources are particularly significant to the urban Kinnickinnic River watershed because of their recreational, educational, and aesthetic values, and because of the element of naturalness and diversity that they impart to the urban environment of the watershed.

Existing and Potential Park, Outdoor Recreation, and Related Open Space Sites

A total of 97 existing park, outdoor recreation, and related open space sites lie within the watershed, encompassing a combined area of 1,113 acres, or about 7 percent of the total area of the watershed. A watershedwide inventory indicated that no significant potential resource-oriented recreation and related open space sites remained within the watershed.

Environmental Corridors

The delineation of natural resource and natural resource-related elements produces an essentially lineal pattern of narrow, elongated areas which have been termed "environmental corridors" by the Commission. As of 1970, gross primary environmental corridors in the watershed occupied approximately 558 acres, or 3 percent of the watershed area, consisting mainly of the primary environmental corridor lands along the Kinnickinnic River which are largely coincident with the public parks and parkways of the Milwaukee County park system and are available for public recreational use. The continued preservation of these corridors in park and related open space uses is essential to maintaining the overall quality of the environment in the watershed.

Water Law

With the passage of the Federal Water Pollution Control Act Amendments of 1972, the U.S. Congress set in motion a series of actions which will have many ramifications for water quality management within the Kinnickinnic River watershed. Water use objectives and supporting water quality standards now are required for all navigable waters in the United States, and it is a national goal to eliminate the discharge of pollutants into the navigable waters by 1985. To meet this goal, the Act requires the enactment of specific effluent limitations for all point sources of water pollution to be enforced through a pollutant discharge permit system.

Responsibility for water quality management in Wisconsin is centered in the Wisconsin Department of Natural Resources. The Department is given authority to prepare long-range water resources plans, to establish water use objectives and supporting water quality standards applicable to all waters of the state, to establish a pollutant discharge permit system, and to issue pollution abatement orders. In addition, the Metropolitan Sewerage District of the County of Milwaukee has authority and responsibility extending over the entire Kinnickinnic River watershed for water pollution abatement, flood control, and the construction of sanitary trunk sewers and sewage treatment plants. The District, through its two Commissions, has historically engaged in a broad program of improving watercourses in the Kinnickinnic River watershed by widening and deepening such watercourses so as to accommodate the expected flow of storm and surface drainage waters from the areas involved.

Surface Water Hydrology and Hydraulics

Quantitative knowledge of the complex hydrologic cycle as it affects the watershed is necessary to assess the availability of surface water and groundwater for various uses and to improve the water resources management potential. The quantitative relationships between inflow and outflow, termed the hydrologic budget, were determined for the watershed. Precipitation is the primary source of water to the watershed and averages about 30 inches annually. Surface water runoff and evapotranspiration losses constitute the primary outflow from the basin. The average annual runoff approximates 15 inches, and the annual evapotranspiration loss also totals about 15 inches.

The streamflow and flood stage records available for the Kinnickinnic River stream system reveal two key characteristics of the watersheds' hydrologic-hydraulic system. First, major flood discharges in the watershed tend to result from rainfall events as opposed to either snowmelt or combined rainfall-snowmelt events. Second, as a result of extensive urbanization and the attendant large extent of impervious surface and extensive storm water drainage systems and channelization works, the response of the watershed to large rainfall events is rapid. Peak discharges near the lower end of the watershed generally occur within two hours after the initiation of an event.

Hydrologic-hydraulic information, including land use, channel slope, hydraulic structure, and channel modification data, was inventoried and analyzed for each of the subwatersheds and confirmed the relatively homogeneous character of this intensely urbanized basin. Approximately 15.5 of the 18.1 lineal miles of streams within the watershed were selected for development of detailed flood hazard information including discharge-frequency relationships, flood stage profiles, and mapped areas of inundation for selected flood recurrence intervals. Detailed data were obtained for 84 hydraulically significant bridges, culverts, sills, and drop structures, and 225 floodland cross-sections were prepared for that portion of the stream systems modeled under the Kinnickinnic River watershed study.

The Kinnickinnic River and its major tributaries form an integral part of the major storm water drainage system for an intensely urbanized area of Milwaukee County. The Kinnickinnic River and its major tributaries have been improved throughout most of their 18.1-mile length, with 4.2 miles of the main stem from S. 43rd Street to S. 6th Street being lined with Portland cement concrete; and 3.3 miles of Wilson Park Creek from the Kinnickinnic River main stem to W. Euclid Avenue, W. Morgan Avenue to S. 27th Street, and S. 13th Street to the Chicago & North Western Railway, being concrete-lined or enclosed in concrete box or corrugated metal pipe culverts. In addition, 2.2 miles of Wilson Park Creek from W. Euclid Avenue to W. Morgan Avenue and S. 27th Street have received interim improvements which include channel realignment, widening, and deepening. A total of 3.1 miles, or almost half of the 6.3 miles of the tributaries of the Lyons Park, Cherokee Park, Villa Mann, and Holmes Avenue Creeks and S. 43rd Street ditch, have undergone lined or enclosed channelization.

Water Resources Simulation Model

A quantitative analysis of watershed surface water hydrology, hydraulics, and water quality under existing and alternative future conditions is a fundamental requirement of any comprehensive watershed planning effort. Hydrologic-hydraulic-water quality-flood economics simulation, accomplished with a set of interrelated digital computer programs, is an effective way to conduct this quantitative analysis. The Water Resource Simulation Model developed primarily from existing computer programs for use in the Kinnickinnic River watershed planning program consists of the following five submodels: the Hydrologic Submodel, Hydraulic Submodel 1, Hydraulic Submodel 2, the Water Quality Submodel, and the Flood Economics Submodel.

The principal function of the Hydrologic Submodel is to determine the volume and temporal distribution of runoff from the land to the stream system using meteorological data and land data. Hydraulic Submodel 1 accepts as input the runoff from the land surface for each hydrologic land segment type in the watershed, as produced by the Hydrologic Submodel, aggregates these data with point source discharges and performs routing through the stream system, thereby producing a continuous series of discharge values at predetermined locations along the surface water system of the watershed. Hydraulic Submodel 2 computes flood stages attendant to flood flows of specified recurrence intervals as determined using Hydraulic Submodel 1. This permits the preparation of flood stage profiles to be used in the delineation of flood hazard areas and as input to the Flood Economics Submodel. The Flood Economics Submodel performs two principal functions: the calculation of average annual flood damages to floodland management measures such as floodproofing of structures and removal of structures; and the calculation of the cost of alternative flood control measures, including the cost of construction of alternative configurations such as earthen dikes and concrete floodwalls, and major channelization works. The Water Quality Submodel simulates at selected points throughout the surface water system the time-varying concentration, or levels, of water quality indicators including temperature, dissolved oxygen, fecal coliform bacteria, phosphate-phosphorus, total dissolved solids, carbonaceous biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, and chloride.

Many of the algorithms incorporated within the Water Resource Simulation Model are approximations of complex natural phenomena, therefore, it is necessary to calibrate the model. Calibration consists of comparing simulation results with historic fact and, if a significant difference occurs, making parameter adjustments so as to tailor the model to the natural and man-made features of the planning region and the watershed. The Hydrologic Submodel and Hydraulic Submodels 1 and 2 were successfully calibrated by comparing the simulated discharges to daily streamflows at the cooperatively maintained stream gaging station on the Kinnickinnic River gage at S. 7th Street and by comparing simulated stages to historic stages available at many locations around the watershed. The rational method was used to obtain flood flows for small urban catchments—about 0.5 square mile or less—because of the tendency for the model to underestimate peak flows from very small watersheds. A model sensitivity study indicated that there were no hydraulic structures on the simulated portion of the stream system that would constrict flood flows to the extent that peak discharges would be attenuated. The Water Quality Submodel was calibrated to the surface water system of the Kinnickinnic River watershed by means of data obtained from the Commission's 1976 Index Site Sampling Program.

Flood Characteristics, Damage and Risk

Flood damage and disruption in the Kinnickinnic River watershed have been largely a consequence of the failure to recognize and account for the relationships which exist between the use of land, both within and outside of the natural floodlands of the watershed, and the flood flow behavior of the stream system of the watershed. A distinction is drawn here between flood problems which are among the major water resource problems addressed in the watershed planning effort, and storm water inundation problems, which are beyond the scope of the Kinnickinnic River watershed planning program. Flood problems are defined as damaging inundation which occurs along well-defined rivers and streams as the direct result of water moving out of and away from those rivers and streams, and include both overland and secondary flooding. In contrast, storm water inundation problems are defined as damaging inundation which occurs when storm water runoff en route to rivers and streams and other low-lying areas encounters inadequate conveyance or storage facilities and, as a result, causes localized ponding and surcharging of storm and sanitary sewers.

Research of the available historic records indicated the occurrence of seven major floods in the Kinnickinnic River watershed. These major floods, each of which caused significant damage to property as well as disruption of normal social and economic activities in the watershed, were the floods of March 18, 1912, June 22, 1917, January 24, 1938, March 30, 1960, August 3, 1960, September 18, 1972, and April 21, 1973. Most of these flood events have been accompanied by scattered storm water inundation problems only indirectly related to the flood problem along the major stream. Flood problems have been concentrated along the 3.70-mile-long reach of the Kinnickinnic River bounded at the downstream end by S. 6th Street and at the upstream end by S. 43rd Street, and scattered less severe flood problems have been reported along the Wilson Park Creek and other tributaries.

Extensive channel modifications have been carried out along the Kinnickinnic River, Wilson Park Creek, Lyons Park Creek, and other tributaries in the watershed since 1952, and the historic record through the April 1973 flood experience suggests that these efforts have substantially reduced the flood hazards along the stream reaches affected.

The April 1973 flood was relatively severe in terms of flood discharge, with a peak flow estimated at 4600 cubic feet per second (cfs) and a recurrence interval of 60 years compared to 22 cfs average daily flow and a 100-year recurrence interval flow of 5,000 cfs on the Kinnickinnic River at S. 7th Street. The flood caused damage and disruption primarily along the S. 6th to S. 16th Street reach of the Kinnickinnic River. Due to the severe and urgent nature of the flooding problem in this reach, early in the

Kinnickinnic River watershed planning program the Watershed Committee recommended that the Milwaukee-Metropolitan Sewerage Commissions and the City of Milwaukee proceed immediately to carry out channel improvements in this reach, as outlined in a report by the U.S. Army Corps of Engineers in 1975, consisting of the removal without replacement of 10 and the removal and replacement of four bridges. In addition, the Committee recommended the construction of attendant low dikes and floodwalls as necessary to provide two feet of freeboard.

As already noted, the inventory of historic flooding indicates that rainfall, as opposed to snowmelt or rainfall-snowmelt combinations, has been the principal cause of major floods. This is particularly significant in the heavily urbanized Kinnickinnic River watershed because it means that, with the exception of the winter season, major floods can occur at any time of the year and, when they do occur, they will be characterized by rapid increases in discharge and stage, thereby offering minimal opportunity for advance warning to occupants of riverine areas. The potential risk to human life is illustrated in the historic flood record by several accounts of near drownings, with the threat to human life heightened in highly urbanized watersheds like the Kinnickinnic River watershed because of the proximity of people to the riverine areas, the "flashy" nature of the streams, and the high velocities and steep sidewalls characteristic of channelized reaches.

The principal type of damage experienced in the Kinnickinnic River watershed has been damage to structures—private residences and commercial buildings—and to their contents as a result of overland and attendant secondary flooding. Bridges and culverts and sections of roadways and sidewalks have been damaged by the erosive action of rapidly moving floodwaters so as to require extensive repair or complete rebuilding. A costly type of disruption associated with major flood events in the Kinnickinnic River watershed has been interruption of business activities, not only during flood events but during the postflood cleanup and repair period. In addition, the routine operations of governmental units are usually disrupted during flood events as public officials attempt to provide immediate relief to affected areas. The monetary flood risks attributable to both primary and secondary flooding caused by a 100-year recurrence interval flood occurring under existing conditions are estimated to approximate $9.0 million for the entire Kinnickinnic River watershed.

Surface Water Quality and Pollution

"Water Quality" encompasses the physical, chemical, and biological characteristics of the water. Water is deemed to be polluted when foreign substances caused by or related to human activity are in such a form and concentration so as to render the water unsuitable for a desired beneficial use. An assessment of a variety of data sources dating back to 1908 indicated that the surface waters of the watershed are severely polluted. Many forms of pollution—toxic, organic, nutrient, pathogenic, sediment, and aesthetic—are known to exist in the watershed. The studies indicated that the highest concentrations of pollution and the worst stream water quality conditions were more likely to occur during periods of wet weather—that is, on days when 0.1 inch or more of precipitation occurs—and high stream flows than during periods of dry weather and low stream flows. This may be attributed to the accumulation of pollutants on the surface of the highly urbanized watershed between runoff events and the subsequent transport of those pollutants to the stream system during runoff.

The most serious type of pollution present in the watershed is pathogenic, as evidenced by fecal coliform counts in excess of 50,000 counts per 100 milliliters in samples taken at S. 7th Street and at W. Forest Home Avenue on the Kinnickinnic River. The fecal coliform standard for recreational use is 400 counts per 100 milliliters. The second most serious pollution problem is that of toxic and hazardous substances—particularly heavy metals and PCB's—which together with the extensive channelization limit the development of any fishery in the watershed. Throughout the watershed the dissolved oxygen concentration was generally found to be above 5.0 milligrams per liter, the minimum concentration necessary for the maintenance of fish and aquatic life. In the lower reaches of the Kinnickinnic River, these good conditions generally occur only when the flushing tunnel at S. Chase Avenue is in operation, the dissolved oxygen concentration falling as low as 1.3 mg/l at other times.

The major sources of water pollution in the watershed include 22 combined sewer outfalls and 30 sanitary sewer flow relief devices which intermittently discharge raw sewage to the stream system. A total of 60 residential wastewater outfalls are known to exist within the watershed, but many of these discharge only cooling waters. These point sources of pollution together account for about one-half of the pollution load imposed on the stream system of the watershed. These point sources of pollution generally discharge to the river system only in periods of wet weather.

Diffuse, or nonpoint source, pollution consists of various discharges of pollutants to the surface waters that cannot be traced to specific discrete sources but rather that are carried to the surface waters by means of surface runoff from the land during and after runoff events. Diffuse or nonpoint sources of pollution account for about half of the pollution load imposed on the surface waters of the Kinnickinnic River watershed. A disproportionately large quantity of biochemical oxygen demand, phosphate-phosphorus, total phosphorus, total nitrogen, and dissolved solids is contributed during wet weather conditions. Although wet weather conditions occur on only about 18 percent of the days of the year, they account for well over half of the percent of pollutants transported from the basin.

It is estimated that, due to the urbanizing nature of the Kinnickinnic River watershed, the erosion of sediment from the land surface of the watershed results in the transport of about 450 tons per square mile per year of sediment from the basin by the Kinnickinnic River. The transport of sediment in this quantity can result in water quality problems and other problems including the need to conduct maintenance dredging in the navigable downstream portion of the watershed.

When the flushing tunnel is operating, estuary water quality approximates that of the water being pumped from Lake Michigan and is superior to that of the Kinnickinnic River upstream of the estuary. When the Kinnickinnic River estuary flushing tunnel is not in operation, the most significant water quality effects are low to substandard dissolved oxygen levels and an increase in chloride levels. Atmospheric fallout and washout may be a significant source of the loads of particulate matter, total phosphorus, and nitrogen ultimately carried by the surface water from the Kinnickinnic River watershed. High chloride levels noted in the surface waters of the watershed at all times of the year are most likely attributable to deicing salt applied to the streets and highways in the basin.

The quality of the surface waters in the Kinnickinnic River watershed does not satisfy the standards in the support of the adopted water use objectives. Improvement of surface water quality in the Kinnickinnic River watershed so as to achieve the water use objectives will require a watershedwide water quality management effort aimed at abatement of both point and nonpoint sources of pollution.

WATERSHED DEVELOPMENT OBJECTIVES

The primary objective of the Kinnickinnic River watershed planning program is to assist the local, state, and federal units and agencies of government in abating the serious water and water resource-related problems existing within the Kinnickinnic River basin by developing a workable plan to guide the staged development of multipurpose water resource facilities and related resource conservation and management programs for the watershed. The principal problems to be addressed include flood damage and water pollution, and changing land use as it relates to these two problems.

Following determination of present and probable future conditions within the watershed, a framework of watershed development objectives and supporting principles and standards was established to guide the design of the alternative floodland management measures and the water quality management plan for the watershed and to provide a basis for evaluation of the relative merits of these alternatives. This framework of watershed development objectives and standards envisions a future watershed environment that is safe, healthful, and more pleasant, as well as a more orderly and efficient environment for all life within the watershed.

With respect to water use objectives, the Wisconsin Department of Natural Resources currently classifies the waters of the Kinnickinnic River stream system for restricted use. The water quality standards attendant to that use objective are intended only to protect the public health and to permit the maintenance of the most tolerant life forms. In conformance with the national water quality objectives cited in Public Law 92-500, the water use objectives and supporting water quality standards initially developed under the watershed planning program were intended to permit use of essentially all of the surface waters of the Kinnickinnic River watershed for full body contact recreation and for support of a warmwater fishery.

The inventories and plan design investigations conducted under the watershed study indicated that the attainability of the federally mandated "warmwater fishery and aquatic life, recreational use, and minimum standards" water use objective initially established for the Kinnickinnic River watershed is affected by several factors. The existing and committed channel modifications for flood control, which result in concrete-lined channels, have a significant detrimental effect on the benthic flora and fauna necessary to establish and maintain any fishery. These channel improvements are irrevocable in the sense that they are a necessary working solution to the widespread and costly flooding problems caused by the historic development for urban use of the floodplains of the watershed and by the increased runoff and peak flood discharges produced by the extensive urbanization in the watershed. The inventories and design studies indicated that the water use objectives and supporting water quality standards corresponding to the "limited fishery and aquatic life, limited recreational use, and minimum standards" objectives, as established under the Commission areawide water quality management planning program, are more realistic for the Kinnickinnic River watershed than the originally proposed objectives and standards. The water use objectives and supporting water quality standards of the watershed plan were amended to reflect these findings as allowed under Public Law 92-500. The amended water use objectives and supporting water quality standards are intended to permit use of essentially all of the surface waters of the Kinnickinnic River watershed for partial body contact recreation and for support of a limited fishery.

ALTERNATIVE PLAN SUBELEMENTS

In the preparation of the comprehensive plan for the physical development of the Kinnickinnic River watershed, a concerted effort was made to offer for public evaluation a full range of physically feasible alternative plan subelements which might resolve existing water resource and water resource-related problems and prevent future development of such problems within the framework of the adopted watershed development objectives and supporting standards. The alternative floodland management subelements and the alternative water quality management subelements were evaluated insofar as possible in terms of technical and economic feasibility, likely environmental impact, financial and legal feasibility, and public acceptability and with respect to the satisfaction of the watershed development objectives. The land use plan element was extracted from the adopted regional land use plan and the adopted regional park and open space plan, both of which included evaluations in terms of the technical, economic, environmental, financial, and legal feasibility and public acceptability and with respect to the satisfaction of specified development objectives.

Alternative Floodland Management Subelements

The available floodland management measures from which the floodland management plan element was synthesized under the watershed planning process may be broadly subdivided into two categories: structural measures and nonstructural measures. A total of five structural floodland measures were identified for possible application, either individually or in various combinations, to specific flood-prone reaches of the watershed: 1) floodwater storage facilities, 2) floodwater diversion facilities, 3) dikes and floodwalls, 4) major channel modifications, and 5) bridge and culvert modification or replacement. The eleven nonstructural measures identified for possible inclusion in the floodland management element include: 1) reservation of floodlands for recreational and related open space uses, 2) floodland regulations, 3) control of land use outside of the floodlands, 4) structure floodproofing, 5) structure removal, 6) channel maintenance, 7) flood insurance, 8) lending institution policies, 9) realtor policies, 10) community utility policies, and 11) emergency programs.

A hydrologic and hydraulic flood flow simulation model was used to qualitatively evaluate the effect of the planned land use and committed channel modifications on the flood flow behavior of the Kinnickinnic River watershed. This analysis indicated that, due to the planned land use and the committed channel modifications, peak flood flows at the watershed outlet could be expected to increase by 60 percent, a relatively small increase compared to those found in developing but less urbanized areas, due to the high degree of urbanization already present in the watershed.

The results of a historic flood survey combined with the results of the hydrologic-hydraulic simulation indicated that only one reach, that on Wilson Park Creek—Edgerton Channel—in the City of Cudahy, would have a significant flooding problem after the completion of the committed channel modifications. Various combinations of structural and nonstructural floodland measures were evaluated for this reach, resulting in the selection of a compatible combination of measures for inclusion in the watershed plan.

In addition to determining the applicability of the various structural and nonstructural floodland management measures, the plan preparation process examined accessory floodland management measures that could meet special needs within the watershed. Accessory floodland management measures that were considered include the maintenance of streamflow gages in the watershed, the periodic cleaning and maintenance of the channel system, and the identification of the flood characteristics of the estuary and lower reaches of the Kinnickinnic River.

Alternative Water Quality Management Subelements

The preparation of the water quality management plan element emphasized the refinement and extension of water quality recommendations made under other Commission studies. These adopted plan elements have previously recommended that the Milwaukee-Metropolitan Sewerage Commissions undertake an extensive preliminary engineering study directed at providing specific recommendations for the abatement of combined sewer overflows in the entire combined sewer service area—an engineering study that is currently underway. In addition, the adopted plan elements recommended the gradual abatement of pollution from sewage flow relief devices through the construction of necessary metropolitan and local relief and trunk sewers.

Under the watershed study, a series of water quality simulation applications was conducted in order to determine the likely consequences on stream water quality of the planned development conditions and alternative reductions in the diffuse source pollutant loading rates. These analyses indicated that little change in water quality over the watershed may be expected under the year 2000 land use plan and committed channel improvement conditions. Furthermore, an evaluation, using the simulation model, of two water quality management alternatives consisting of a 25 percent and a 50 percent reduction in diffuse source pollutant loading rates indicated that only modest improvements in water quality would be achieved with the higher reduction. A recently developed empirical method was used to determine the pollution potential of subbasins in the watershed based on the natural and cultural features of the subbasins.

RECOMMENDED WATERSHED PLAN

Alternative plan subelements were evaluated individually in various compatible combinations and, as a result, a comprehensive watershed plan was synthesized consisting of a land use element, a floodland management element, and a water quality management element. The resultant comprehensive watershed development plan, which is recommended for adoption as a guide for the physical development of the Kinnickinnic River watershed contains the following salient proposals.

Land Use Plan Element

The recommended land use plan element for the Kinnickinnic River watershed consists of a land use plan subelement, an open space preservation plan subelement, and an outdoor recreation plan subelement. More specifically, the recommended land use plan element proposes the following measures:

1. Implementation of the recommended regional land use plan for the year 2000 adopted by the Commission in 1977. This land use plan subelement, shown on Map 44 in Chapter XI of this report, would meet the social, physical, and economic needs of the future watershed population by allocating sufficient land to each of the various major land use categories to satisfy the known and anticipated demand for each use. While the highly developed value of the watershed does not allow for significant additional urban development, sound land use planning is particularly important in the watershed to preserve the positive aspects of the existing land use pattern and to resolve those negative aspects, including environmental problems, that detract from the

overall quality of life in this highly urbanized basin. Under the recommended plan, the anticipated demand for urban land uses would be accommodated by the conversion of about one square mile of existing "unused" open lands, and as may be necessary and desirable, renewal and redevelopment of existing urban areas.

2. The open space preservation plan subelement recommends continued maintenance and preservation of the 325 acres of existing net primary environmental corridors along the Kinnickinnic River from S. 16th Street to S. 69th Street, and protection through public land use regulation of that portion of the Lake Michigan shoreline primary environmental corridor, about 232 gross acres, crossing the eastern limits of the watershed, as shown on Map 44 in Chapter XI of this report.

3. The outdoor recreation plan subelement recommends the development of the four-mile segment of a recommended recreation corridor passing across the eastern end of the watershed in a generally north-south direction; the continued maintenance of Jackson Park—a large, general-use, outdoor recreation site; the continued use of 16 existing community and neighborhood parks partially or wholly within the watershed; the completion of the development of two neighborhood parks; the acquisition and development of three new neighborhood parks; and detailed engineering and environmental studies concerning the location of boat launching ramps and mooring facilities in the estuary portion of the watershed. In addition, this subelement recommends the development of urban outdoor recreation facilities for community and neighborhood parks, the type and quantity of which would be based on a more detailed study of neighborhood needs.

Floodland Management Plan Element

The recommended floodland management plan element for the Kinnickinnic River watershed consists of a carefully selected combination of structural and nonstructural measures. More specifically, the recommended floodland management plan element proposes the following 13 measures:

1. Completion of the committed flood control works on the Kinnickinnic River and Wilson Park Creek consisting of: the removal without replacement of 10 and the removal and replacement of four bridges, and the construction of attendant earthen dikes and concrete floodwalls and channel improvements as necessary to provide two feet of freeboard in that reach of the Kinnickinnic River between S. 5th Street extended and S. 16th Street; and channel improvements along Wilson Park Creek from W. Euclid Avenue to S. 6th Street, all as shown on Map 47 and Map 47A in Chapter XII of this report.

2. Implementation of a structural floodland management subelement for the City of Cudahy, as shown on Map 57 in Chapter XIV consisting of the enclosure of the channel for 0.8 mile from S. Whitnall Avenue downstream to the existing improved channel in General Mitchell Field.

3. Replacement or modification of two bridges and culverts on the major stream system of the Kinnickinnic River watershed, Chase Avenue and S. 43rd Street on the Kinnickinnic River, which have inadequate hydrologic-hydraulic capacity as manifested by overtopping of the approach road during specified major flood events, so as to eliminate interference with the desirable operation of the highway and railroad transportation system. This replacement or modification would be gradually accomplished as river crossings are replaced or modified for transportation system improvement or maintenance purposes.

4. Design of all new or replacement river crossings within the watershed so as to satisfy the applicable objectives and standards adopted under the study. Of particular importance is the standard which requires that all new replacement crossings be designed so as to accommodate 100-year recurrence interval flood events under year 2000 plan conditions without raising the peak discharge more than 0.1 foot above the peak stage for the 100-year recurrence interval flood as established in the watershed plan.

5. Modification of existing floodland and related regulations or preparation of new such regulations by the Cities of Cudahy, Milwaukee, and West Allis based upon the new flood hazard data and the floodland management concepts and recommendations set forth in this report. The regulations recommended for the 15.5 miles of watershed stream system in these communities are intended to recognize the commitment to urban development that already exists while preserving a sufficient floodway area to provide for the safe conveyange of the 100-year recurrence interval flood flow.

6. Continuation of the significant steps that have already been taken by watershed communities toward participation in the federal flood insurance program in the form of authorization by the U.S. Department of Housing and Urban Development, in cooperation with the Wisconsin Department of Natural Resources, of insurance rate studies in the Cities of West Allis and Cudahy. It is further recommended that contractors retained by the U.S. Department of Housing and Urban Development to conduct the flood insurance rate studies base those studies on the flood hazard data developed under the watershed program. Finally, the watershed plan recommends that owners of property in flood-prone areas purchase flood

insurance so as to provide some financial relief for losses incurred in floods which may occur prior to completion of committed flood control works.

7. Continuation by lending institutions of the policy of determining the flood-prone status of properties prior to the granting of a mortgage. It is further recommended that the principal source of flood hazard information be that developed under the watershed planning program.

8. Continuation of the policy by real estate brokers and salesmen and their agents to inform potential purchasers of property of any flood hazard which may exist at a site. It is further recommended that the principal source of flood hazard information be that developed under the watershed planning program.

9. Adoption of policies by governmental units and agencies having responsibility for public utilities and facilities—such as water supply, sewerage, streets, and highways—that complement the floodland management recommendations for the Kinnickinnic River watershed.

10. Development of emergency procedures by watershed communities to provide floodland residents and other property owners with information about floods already in progress. The flood information procedures would be necessary until committed channel modifications are completed and might be selected from the following: monitoring of National Weather Service broadcasts during periods of rainfall or snowmelt, patroling of riverine areas to detect rising stages and bankfull conditions, broadcasting of emergency messages over local radio and television stations, use of police patrol cars or other vehicles equipped with public address systems, and use of warning sirens—particularly during nighttime hours.

11. Maintenance of a basic stream gaging network within the watershed consisting of continued operation of one continuous recorder gage that was temporarily installed for purposes of the Kinnickinnic River watershed study at the S. 7th Street crossing of the Kinnickinnic River; continued operation of the partial record station operated by the U.S. Geological Survey in cooperation with the Wisconsin Departments of Transportation and Natural Resources at S. 27th Street on the Kinnickinnic River; and continued maintenance of crest stage or staff gage networks by the City of Milwaukee and the Milwaukee-Metropolitan Sewerage Commissions.

12. Establishment of a program to carry out periodic cleaning and maintenance of both stream channels and of the bridge and culvert waterway openings by those civil divisions and governmental units within the watershed affected by or having jurisdiction over the watershed stream system.

13. Establishment of a new flood protection elevation at least two feet above the 100-year recurrence interval peak flood stage profile under the year 2000 land use plan conditions along the lower Kinnickinnic River.

Water Quality Management Plan Element

The recommended plan proposes the abatement of surface water pollution problems within the Kinnickinnic River watershed through the following six measures:

1. Implementation, through construction of the necessary facilities, of the recommendations contained within the preliminary engineering study currently being completed by the Milwaukee-Metropolitan Sewerage Commissions concerning the abatement of pollution from the 22 known combined sewer outfalls in the lower reaches of the Kinnickinnic River watershed.

2. Gradual elimination through trunk and relief sewer construction and other measures within the framework of the recently instituted Wisconsin Pollutant Discharge Elimination System of the 30 known sanitary sewer system flow relief devices—crossovers, bypasses, and relief pumping stations—discharging directly or indirectly to the Kinnickinnic River and tributaries during wet weather.

3. Gradual abatement of pollution from the 60 industrial discharges to the Kinnickinnic River and its tributaries under provisions contained within the Wisconsin Pollutant Discharge Elimination System.

4. An approximately 25 percent reduction in nonpoint source pollution through implementation of the following land management measures: proper material storage and runoff control on industrial and commercial sites; control of sediment and debris during demolition and construction activities; street deicing material control; public education programs to promote proper use of fertilizers and pesticides; pet waste and litter control ordinances; the application of minimal soil conservation practices to the rural land remaining in the watershed; and stream bank erosion control.

5. Implementation of measures designed to control additional sources of toxic and hazardous substances, including accidental spills and intermittent discharges through surface and floor drains connected to storm sewers and surface waters.

6. Incorporation into the water quality management plan element of the water quality monitoring

program recommendations being developed under the areawide water quality planning and management program.

ACHIEVEMENT OF OBJECTIVES AND STANDARDS

In its most basic sense, planning is a rational process for establishing and meeting objectives. The objectives and supporting standards adopted for the Kinnickinnic River watershed constitute the overall goals of the comprehensive plan, and the degree to which those objectives and standards are likely to be satisfied provides a measure of the success of the plan preparation process. Accordingly, an evaluation was conducted of the comprehensive plan based on its ability to meet the watershed development objectives and standards.

The relatively small number of standards identified that cannot be met or can only be partially met under the recommended comprehensive plan for the Kinnickinnic River watershed support objectives that are inextricably related to the underlying natural resource base. The failure to fully meet those standards reflects the already deteriorated condition of the underlying natural resource base of this urbanizing watershed. It appears physically impossible to fully achieve some of the standards because the necessary natural resource base elements are no longer present in sufficient quantity and quality.

In summary, the recommended watershed plan could result in substantial achievement of the adopted watershed development objectives and standards and, as a result, implementation of the plan may be expected to provide a safer, more healthful, and more pleasant, as well as a more orderly and efficient, environment for all life within the watershed.

CONSEQUENCES OF NOT IMPLEMENTING THE RECOMMENDED PLAN

The recommended comprehensive plan for the Kinnickinnic River watershed provides, within the framework of the adopted watershed development objectives and standards, the best combination of measures for resolving such water resource and water resource-related problems as flooding, water pollution, diminishing quality of the natural resource base, and changing land use that presently plague the watershed or may be expected to do so in the future. In the absence of such a sound comprehensive plan, a multitude of incorrect decisions may be made and courses of action are likely to be followed that will lead to the aggravation of existing water resource and water resource-related problems, as well as the development of new problems. Accordingly, an analysis was conducted to identify and, where feasible, to quantify the likely consequences of not adopting and implementing the recommendations contained within the watershed plan. This analysis of negative consequences was intended primarily to support and reinforce the need for implementing the recommended rational, long-range, comprehensive plan for the urbanizing Kinnickinnic River watershed.

Likely consequences of not implementing the recommended comprehensive plan for the Kinnickinnic River watershed include:

- Loss of recreational, aesthetic, and cultural values found in park and open space lands.
- Lack of recreation lands to meet demand which results as the leisure time, as well as the environmental awareness, of residents increases.
- Continuation of average annual flood damage risks of $47,000 per year or more in the City of Cudahy and about $670,000 per year or more in the City of Milwaukee as the result of failure to implement the recommended primarily structural flood control measures.
- Potential for monetary flood losses of $240,000 or more in the City of Cudahy and about $8.7 million or more in the City of Milwaukee under a 100-year recurrence interval flood event as the result of failure to implement the recommended flood control measures.
- Continued and increased interference with the safe and efficient operation of highway and railroad facilities during flood events as a result of failure to implement the bridge replacement and bridge design recommendations contained within the watershed plan.
- Incurrence of high monetary flood losses by owners of flood-prone structures and property as a result of failure to participate in the federal flood insurance program.
- Acquisition of flood-prone lands and structures by unwary buyers as a result of failure to continue the desirable lending institution and realtor policies concerning the full disclosure of the flood vulnerability of riverine-area land structures.
- Incurrence of unnecessary damage to property as well as unnecessary risks to the safety and well being of property owners as a result of failure by flood-prone communities to adopt emergency measures to be invoked during flood events.
- Incurrence of public health hazards including risk of contacting toxic materials and infectious diseases as a result of failure to abate combined sewer overflow, eliminate separate sanitary sewer flow relief devices and industrial waste discharges, and implement diffuse source pollution control measures.
- Input of organic materials and resulting dissolved oxygen depletion and interference with maintenance of warmwater fishery as a result of failure to eliminate municipal sewage treatment plants and implement land management practices.

- Loss of the opportunity to monitor the effects of future development in the watershed and to ultimately refine the simulation modeling as a result of failure to implement the stream gaging recommendations.

COST ANALYSIS

In order to assist public officials in evaluating the recommended comprehensive Kinnickinnic River watershed plan, a summary of the costs of applicable adopted regional plans was presented and a preliminary capital improvement program for watershed plan elements with attendant operation and maintenance costs was prepared which, if followed, would result in total watershed plan implementation by the year 2000. Capital costs and operations and maintenance expenditures assigned to the Kinnickinnic River watershed plan exclude the cost of pollution abatement measures recommended in the adopted regional sanitary sewerage system plan for implementation within the Kinnickinnic River watershed, since these costs were included in the sewerage system plan. There are no costs directly required for implementation of the recommended land use plan element because park and open space acquisition costs and facilities development costs recommended for the watershed are included in the implementation plan of the regional park and open space study.

The preliminary capital improvement program includes the staging of the necessary land acquisition and facility construction and the distribution of the attendant costs including operation and maintenance expenditures over a 22-year period. This expenditure program is presented in summary form for the watershed as a whole in Table 83 in Chapter XIV of this report. The ultimate adoption of capital improvement programs for implementation of the watershed plan will require a determination by the responsible public officals of not only those plan subelements which are to be implemented, and the timing of such implementation, but of the principal beneficiaries and available best means of financing.

The full capital investment and operation and maintenance costs of implementing the recommended comprehensive plan for the Kinnickinnic River watershed are estimated at $10.2 million over the 22-year plan implementation period. Of this total cost, about $5.0 million, or about 49 percent, is required for implementation of the recommended floodland management element, and about $5.2 million, or about 51 percent, is required for implementation of the diffuse source pollution control measures subelement of the recommended water quality management element.

The average annual cost of capital investment and operation and maintenance required for plan implementation would be approximately $462,600, or about $2.84 per capita per year over the 22-year plan implementation period. The average annual cost of implementation of the floodland management plan element and the water quality management plan element, respectively, would approximate, respectively $224,800, or about $1.38 per capita, and $237,800 or $1.46 per capita.

In order to assess the possible impact of implementation of the watershed plan on the public financial resources of the local units of government within the watershed, an analysis was made of recent public expenditures for major channel modifications for comparison to the cost associated with the recommended comprehensive plan for the watershed. Expenditures by the Milwaukee-Metropolitan Sewerage Commissions and the City of Milwaukee for channel modifications within the Kinnickinnic River watershed for the 18-year period from 1960 through 1977 total approximately $8.0 million, or an average of approximately $500,000 per year. Because the estimated total cost of implementing the structural measures contained within the floodland management plan element of the Kinnickinnic River watershed plan is $5.9 million, with an average of $1,680,000 per year recommended to be expended during an intensive four-year construction phase, it may be concluded that sufficient monies to implement this element of the plan should be available within the watershed.

Based upon the public financial resource analysis made under the watershed planning program and under the regional sanitary sewerage system and regional park and open space planning programs, it may be concluded that the cost of implementing the watershed plan would be reasonably achievable by continuing the approximate current public expenditure patterns and trends for park and outdoor recreation purposes, flood control, and pollution abatement. It is clear that if the adopted watershed development objectives and standards are to be met, and if the associated desired environmental quality within the watershed is to be achieved and maintained, the level of expenditures needed to implement the recommended watershed plan is necessary and fully warranted.

IMPLEMENTATION

The legal and governmental framework existing within the Kinnickinnic River watershed is such that existing state, areawide, county, and local units of government can readily implement all of the major recommendations contained in the comprehensive Kinnickinnic River watershed plan; that is, no significant additional statutory authority, governmental agencies, or institutional arrangements are needed to implement the plan. A comprehensive, cooperative, intergovernmental plan implementation program has been prepared which indicates the specific action which will be required by each level, agency, and unit of government operating within or having responsibility within the watershed if the recommended watershed plan is to be fully implemented.

At the local level, plan implementation entities include the governing bodies of the five cities and one village within the watershed, Milwaukee County, and the soil and water conservation district. At the areawide level, the plan implementation entity is the Metropolitan Sewerage District of the County of Milwaukee. At the state level, implementation entities include the Wisconsin Departments of Natural Resources and Transportation and the Wisconsin Board of Soil and Water Conservation

Districts. At the federal level, plan implementation entities include the U.S. Department of Housing and Urban Development; the U.S. Environmental Protection Agency; the U.S. Department of the Interior, Heritage, Conservation and Recreation, and Geological Survey; the U.S. Department of Agriculture, Soil Conservation Service; and the U.S. Department of the Army, Corps of Engineers.

Primary emphasis in Kinnickinnic River watershed plan implementation is based upon actions by the Wisconsin Department of Natural Resources; the Metropolitan Sewerage District of the County of Milwaukee; the County Board of Milwaukee County; and individual municipal units of government.

The specific plan implementation responsibilities suggested for each level, agency, and unit of government operating within or having responsibilities within the Kinnickinnic River watershed are set forth in the summary section of Chapter XV of this report and in Table 88 of that chapter. In the final analysis, implementation of the recommended Kinnickinnic River watershed plan must proceed in a comprehensive, fully coordinated fashion with the assistance and cooperation of all affected levels, units, and agencies of government within the watershed.

CONCLUSION

Although the cost of adopting and implementing the recommended comprehensive watershed plan for the Kinnickinnic River basin and the related pollution abatement measures included in the adopted regional sanitary sewerage system plan may appear high, the cost of not doing so would be even higher. This is true measure not only in monetary terms but in terms of an irreversible deterioration of the natural resource base and a decline in the overall quality of the environment and, hence, the overall quality of life within the watershed. Failure to act upon the plan recommendations in a timely manner will inevitably commit local units of government within the watershed to an unnecessary expenditure of large amounts of public funds for future corrective measures.

Adoption and implementation of the recommended comprehensive plan for the Kinnickinnic River watershed may be expected to result in the substantial achievement of the adopted watershed development objectives and standards. As a result, implementation of the plan may be expected to provide a safer, more healthful, and more pleasant, as well as more orderly and efficient, environment for all life in the watershed. Implementation of the recommended plan would abate the most serious and costly environmental problems of the watershed, including flooding and water pollution, and would minimize the development of new problems.

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APPENDICES

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Appendix A

KINNICKINNIC RIVER WATERSHED COMMITTEE

Robert J. Mikula, Chairman	Director of Parks, Recreation, and Culture, Milwaukee County Park Commission
Edwin J. Laszewski, Jr., Vice-Chairman	City Engineer, City of Milwaukee
Kurt W. Bauer, Secretary	Executive Director, SEWRPC
Raymond T. Dwyer	City Engineer, City of Greenfield
Anthony A. Pitrof	Manager of Systems Planning Engineering, Milwaukee-Metropolitan Sewerage Commissions
Stanley Polewski	Proprietor, Polewski Pharmacy, Milwaukee
Ronald J. Rutkowski	Director of Public Works, City of Cudahy
Rodolfo N. Salcedo	Environmental Scientist, Department of City Development, Milwaukee
Frank C. Schultz	District Engineer, Wisconsin Department of Natural Resources
John E. Schumacher	City Engineer, City of West Allis
Frank J. Wabiszewski	Vice-President, Maynard Electric Steel Casting Company, Milwaukee
Henry B. Wildschut	County Highway Commissioner and Director of Public Works, Milwaukee

The following individuals also participated actively in the work of the Committee during preparation of the watershed plan: Irving Heipel, Landscape Architect, Milwaukee County Park Commission; James E. Foley, Airport Engineer, Milwaukee County Department of Public Works; William Manske, Sewer Research Engineer, Department of Public Works, City of Milwaukee; and Donald G. Wieland, Director of Engineering, Milwaukee-Metropolitan Sewerage Commissions.

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Appendix B

RAINFALL AND RUNOFF DATA FOR STORM WATER DRAINAGE AND FLOOD CONTROL FACILITY DESIGN

Table B-1

POINT RAINFALL INTENSITY-DURATION-FREQUENCY EQUATIONS FOR MILWAUKEE, WISCONSIN[a]

Recurrence Interval (years)	Equation[b]	
	Duration of 5 Minutes or More But Less Than 60 Minutes	Duration of 60 Minutes or More Through 24 Hours
2	$i = \frac{87.5}{15.4 + t}$	$i = 28.9\ t^{-0.781}$
5	$i = \frac{120.2}{16.6 + t}$	$i = 38.2\ t^{-0.776}$
10	$i = \frac{141.8}{17.1 + t}$	$i = 44.2\ t^{-0.772}$
25	$i = \frac{170.1}{17.8 + t}$	$i = 52.3\ t^{-0.771}$
50	$i = \frac{190.1}{18.0 + t}$	$i = 57.3\ t^{-0.768}$
100	$i = \frac{211.4}{18.4 + t}$	$i = 63.5\ t^{-0.768}$

[a] *The equations are based on Milwaukee rainfall data for the 64-year period of 1903 to 1966. These equations are applicable, within an accuracy of 10 percent, to the entire Southeastern Wisconsin Planning Region.*

[b] *i = Rainfall intensity in inches per hour.*
t = Duration in minutes.

Source: SEWRPC.

Table B-2

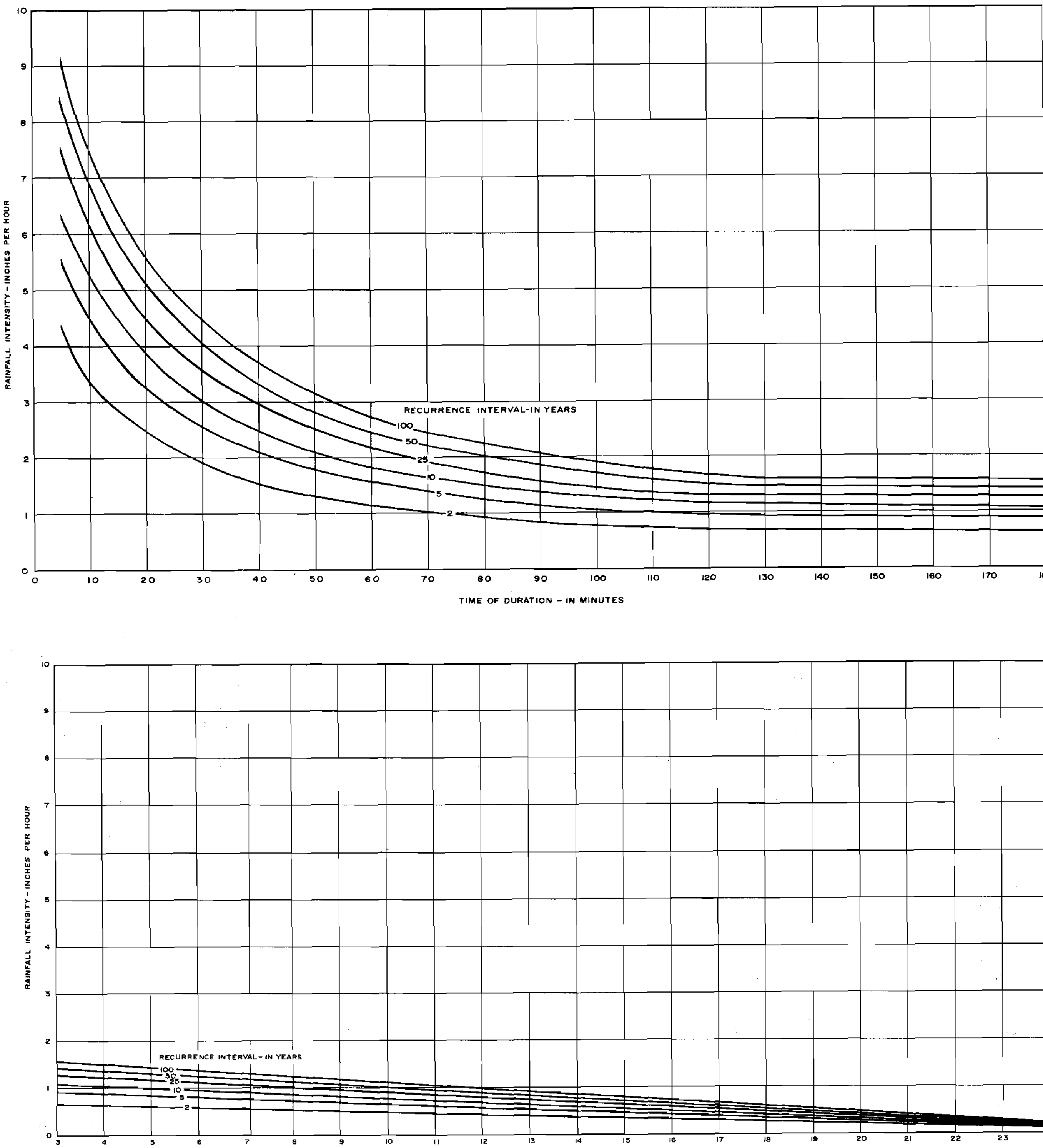
WEIGHTED RUNOFF COEFFICIENTS FOR USE IN THE RATIONAL FORMULA

Land Use	Percent Impervious Area	Hydrologic Soil Group											
		A			B			C			D		
		Slope Range (percent)			Slope Range (percent)			Slope Range (percent)			Slope Range (percent)		
		0 - 2	2 - 6	6 & Over	0 - 2	2 - 6	6 & Over	0 - 2	2 - 6	6 & Over	0 - 2	2 - 6	6 & Over
Industrial.	90	0.67 0.85	0.68 0.85	0.68 0.86	0.68 0.85	0.68 0.86	0.69 0.86	0.68 0.86	0.69 0.86	0.69 0.87	0.69 0.86	0.69 0.86	0.70 0.88
Commercial . . .	95	0.71 0.88	0.71 0.89	0.72 0.89	0.71 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.90	0.72 0.89	0.72 0.89	0.72 0.90
High-Density Residential. . . .	60	0.47 0.58	0.49 0.60	0.50 0.61	0.48 0.59	0.50 0.61	0.52 0.64	0.49 0.60	0.51 0.62	0.54 0.66	0.51 0.62	0.53 0.64	0.56 0.69
Medium-Density Residential. . . .	30	0.25 0.33	0.28 0.37	0.31 0.40	0.27 0.35	0.30 0.39	0.35 0.44	0.30 0.38	0.33 0.42	0.38 0.49	0.33 0.41	0.36 0.45	0.42 0.54
Low-Density Residential. . . .	15	0.14 0.22	0.19 0.26	0.22 0.29	0.17 0.24	0.21 0.28	0.26 0.34	0.20 0.28	0.25 0.32	0.31 0.40	0.24 0.31	0.28 0.35	0.35 0.46
Agriculture. . . .	5	0.08 0.14	0.13 0.18	0.16 0.22	0.11 0.16	0.15 0.21	0.21 0.28	0.14 0.20	0.19 0.25	0.26 0.34	0.18 0.24	0.23 0.29	0.31 0.41
Open Space . . .	2	0.05 0.11	0.10 0.16	0.14 0.20	0.08 0.14	0.13 0.19	0.19 0.26	0.12 0.18	0.17 0.23	0.24 0.32	0.16 0.22	0.21 0.27	0.28 0.39
Freeways and Expressways. . .	70	0.57 0.70	0.59 0.71	0.60 0.72	0.58 0.71	0.60 0.72	0.61 0.74	0.59 0.72	0.61 0.73	0.63 0.76	0.60 0.73	0.62 0.75	0.64 0.78

Source: SEWRPC.

Figure B-1

POINT RAINFALL INTENSITY-DURATION-FREQUENCY CURVES FOR MILWAUKEE, WISCONSIN[a]
(ARITHMETIC SCALES)

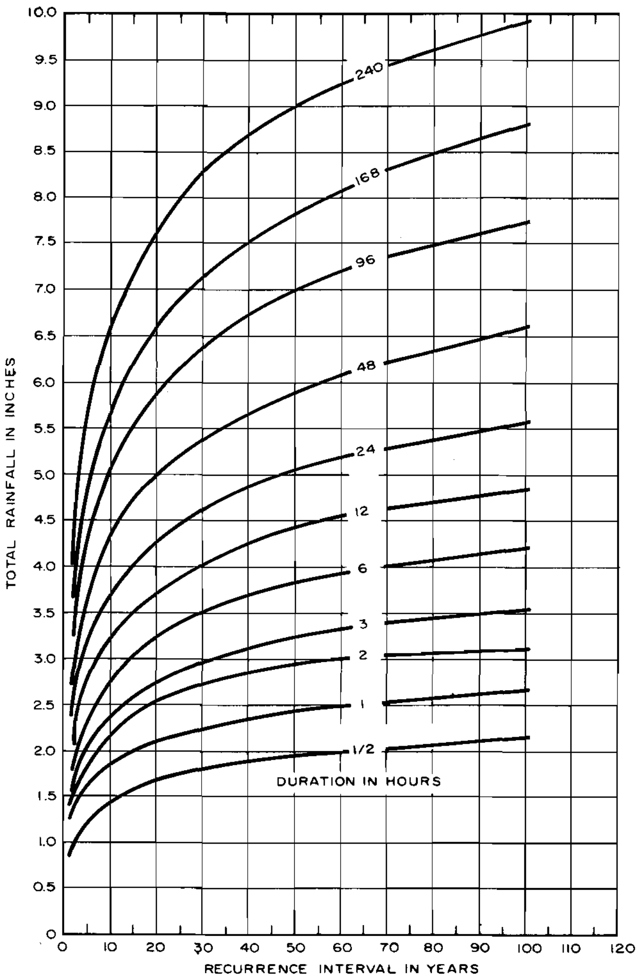


[a] The curves are based on Milwaukee rainfall data for the 64-year period of 1903 to 1966. These curves are applicable within an accuracy of ± 10 percent to the entire Southeastern Wisconsin Planning Region.

Source: SEWRPC.

Figure B-2

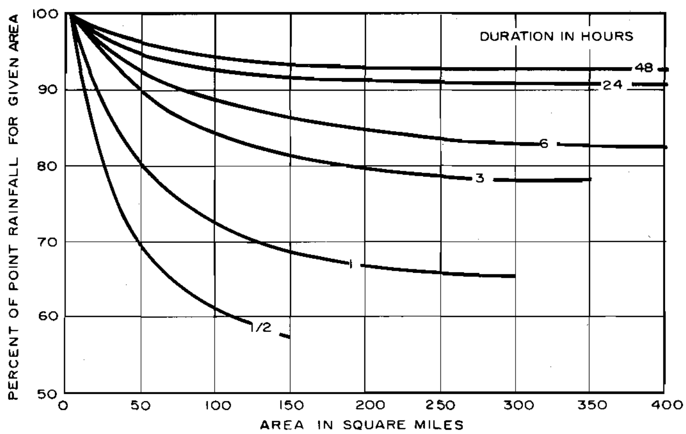
POINT RAINFALL DEPTH-DURATION-FREQUENCY RELATIONSHIPS IN THE REGION AND THE KINNICKINNIC RIVER WATERSHED



Source: National Weather Service and SEWRPC.

Figure B-3

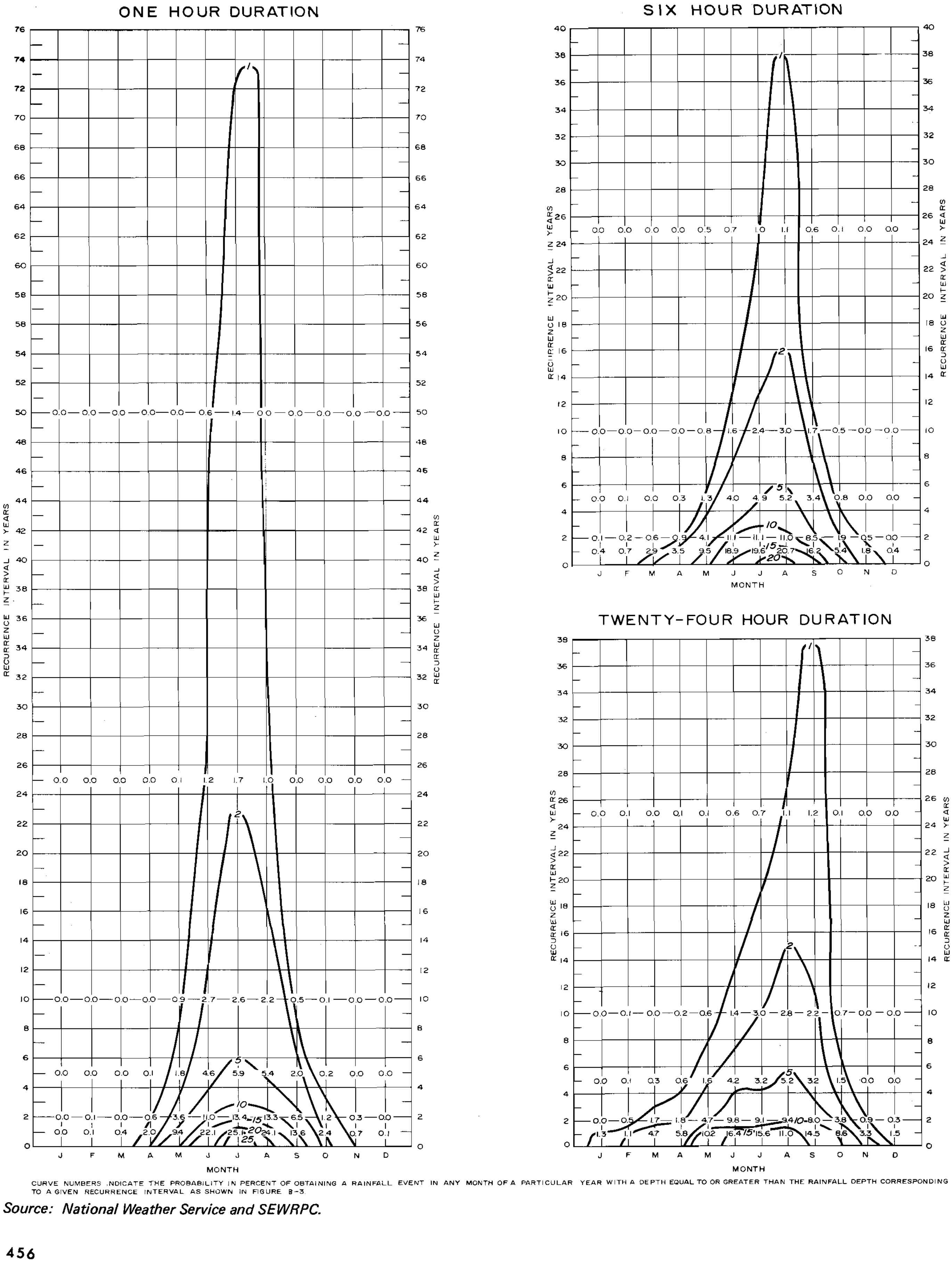
RAINFALL DEPTH-DURATION-AREA RELATIONSHIPS IN THE REGION AND THE KINNICKINNIC RIVER WATERSHED



Source: National Weather Service and SEWRPC.

Figure B-4

SEASONAL VARIATION OF RAINFALL EVENT DEPTH IN THE REGION AND THE KINNICKINNIC RIVER WATERSHED

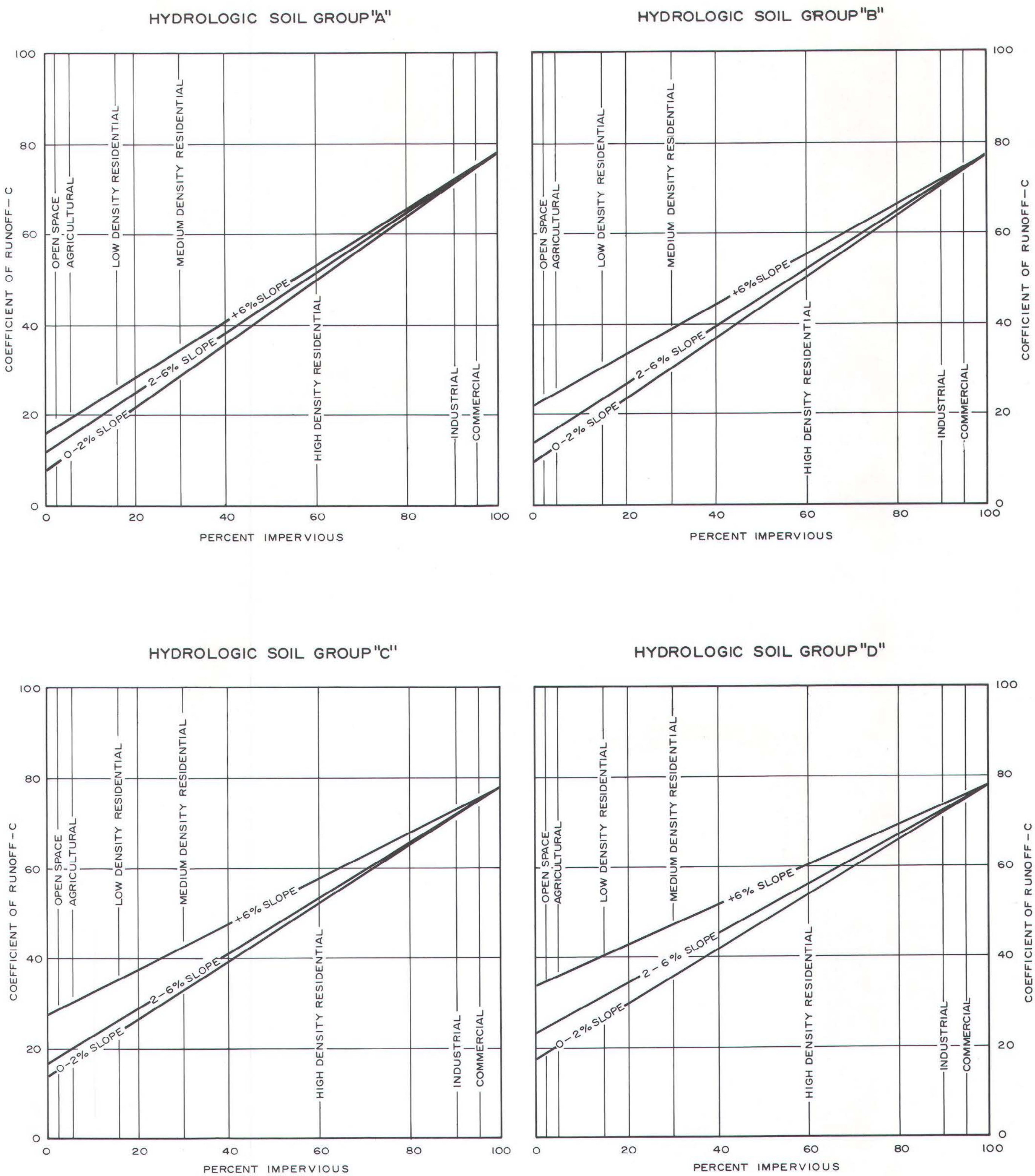


CURVE NUMBERS INDICATE THE PROBABILITY IN PERCENT OF OBTAINING A RAINFALL EVENT IN ANY MONTH OF A PARTICULAR YEAR WITH A DEPTH EQUAL TO OR GREATER THAN THE RAINFALL DEPTH CORRESPONDING TO A GIVEN RECURRENCE INTERVAL AS SHOWN IN FIGURE B-3.

Source: National Weather Service and SEWRPC.

Figure B-5

COEFFICIENT OF RUNOFF CURVES FOR HYDROLOGIC SOIL GROUPS



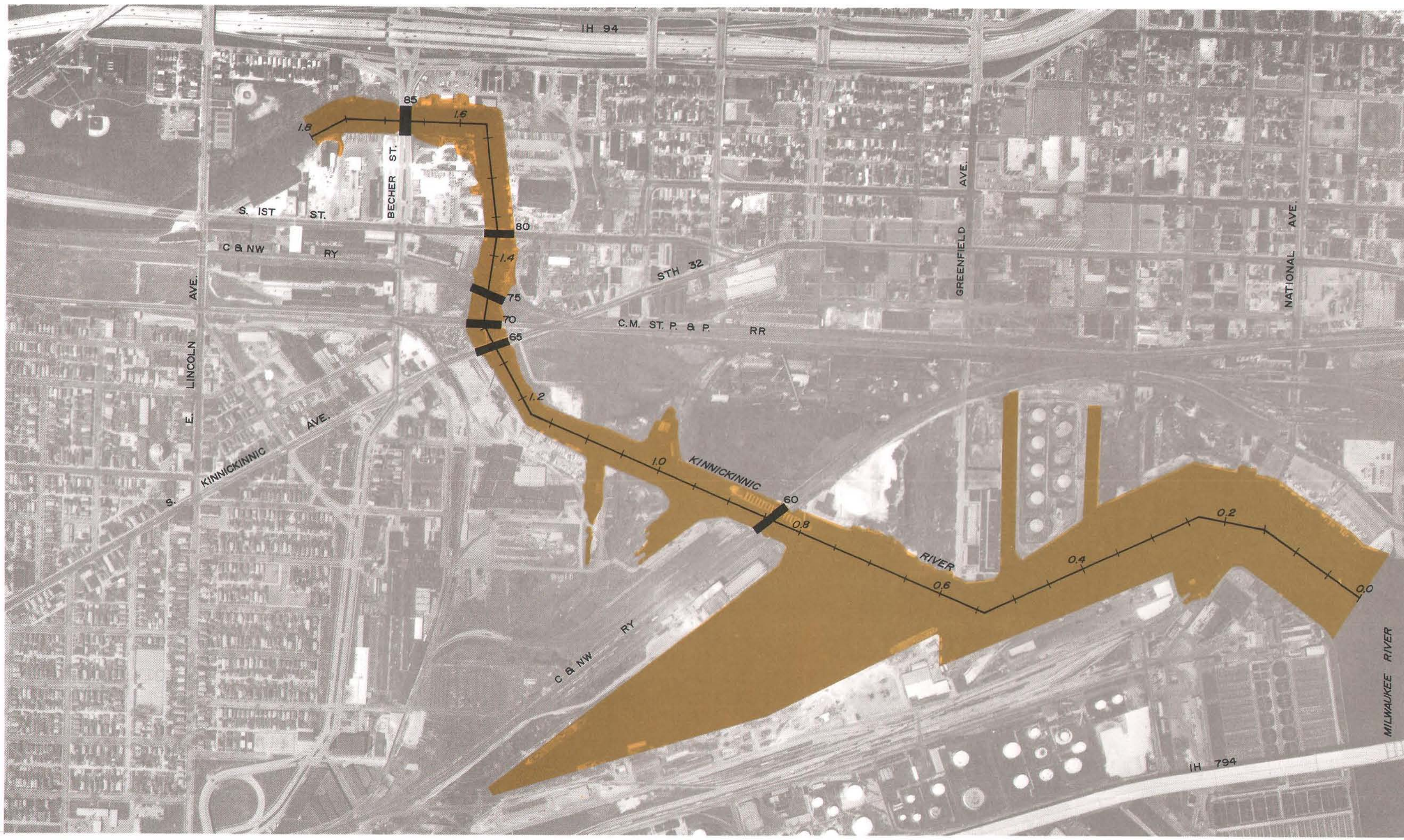
Source: SEWRPC.

Appendix C

FLOOD STAGE AND STREAMBED PROFILES AND AERIAL PHOTOGRAPHS SHOWING AREAS SUBJECT TO FLOODING

Map C-1

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG THE KINNICKINNIC RIVER (RIVER MILE 0.00 TO 1.80)



LEGEND

1.0 — APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODPLAIN -- EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

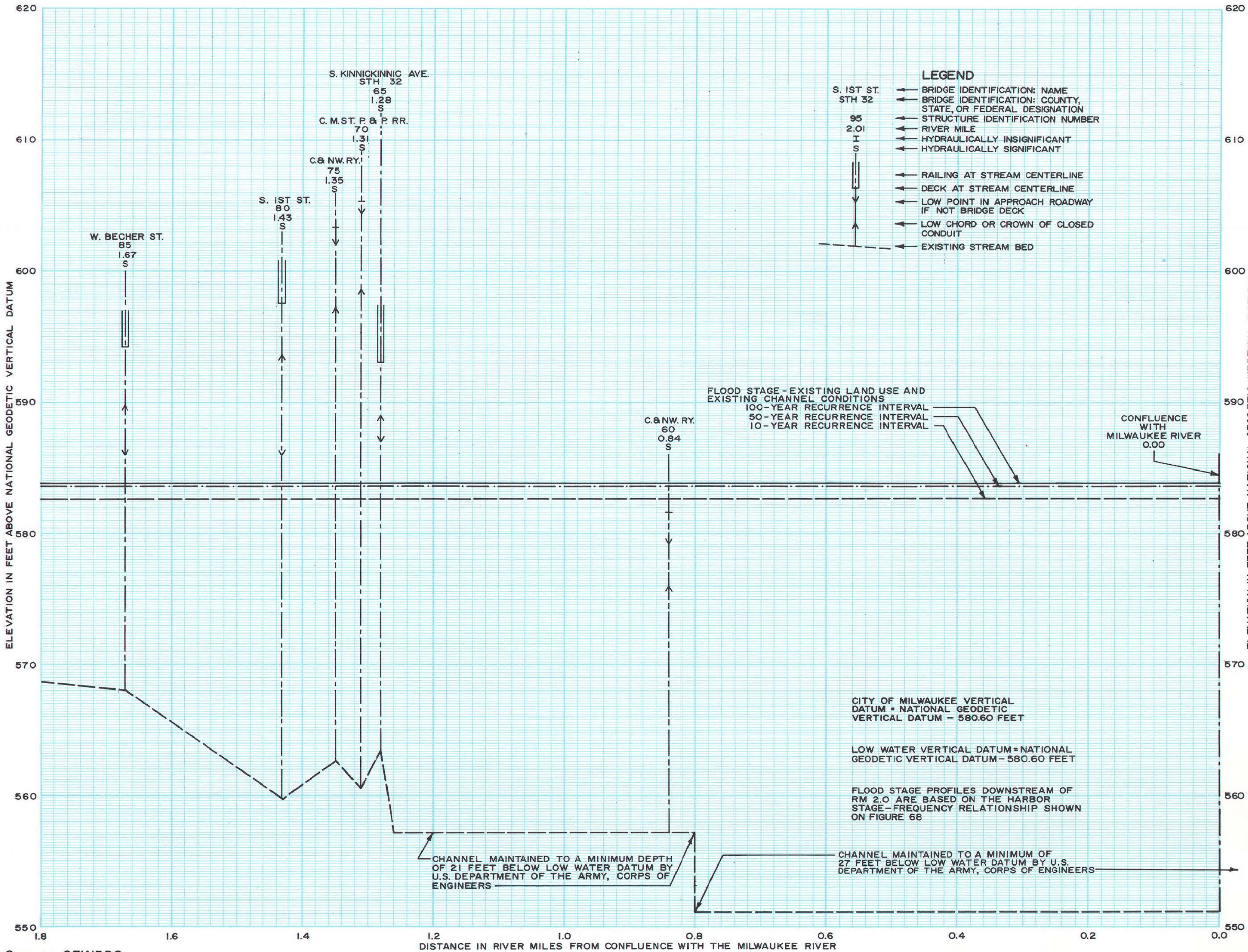
210 — EXISTING STRUCTURE TO BE RETAINED AND STRUCTURE NUMBER

GRAPHIC SCALE
0 0.1 0.2 MILE
DATE OF PHOTOGRAPHY MAY 1975

Source: SEWRPC.

Figure C-1

FLOOD STAGE AND STREAMBED PROFILE FOR THE KINNICKINNIC RIVER (RIVER MILE 0.00 TO 1.80)



Source: SEWRPC.

Map C-2

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG THE KINNICKINNIC RIVER (RIVER MILE 1.80 TO 3.60)

LEGEND

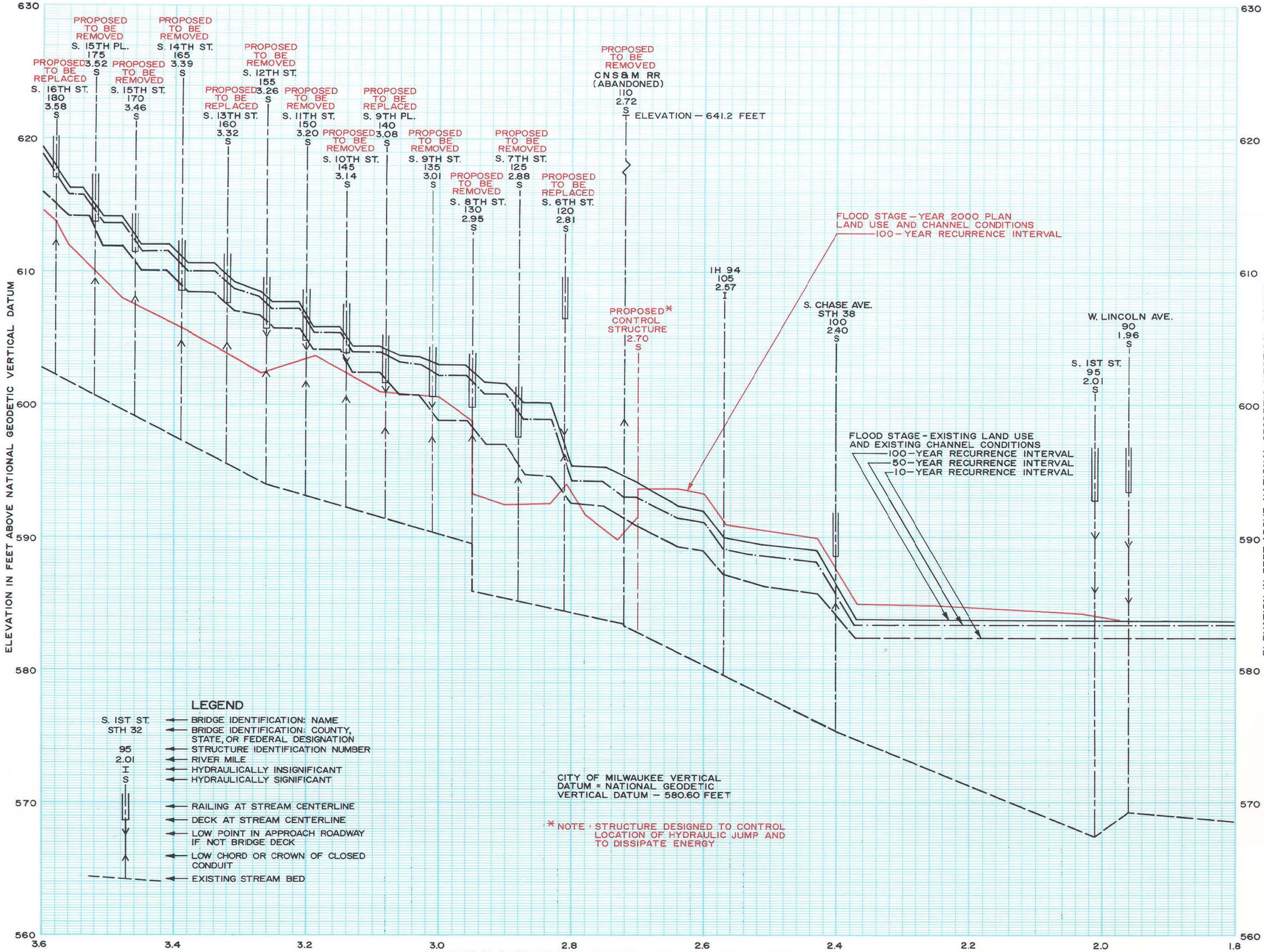
1.0	APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING
	100-YEAR RECURRENCE INTERVAL FLOODPLAIN — EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS
	APPROXIMATE 100-YEAR RECURRENCE INTERVAL FLOODPLAIN — PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS (SAME AS WITH EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS IF NOT SHOWN)
240	EXISTING STRUCTURE TO BE RETAINED AND STRUCTURE NUMBER
210	EXISTING STRUCTURE TO BE REMOVED AND STRUCTURE NUMBER
180	EXISTING STRUCTURE TO BE REPLACED AND STRUCTURE NUMBER
	PROPOSED STRUCTURE

GRAPHIC SCALE
0 0.1 0.2 MILE
DATE OF PHOTOGRAPHY MAY 1975

Source: SEWRPC.

Figure C-2

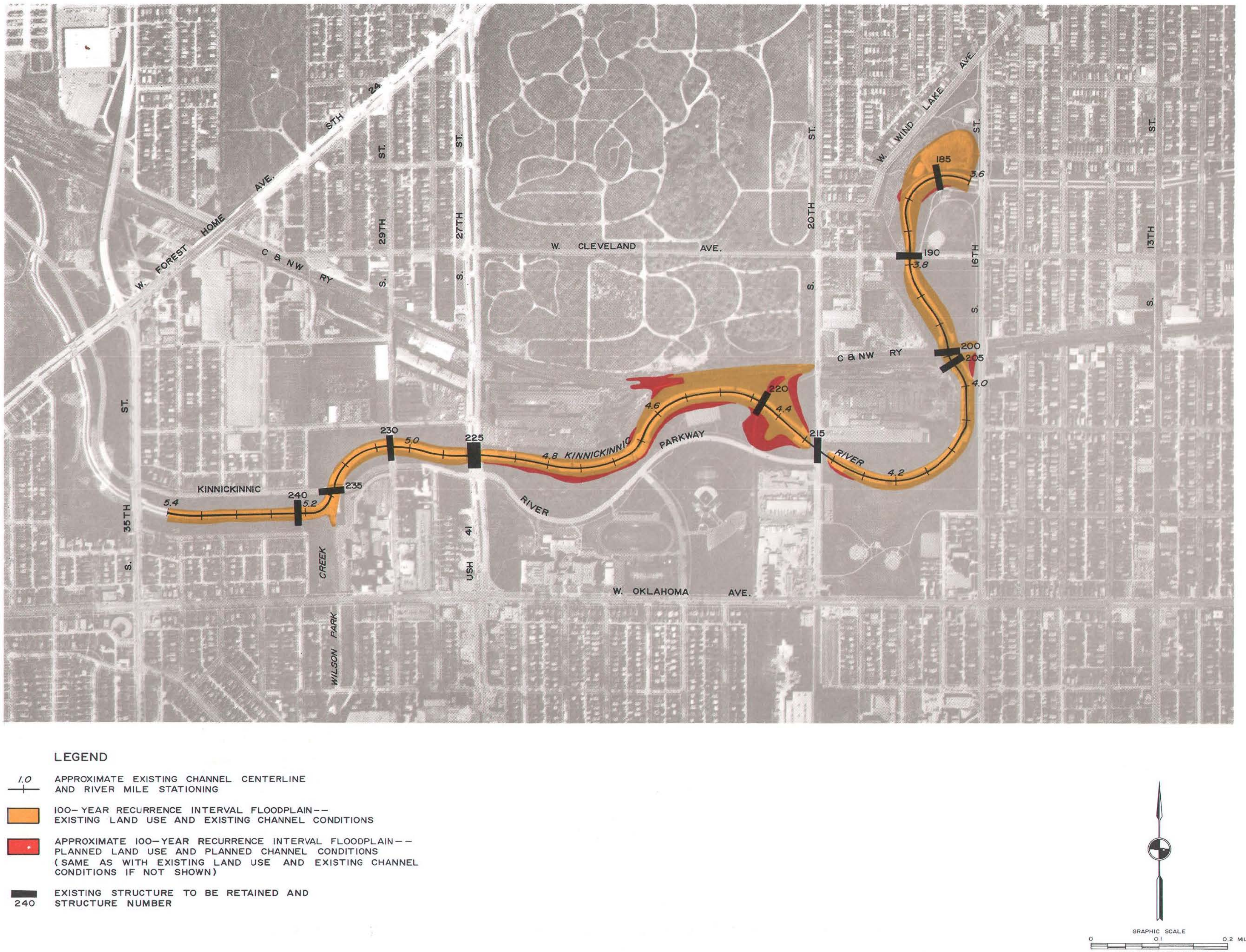
FLOOD STAGE AND STREAMBED PROFILE FOR THE KINNICKINNIC RIVER (RIVER MILE 1.80 TO 3.60)



Source: SEWRPC.

Map C-3

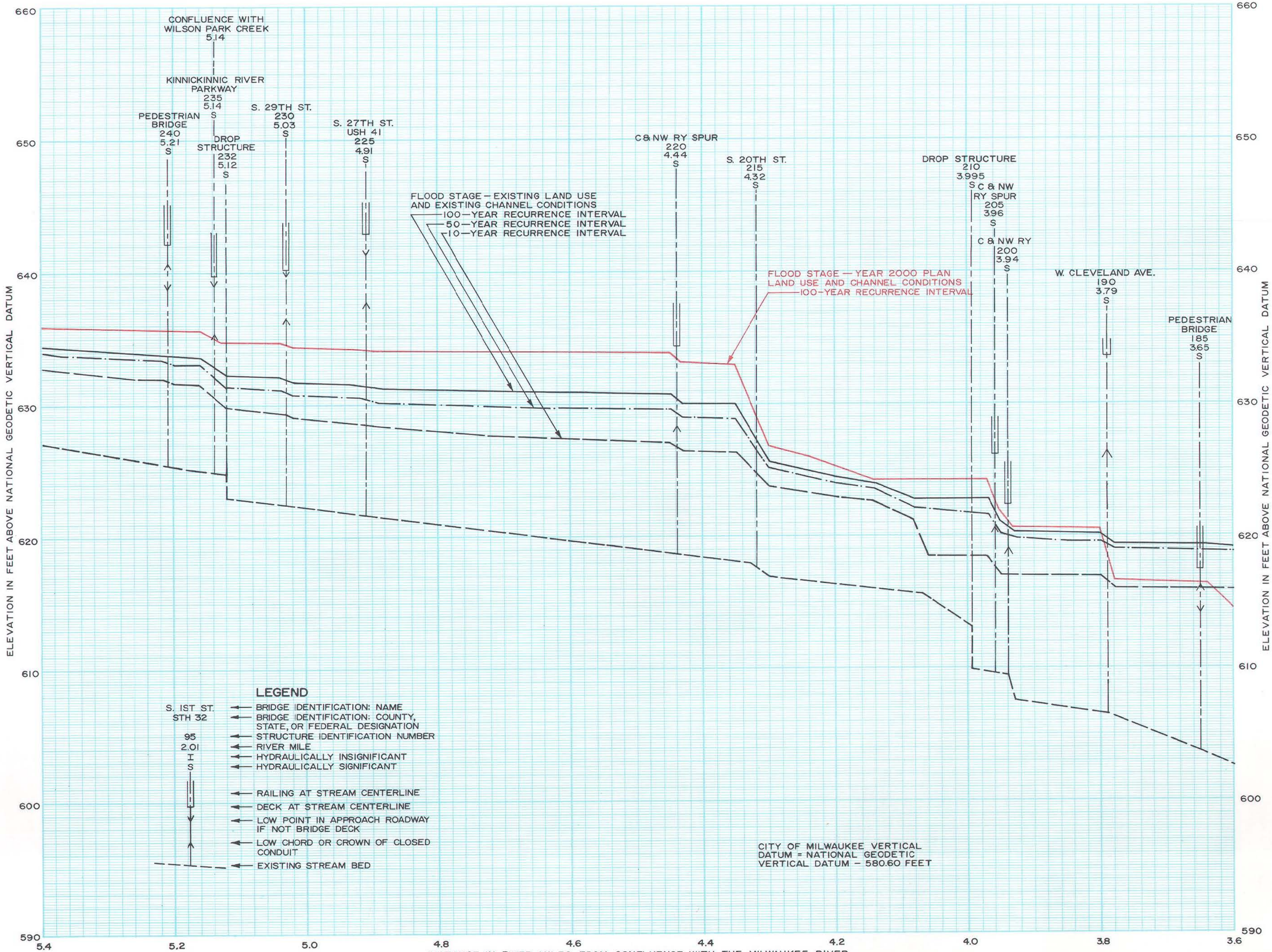
AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG THE KINNICKINNIC RIVER (RIVER MILE 3.60 TO 5.40)



Source: SEWRPC.

Figure C-3

FLOOD STAGE AND STREAMBED PROFILE FOR THE KINNICKINNIC RIVER (RIVER MILE 3.60 TO 5.40)



Source: SEWRPC.

Map C-4

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG THE KINNICKINNIC RIVER (RIVER MILE 5.40 TO 7.20)

LEGEND

1.0 APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODPLAIN-- EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

240 EXISTING STRUCTURE TO BE RETAINED AND STRUCTURE NUMBER

GRAPHIC SCALE

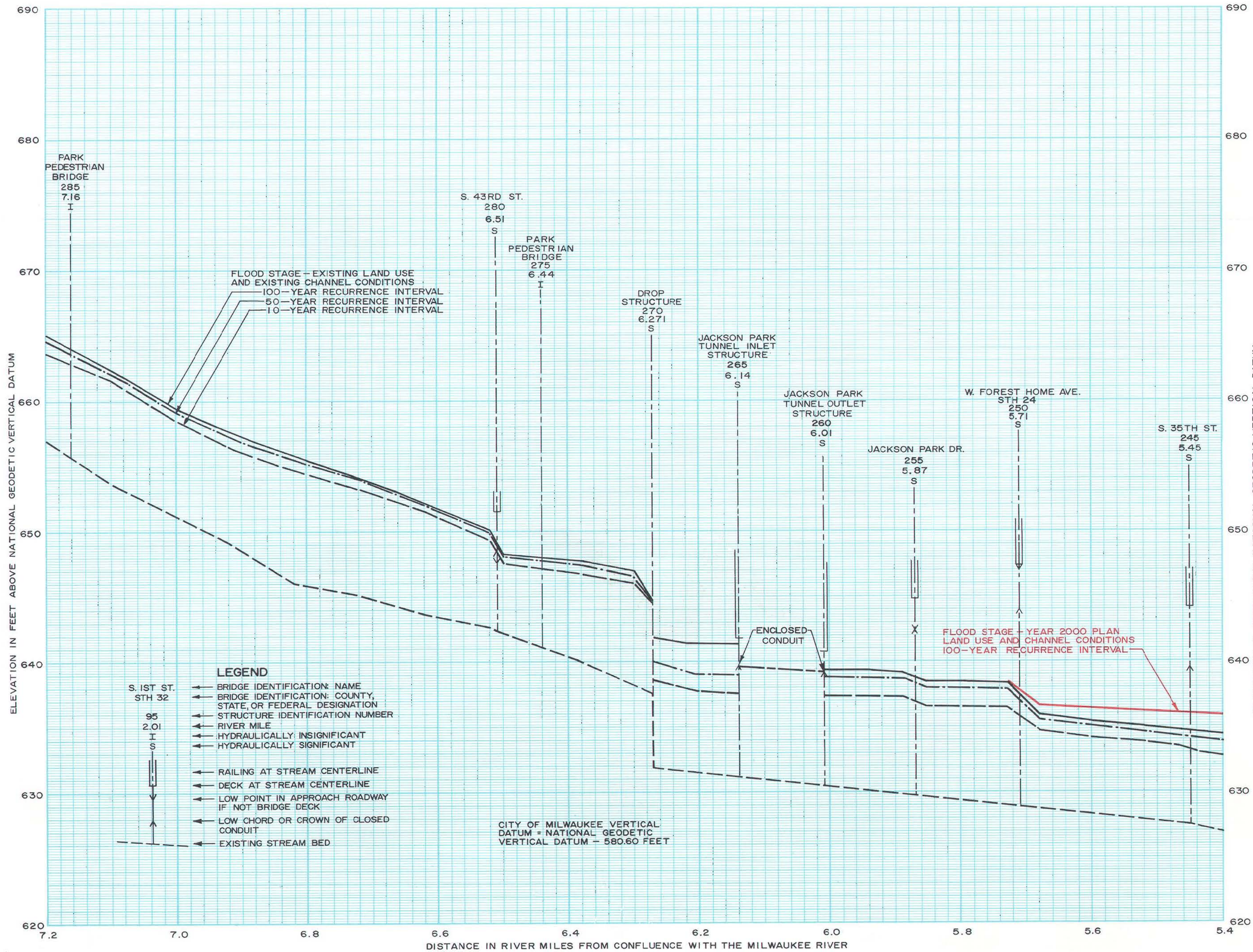
0 0.1 0.2 MILE

DATE OF PHOTOGRAPHY MAY 1975

Source: SEWRPC.

Figure C-4

FLOOD STAGE AND STREAMBED PROFILE FOR THE KINNICKINNIC RIVER (RIVER MILE 5.40 TO 7.20)



Source: SEWRPC.

Map C-5

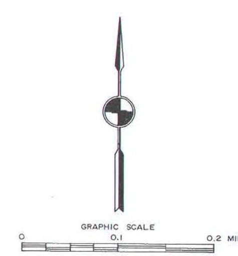
AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG THE KINNICKINNIC RIVER (RIVER MILE 7.20 TO 8.05)

LEGEND

1.0 — APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODPLAIN — — EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

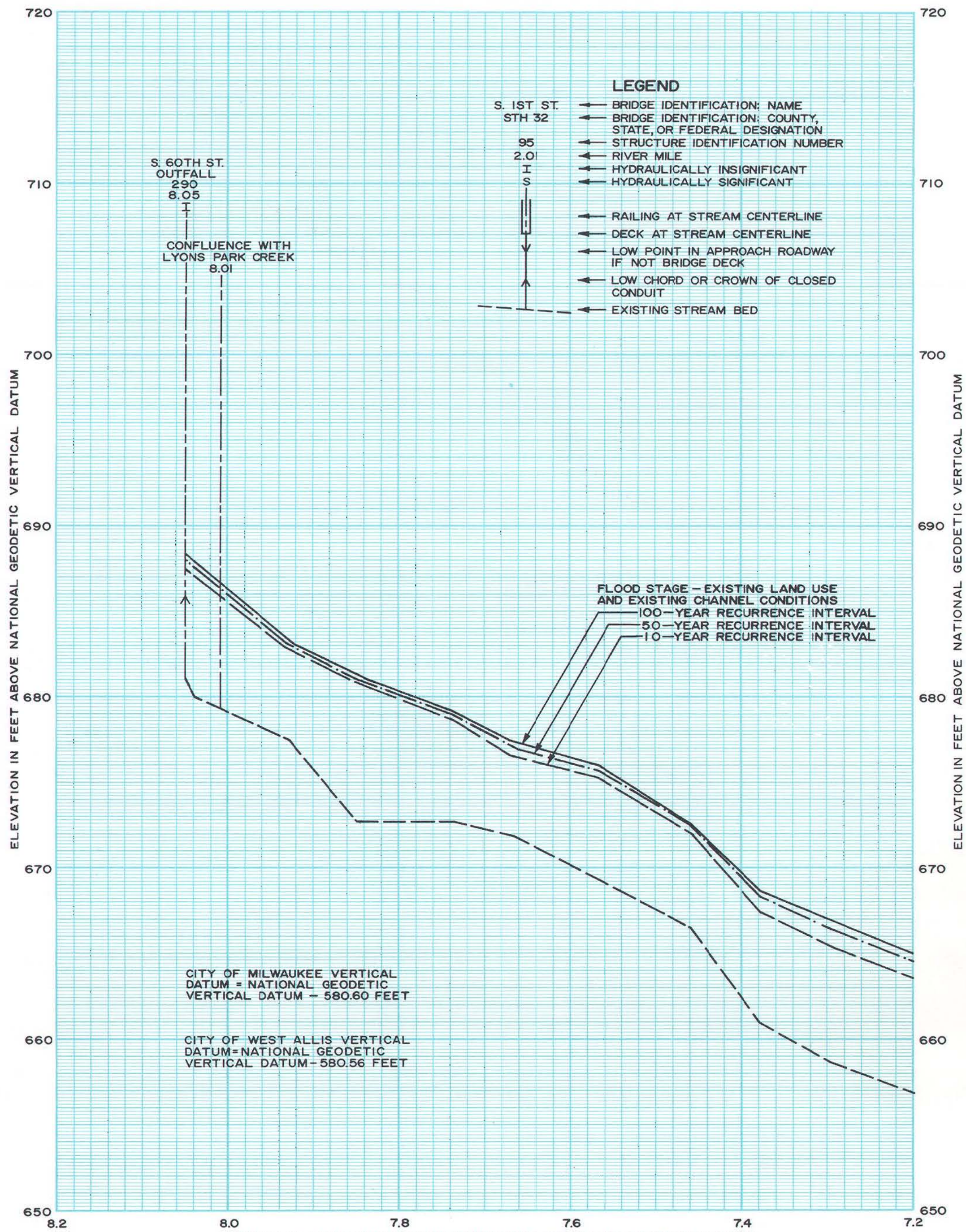
240 — EXISTING STRUCTURE TO BE RETAINED AND STRUCTURE NUMBER



Source: SEWRPC.

Figure C-5

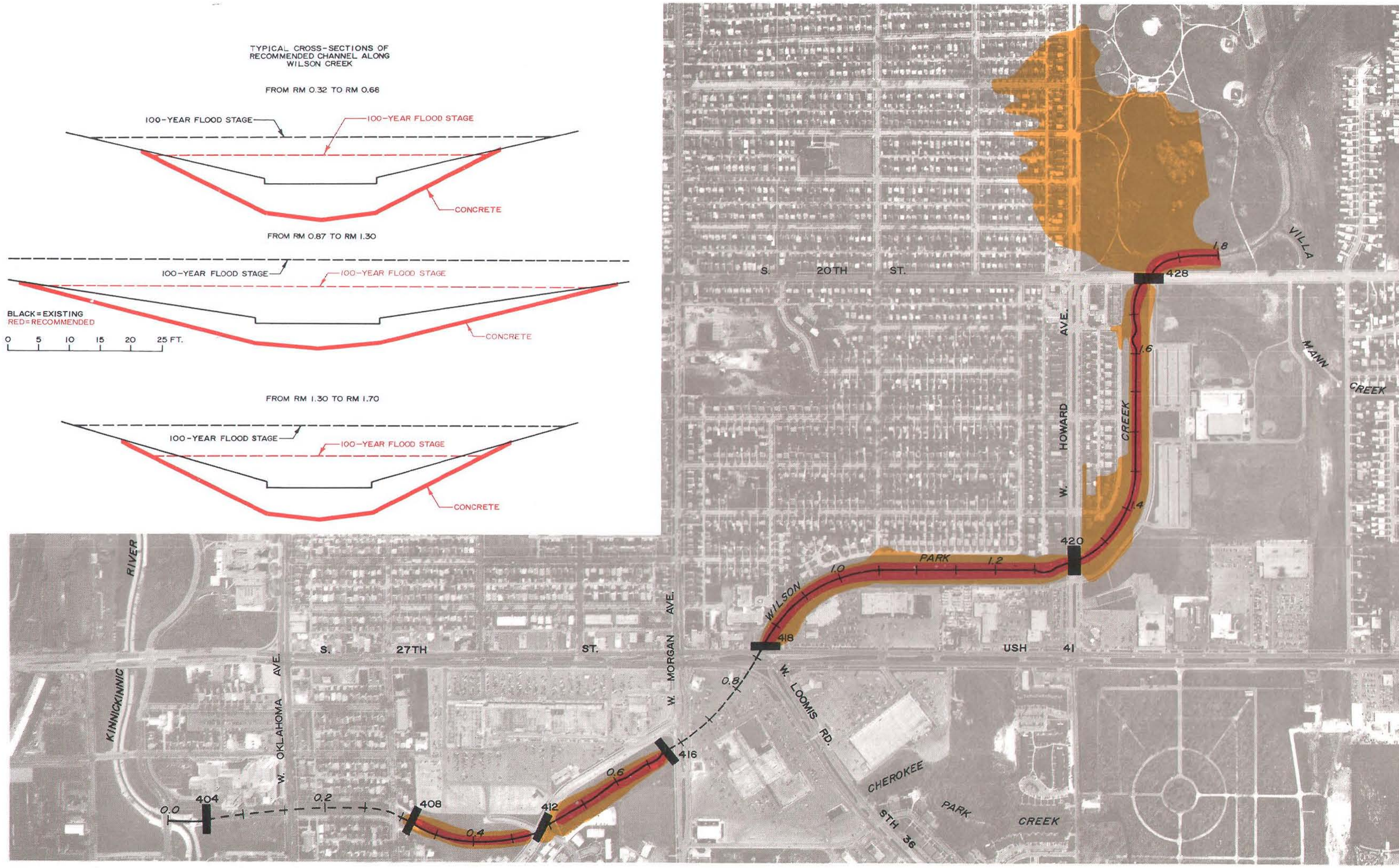
FLOOD STAGE AND STREAMBED PROFILE FOR THE KINNICKINNIC RIVER (RIVER MILE 7.20 TO 8.05)



Source: SEWRPC.

Map C-6

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG WILSON PARK CREEK (RIVER MILE 0.00 TO 1.80)



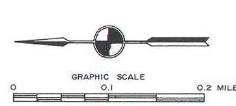
LEGEND

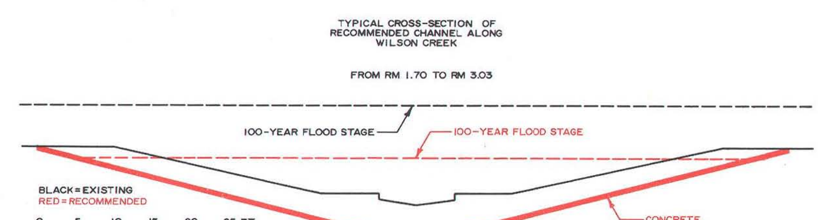
1.0 — APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODPLAIN -- EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

APPROXIMATE 100-YEAR RECURRENCE INTERVAL FLOODPLAIN -- PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS (SAME AS WITH EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS IF NOT SHOWN)

240 — EXISTING STRUCTURE TO BE RETAINED AND STRUCTURE NUMBER

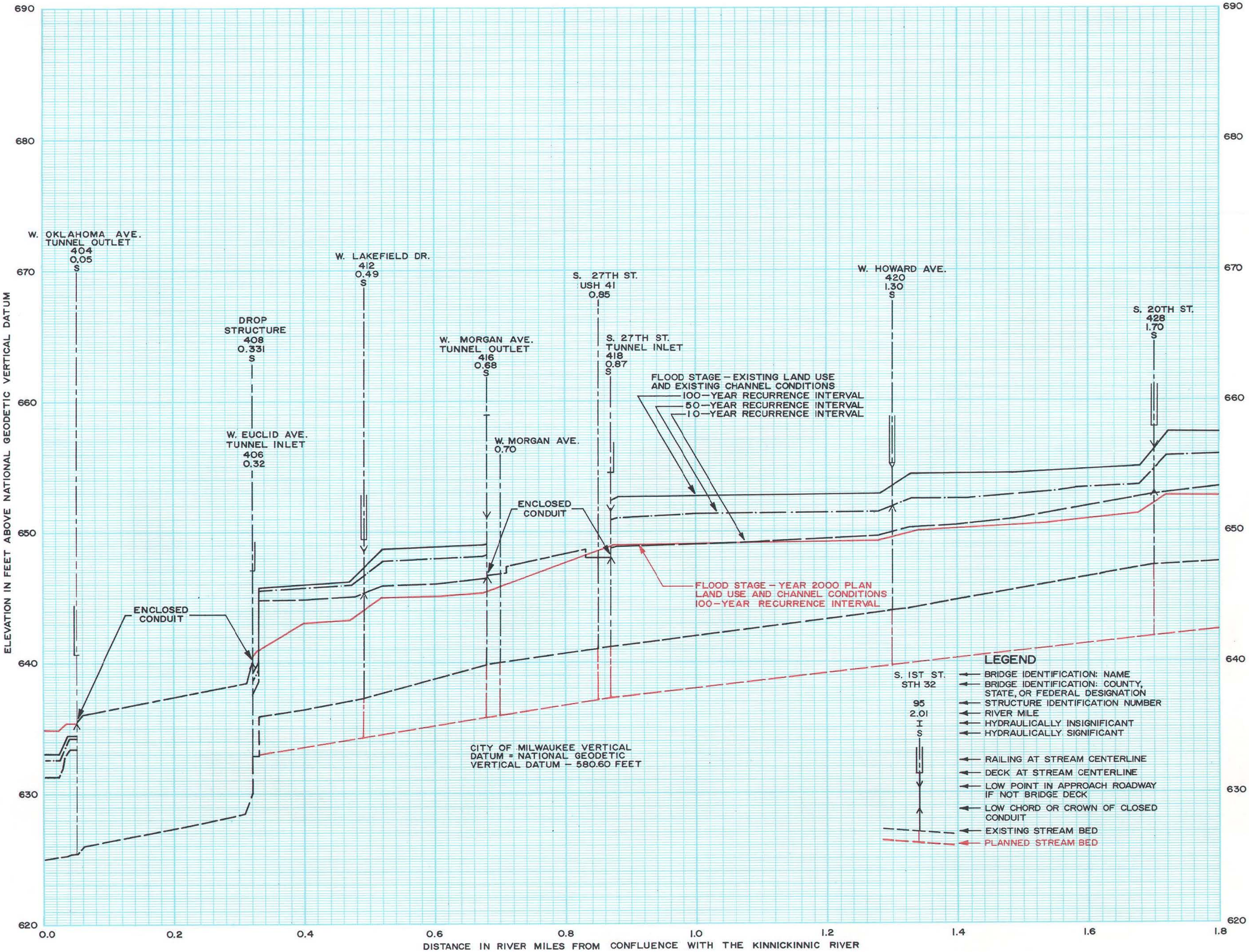




Source: SEWRPC.

Figure C-6

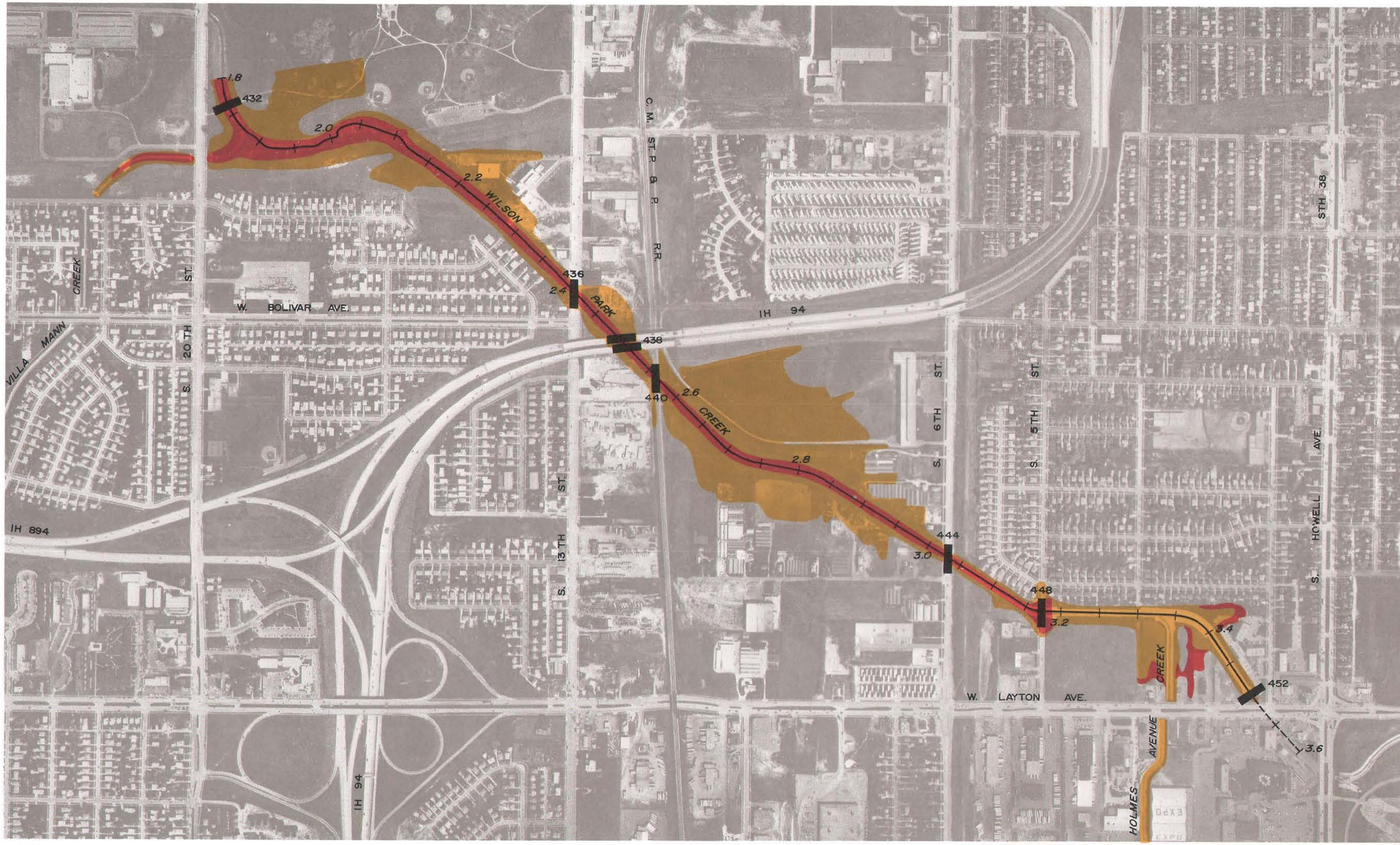
FLOOD STAGE AND STREAMBED PROFILE FOR WILSON PARK CREEK (RIVER MILE 0.00 TO 1.80)



Source: SEWRPC.

Map C-7

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG THE WILSON PARK CREEK (RIVER MILE 1.80 TO 3.60)



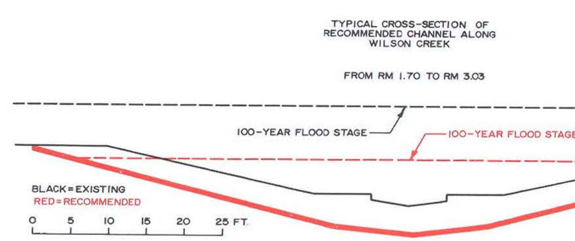
LEGEND

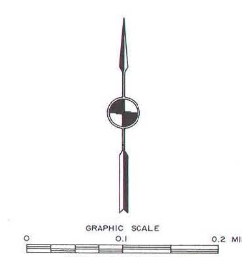
1.0 APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODPLAIN -- EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

APPROXIMATE 100-YEAR RECURRENCE INTERVAL FLOODPLAIN -- PLANNED LAND USE AND PLANNED CHANNEL CONDITIONS (SAME AS WITH EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS IF NOT SHOWN)

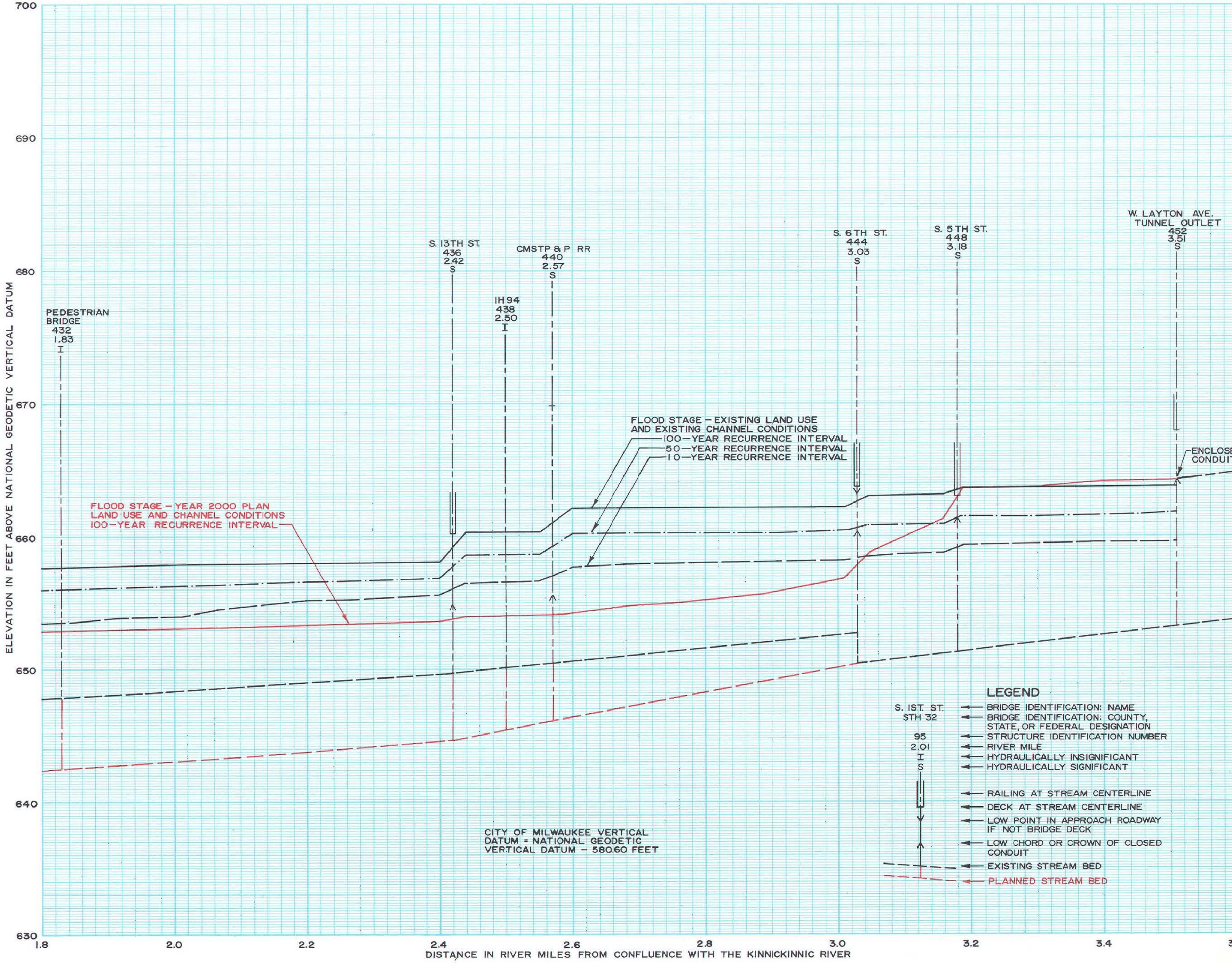
240 EXISTING STRUCTURE TO BE RETAINED AND STRUCTURE NUMBER





Source: SEWRPC.

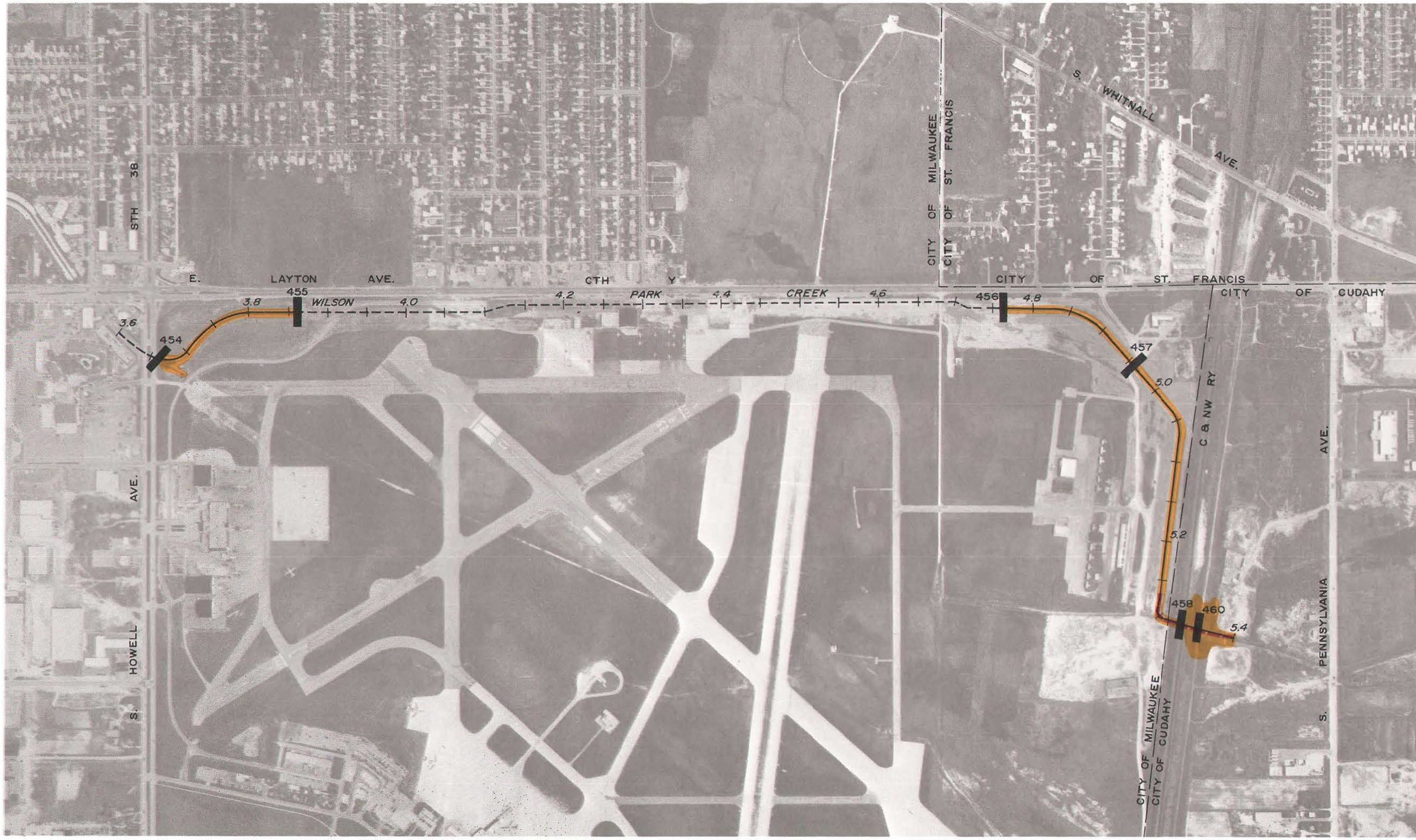
FLOOD STAGE AND STREAMBED PROFILE FOR WILSON PARK CREEK (RIVER MILE 1.80 TO 3.60)



Source: SEWRPC.

Map C-8

AERIAL PHOTOGRAPH SHOWNING AREAS SUBJECT TO FLOODING ALONG WILSON PARK CREEK (RIVER MILE 3.60 TO 5.40)



LEGEND

APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING (1.0)

100-YEAR RECURRENCE INTERVAL FLOODPLAIN -- EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

EXISTING STRUCTURE TO BE RETAINED AND STRUCTURE NUMBER (240)

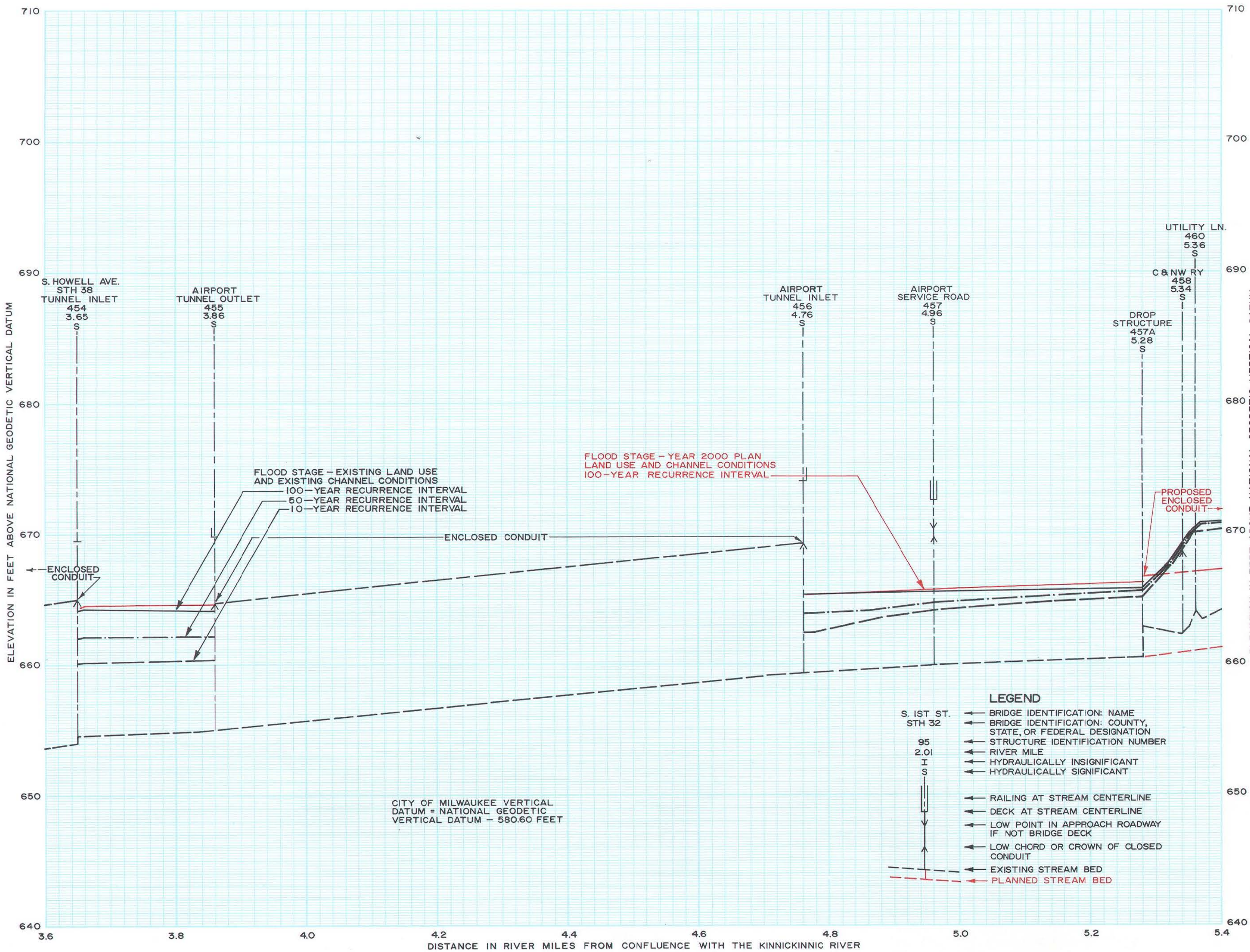
PROPOSED ENCLOSED CONDUIT

GRAPHIC SCALE
0 0.1 0.2 MILE
DATE OF PHOTOGRAPHY MAY 1975

Source: SEWRPC.

Figure C-8

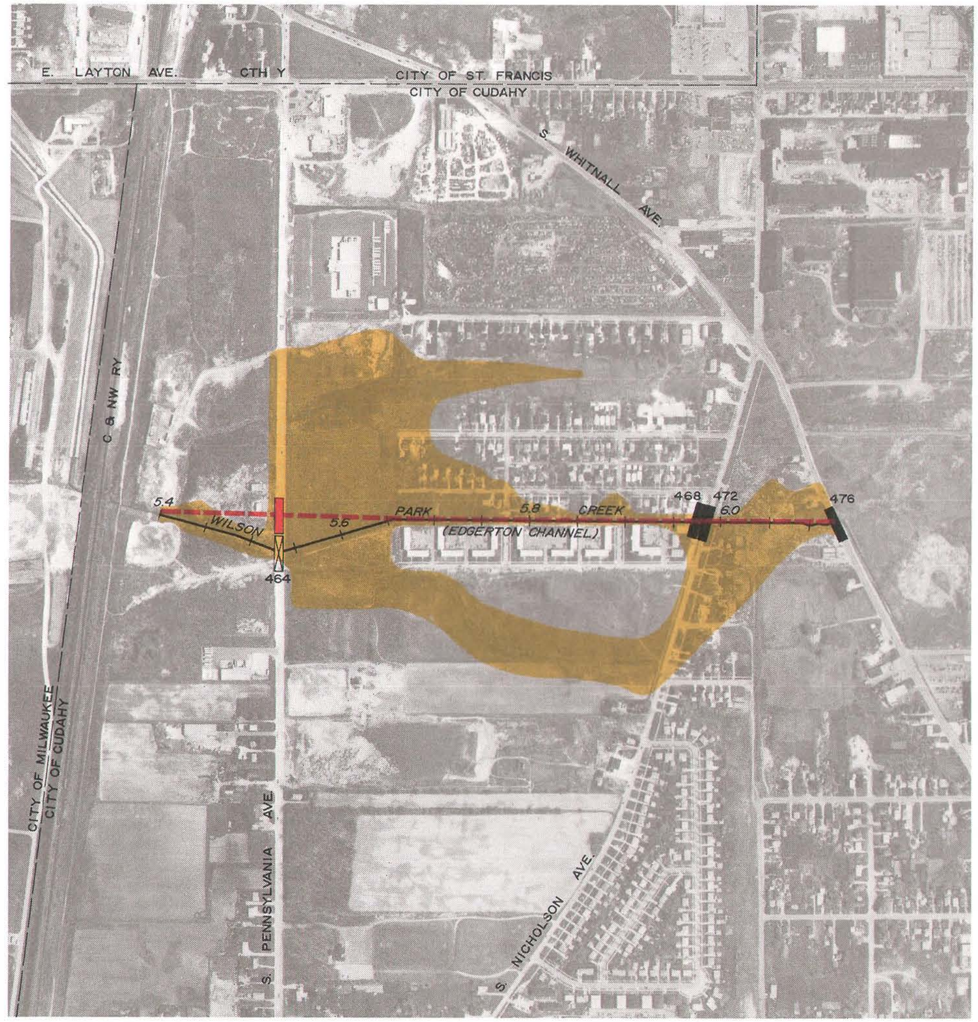
FLOOD STAGE AND STREAMBED PROFILE FOR WILSON PARK CREEK (RIVER MILE 3.60 TO 5.40)



Source: SEWRPC.

Map C-9

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG WILSON PARK CREEK (RIVER MILE 5.40 TO 6.12)



LEGEND

1.0 — APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

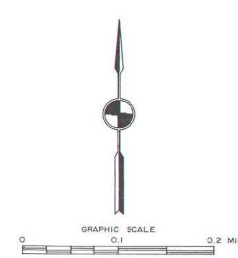
100-YEAR RECURRENCE INTERVAL FLOODPLAIN — — EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

240 — EXISTING STRUCTURE TO BE RETAINED AND STRUCTURE NUMBER

210 — EXISTING STRUCTURE TO BE REMOVED AND STRUCTURE NUMBER

PROPOSED STRUCTURE

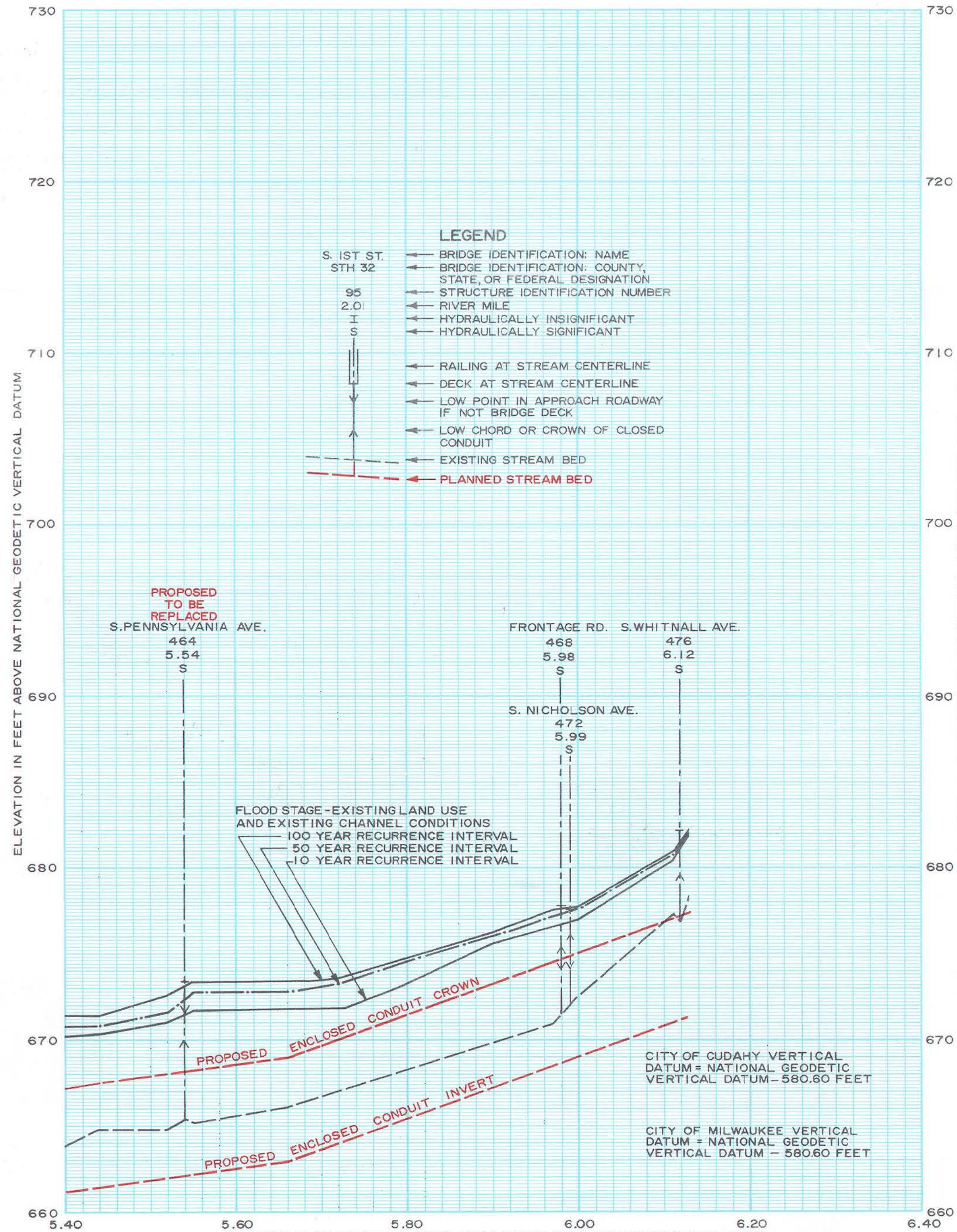
PROPOSED ENCLOSED CONDUIT



Source: SEWRPC.

Figure C-9

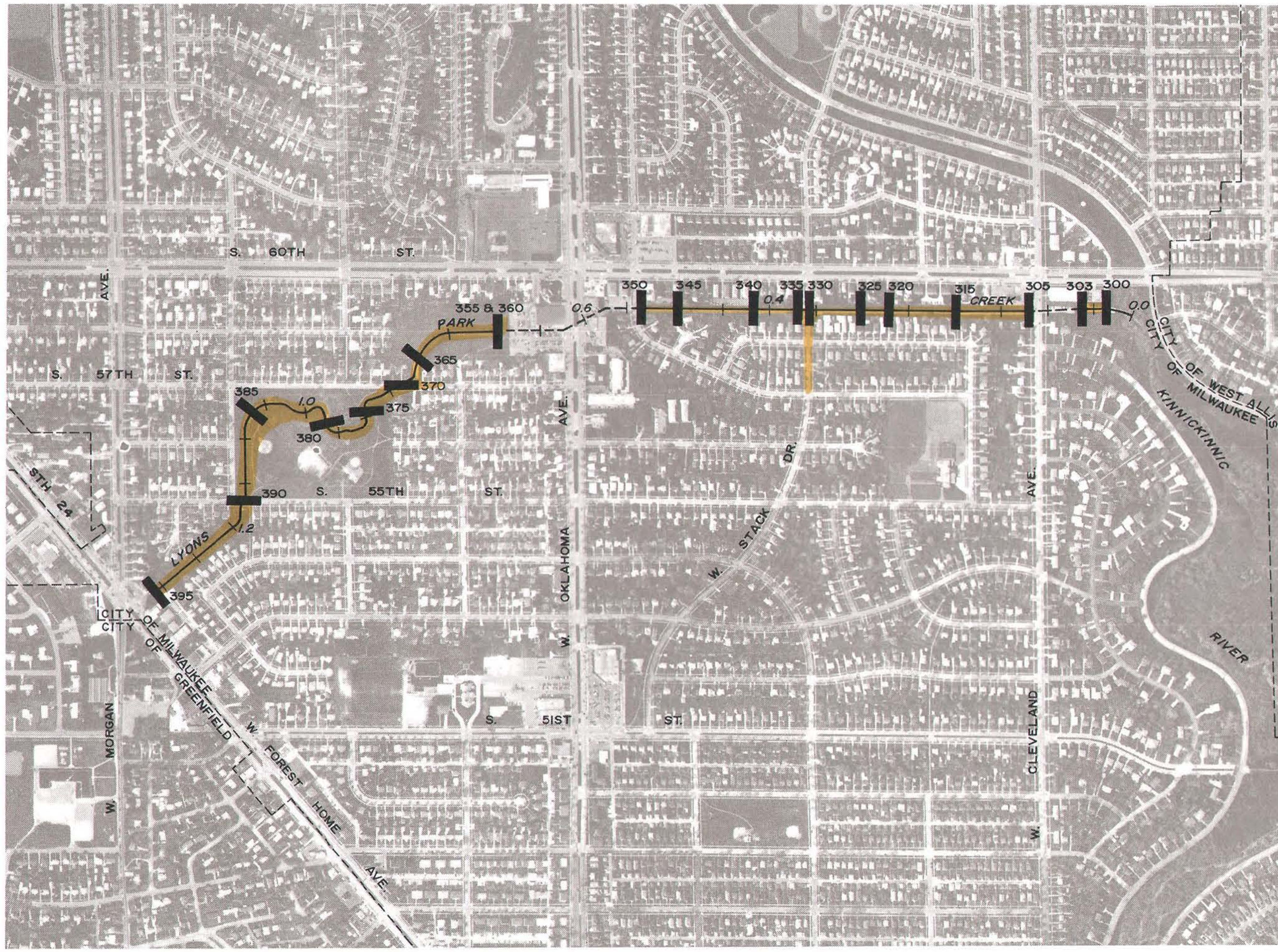
FLOOD STAGE AND STREAMBED PROFILE FOR WILSON PARK CREEK (RIVER MILE 5.40 TO 6.12)



Source: SEWRPC.

Map C-10

AERIAL PHOTOGRAPH SHOWING AREAS SUBJECT TO FLOODING ALONG LYONS PARK CREEK (RIVER MILE 0.00 TO 1.31)



LEGEND

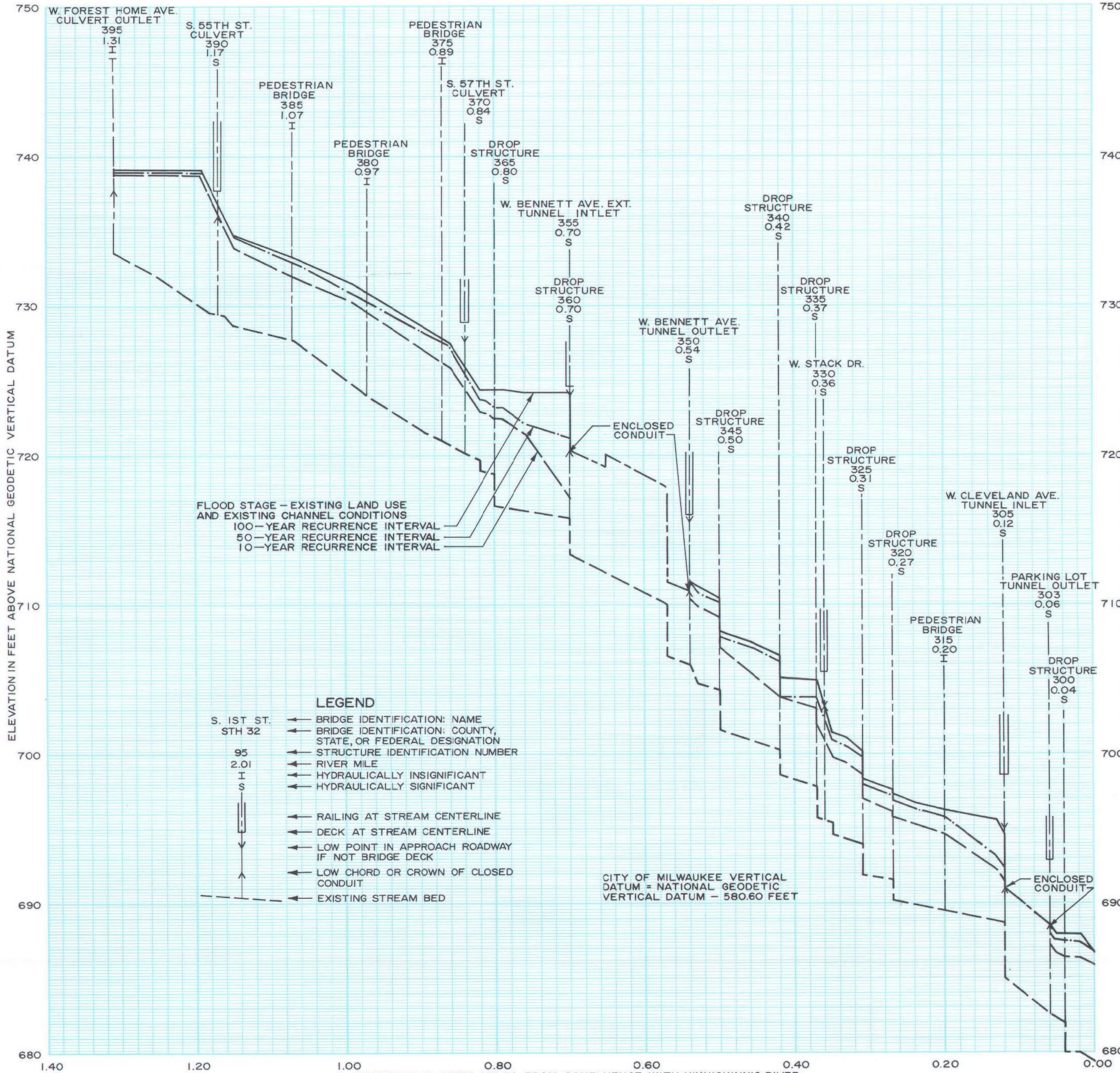
1.0 — APPROXIMATE EXISTING CHANNEL CENTERLINE AND RIVER MILE STATIONING

100-YEAR RECURRENCE INTERVAL FLOODPLAIN -- EXISTING LAND USE AND EXISTING CHANNEL CONDITIONS

240 — EXISTING STRUCTURE TO BE RETAINED AND STRUCTURE NUMBER

Source: SEWRPC.

FLOOD STAGE AND STREAMBED PROFILE FOR LYONS PARK CREEK (RIVER MILE 0.00 TO 1.31)



Source: SEWRPC.

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Appendix D

HYDROLOGIC-HYDRAULIC SUMMARY FOR EXISTING LAND USE AND FLOODLAND CONDITIONS

Table D-1

HYDROLOGIC-HYDRAULIC SUMMARY—KINNICKINNIC RIVER EXISTING 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	Structure Type and Hydraulic Significance[a]	Date of Construction or Major Reconstruction	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)
60	Chicago & North Western Railway	0.84	1S	–	3,800	582.5	582.5	5,600	583.5	583.5	6,400	583.8	583.8
65	Kinnickinnic Avenue (STH 32)	1.28	1S	1907	3,800	582.5	582.5	5,600	583.5	583.5	6,400	583.8	583.8
70	Chicago, Milwaukee, St. Paul & Pacific Railroad	1.31	1S	–	3,800	582.5	582.5	5,600	583.5	583.5	6,400	583.8	583.8
75	Chicago & North Western Railway	1.35	1S	–	3,800	582.5	582.5	5,600	583.5	583.5	6,400	583.8	583.8
80	S. 1st Street	1.43	1S	1955	3,600	582.5	582.5	5,200	583.5	583.5	6,000	583.8	583.8
85	Becher Street	1.67	1S	1966	3,600	582.5	582.5	5,200	583.5	583.5	6,000	583.8	583.8
90	Lincoln Avenue	1.96	1S	1928	3,600	582.5	582.5	5,200	583.5	583.5	6,000	583.8	583.8
95	S. 1st Street	2.01	1S	1952	3,600	582.5	582.5	5,200	583.5	583.5	6,000	583.8	583.8
100	Chase Avenue	2.40	1S	1931	3,600	585.8	582.5	5,200	588.2	583.5	6,000	589.1	583.8
105	IH 94	2.57	1I	–	3,600	–	–	5,200	–	–	6,000	–	–
110	Chicago, North Shore & Milwaukee Railroad (abandoned)	2.72	1S	–	3,600	592.3	590.8	5,200	594.2	593.0	6,000	595.3	594.1
120	S. 6th Street	2.81	1S	1953	2,800	594.6	592.5	4,350	598.9	594.3	5,000	600.2	595.4
125	S. 7th Street	2.88	1S	1901	2,800	597.0	594.6	4,350	600.8	598.9	5,000	601.6	600.2
130	S. 8th Street	2.95	1S	1907	2,800	598.8	597.0	4,350	602.2	600.8	5,000	602.9	601.7
131	Drop Structure	2.95	1S	–	2,800	598.8	597.0	4,350	602.2	600.8	5,000	602.9	601.7
135	S. 9th Street	3.01	1S	1911	2,800	600.7	598.8	4,350	603.0	602.2	5,000	603.6	603.0
140	S. 9th Place	3.08	1S	1908	2,800	602.4	600.7	4,350	603.9	603.1	5,000	604.4	603.7
145	S. 10th Street	3.14	1S	1911	2,800	604.1	602.4	4,350	605.4	603.9	5,000	605.8	604.4
150	S. 11th Street	3.20	1S	1909	2,800	605.7	604.1	4,350	607.2	605.4	5,000	607.7	605.8
155	S. 12th Street	3.26	1S	1907	2,800	606.6	605.5	4,350	608.1	607.2	5,000	608.5	607.7
160	S. 13th Street	3.32	1S	1912	2,800	608.4	607.0	4,350	610.0	608.7	5,000	610.6	609.2
165	S. 14th Street	3.39	1S	1913	2,800	610.0	608.4	4,350	611.5	610.0	5,000	612.0	610.6
170	S. 15th Street	3.46	1S	1913	2,800	611.8	610.0	4,350	613.6	611.4	5,000	614.1	611.9
175	S. 15th Place	3.52	1S	1920	2,800	614.2	611.8	4,350	615.8	613.6	5,000	616.3	614.1
180	S. 16th Street	3.58	1S	1926	2,800	615.9	614.1	4,350	618.7	615.8	5,000	619.2	616.3
185	Pedestrian Bridge	3.65	1S	–	2,800	616.1	616.1	4,050	618.9	618.9	4,650	619.4	619.4
190	Cleveland Avenue	3.79	1S	1918	2,800	617.0	616.1	4,050	619.6	618.9	4,650	620.2	619.4
200	Chicago & North Western Railway	3.94	1S	–	2,800	617.1	617.1	4,050	620.3	619.7	4,650	621.1	620.3
205	Railroad Spur	3.96	1S	–	2,800	618.5	617.1	4,050	621.7	620.3	4,650	622.8	621.1
210	Drop Structure	3.991	1S	–	2,800	617.8	618.5	4,050	621.4	621.7	4,650	622.5	622.8
215	S. 20th Street	4.32	1S	1934	2,800	626.4	623.8	4,050	628.9	625.1	4,650	630.0	625.7
220	Chicago & Northwestern Railway Spur	4.44	1S	–									
225	S. 27th Street (USH 41)	4.91	1S	1962	2,800	628.7	628.4	4,050	630.6	630.2	4,650	631.6	631.3
230	S. 29th Street	5.03	1S	1961	2,800	629.4	629.1	4,050	631.2	630.8	4,650	632.1	631.8
232	Drop Structure	5.12	3S	–	2,800	631.2	629.8	4,050	632.5	631.4	4,650	633.0	632.3
235	Kinnickinnic River Parkway	5.14	1S	–	2,800	631.5	631.2	4,050	633.0	632.5	4,650	633.6	633.0
240	Pedestrian Bridge	5.21	1S	–	1,600	632.0	631.7	2,250	633.4	633.1	2,550	633.9	633.7
245	S. 35th Street	5.45	1S	1961	1,600	633.6	633.0	2,250	634.3	634.1	2,550	634.8	634.6
250	W. Forest Home Avenue	5.71	1S	1930	1,350	636.5	634.8	1,850	637.9	635.6	2,050	638.4	636.0
255	Jackson Park Drive	5.87	1S	–	1,350	637.3	636.6	1,850	638.7	638.0	2,050	639.2	638.5
260	Jackson Park Tunnel Outlet Structure	6.01	4S	–	1,350	–	637.4	1,850	–	638.8	2,050	–	639.4
265	Jackson Park Tunnel Inlet Structure	6.14	4S	–	1,350	637.6	–	1,850	639.0	–	2,050	641.4	–
270	Drop Structure	6.271	3S	–	790	644.9	638.6	1,050	644.6	640.0	1,200	644.6	641.9
275	Park Pedestrian Bridge	6.44	1I	–	790	–	–	1,050	–	–	1,200	–	–
280	S. 43rd Street	6.51	1S	–	790	649.3	647.5	1,050	649.9	648.0	1,200	650.1	648.2
285	Park Pedestrian Bridge	7.16	1I	–	790	–	–	1,050	N/A	N/A	1,200	–	–
290	S. 60th Street Outfall	8.05	4I	–	790	–	–	1,050	–	–	1,200	–	–

NOTE: N/A indicates data not available.

[a] Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir; 3—drop structure or natural channel drop; 4—fords, outfalls, or inlet or outlet structures. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.

Source: SEWRPC

Table D-2

HYDROLOGIC-HYDRAULIC SUMMARY—WILSON PARK CREEK EXISTING 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	Structure Type and Hydraulic Significance[a]	Date of Construction or Major Reconstruction	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)
400	Outlet Control Sill	0.00	2S	–	1,450	631.3	–	2,000	632.6	–	2,250	633.0	–
404	W. Oklahoma Avenue Tunnel Outlet	0.05	4S	–	1,450	–	633.4	2,000	–	634.2	2,250	–	634.5
406	W. Euclid Avenue Tunnel Inlet	0.32	4S	–	1,450	638.5	–	2,000	638.8	–	2,250	639.2	–
416	W. Lakefield Drive	0.49	1S	1952	1,450	645.8	645.0	2,000	647.8	645.9	2,250	648.7	646.2
412	W. Morgan Avenue Tunnel Outlet	0.68	4S	1954	1,300	–	646.3	1,700	–	648.1	1,900	–	648.9
418	S. 27th Street Tunnel Inlet	0.87	4S	1954	1,300	649.0	–	1,700	651.1	N/A	1,900	652.7	–
420	Howard Avenue	1.30	1S	1956	1,300	650.3	649.6	1,700	652.5	651.5	1,900	654.4	652.9
428	S. 20th Street	1.70	1S	1958	1,300	653.0	652.6	1,700		653.7	1,900	657.6	655.0
432	Pedestrian Bridge	1.83	1I	–	970	–	–	1,300	–	–	1,450	–	–
436	S. 13th Street	2.42	1S	1960	970	656.5	655.6	1,300	658.6	656.8	1,450	660.3	658.1
438	IH 94	2.50	1I	–	970	–	–	1,300	–	–	1,450	–	–
440	Chicago, Milwaukee, St. Paul & Pacific Railroad	2.57	1S	–	970	657.6	656.7	1,300	660.1	658.7	1,450	662.1	660.3
444	S. 6th Street	3.03	1S	1960	970	658.5	658.2	1,300	660.8	660.4	1,450	663.0	662.2
448	S. 5th Street	3.18	1S	1962	970	659.2	658.7	1,300	661.5	660.9	1,450	663.6	663.1
452	Layton Avenue Tunnel Outlet	3.51	4S	–	460	–	659.7	550	–	661.8	590	–	663.8
454	Howell Avenue Tunnel Inlet	3.65	4S	–	460	660.3	–	550	662.0	–	590	664.2	–
455	Airport Tunnel Outlet	3.86	4S	–	460	–	660.4	550	–	662.2	590	N/A	664.2
456	Airport Tunnel Inlet	4.76	4S	–	460	662.4	–	550	663.9	–	320	665.4	–
457	Airport Service Road	4.96	1S	–	460	664.2	664.1	550	664.8	664.6	320	665.5	665.5
457A	Drop Structure	5.28	3S	–	460	665.6	665.1	550	666.0	665.6	320	665.4	665.7
458	Chicago & North Western Railway	5.34	1S	–	255	670.0	668.4	360	670.8	668.8	410	670.1	667.6
460	Utility Lane	5.36	1S	–	255	670.2	670.0	360	670.9	670.8	410	670.8	670.1
464	Pennsylvania Avenue	5.54	1S	–	260	671.8	671.1	365	672.9	671.6	415	673.4	671.8
468	Frontage Road	5.98	1S	–	270	677.0	676.8	380	677.6	677.3	420	677.8	677.6
472	Nicholson Avenue	5.99	1S	–	270	677.0	677.0	380	677.6	677.6	420	677.8	677.8
476	Whitnall Avenue	6.12	1S	–	270	682.2	680.5	380	682.4	680.8	420	682.4	681.0

NOTE: N/A indicates data not available.

[a] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir; 3—drop structure or natural channel drop; 4—fords, outfalls, or inlet or outlet structures. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

Source: SEWRPC

Table D-3

HYDROLOGIC-HYDRAULIC SUMMARY—LYONS PARK CREEK EXISTING 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	Structure Type and Hydraulic Significance[a]	Date of Construction or Major Reconstruction	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)
300	Drop Structure	0.04	3S	N/A	670	686.7	686.4	980	687.5	687.4	1,150	687.9	687.8
303	Parking Lot Tunnel Outlet	0.06	4S	N/A	670	–	686.7	980	N/A	687.5	1,150	–	687.9
305	W. Cleveland Avenue Tunnel Inlet	0.12	4S	N/A	670	692.3	–	980	693.1	–	1,150	695.0	–
310	Drop Structure	0.12	3S	N/A	670	692.3	–	980	693.1	–	1,150	695.0	–
315	Pedestrian Bridge	0.20	1I	N/A	670	–	–	980	–	–	1,150	–	–
320	Drop Structure	0.27	3S	N/A	670	696.2	695.8	980	697.2	696.8	1,150	697.6	697.3
325	Drop Structure	0.31	3S	N/A	670	698.7	697.0	980	699.8	697.9	1,150	700.2	698.3
330	W. Stack Drive	0.36	1S	N/A	670	701.9	699.8	980	704.8	700.9	1,150	704.9	701.4
335	Drop Structure	0.37	3S	N/A	670	703.1	701.9	980	703.9	704.8	1,150	704.9	704.9
340	Drop Structure	0.42	3S	N/A	670	705.3	704.0	980	706.2	704.8	1,150	706.6	705.1
345	Drop Structure	0.50	3S	N/A	670	709.2	707.0	980	710.2	707.8	1,150	710.5	708.2
350	W. Bennett Avenue Tunnel Outlet	0.54	4S	N/A	670	–	709.9	980	–	710.8	1,150	–	711.2
–	Oklahoma Avenue	0.61	N/A	N/A	670	–	–	980	–	–	1,150	N/A	–
355	W. Lakefield Drive Extension Tunnel Inlet	0.70	4S	N/A	670	720.5	–	980	721.2	–	1,150	724.3	–
360	Drop Structure	0.70	3S	N/A	670	720.5	–	980	721.2	–	1,150	724.3	–
365	Drop Structure	0.80	3S	N/A	670	722.3	722.4	980	723.1	723.2	1,150	724.4	724.4
370	S. 57th Street Culvert	0.84	1S	N/A	670	725.9	722.9	980	728.1	723.7	1,150	727.5	724.0
375	Pedestrian Bridge	0.89	1I	N/A	670	–	–	980	–	–	1,150	–	–
380	Pedestrian Bridge	0.97	1I	N/A	670	–	–	980	–	–	1,150	–	–
385	Pedestrian Bridge	1.07	1I	N/A	670	–	–	980	–	–	1,150	–	–
390	S. 55th St. Culvert	1.17	1S	N/A	670	738.8	733.8	980	739.0	734.6	1,150	739.1	734.8
395	W. Forest Home Avenue Culvert Outlet	1.31	4I	N/A	475	–	N/A	640	–	–	710	–	–

NOTE: N/A indicates data not available.

[a] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir; 3—drop structure or natural channel drop; 4—fords, outfalls, or inlet or outlet structures. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

Source: SEWRPC

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Appendix E

HYDROLOGIC-HYDRAULIC SUMMARY FOR EXISTING LAND USE AND COMMITTED CHANNEL CONDITIONS

Table E-1

HYDROLOGIC-HYDRAULIC SUMMARY—KINNICKINNIC RIVER EXISTING LAND USE AND COMMITTED CHANNEL CONDITIONS[a]

Structure Identification and Selected Characteristics					10-Year Recurrence Interval Flood			50-Year Recurrence Interval Flood			100-Year Recurrence Interval Flood		
Number	Name	River Mile	Structure Type and Hydraulic Significance[b]	Date of Construction or Major Reconstruction	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)
60	Chicago & Northwestern Railway	0.84	1S	–	4,100	582.5	582.5	5,900	583.5	583.5	6,800	583.8	583.8
65	Kinnickinnic Avenue (STH 32)	1.28	1S	1907	4,100	582.5	582.5	5,900	583.5	583.5	6,800	583.8	583.8
70	Chicago, Milwaukee, St. Paul & Pacific Railroad	1.31	1S	–	4,100	582.5	582.5	5,900	583.5	583.5	6,800	583.8	583.8
75	Chicago & Northwestern Railway	1.35	1S	–	4,100	582.5	582.5	5,900	583.5	583.5	6,800	583.8	583.8
80	S. 1st Street	1.43	1S	1955	3,850	582.5	582.5	5,500	583.5	583.5	6,300	583.8	583.8
85	Becher Street	1.67	1S	1966	3,850	582.5	582.5	5,500	583.5	583.5	6,300	583.8	583.8
90	Lincoln Avenue	1.96	1S	1928	3,850	582.5	582.5	5,500	583.5	583.5	6,300	583.8	583.8
95	S. 1st Street	2.01	1S	1952	3,850	582.5	582.5	5,500	583.5	583.5	6,300	583.8	583.8
100	Chase Avenue	2.40	1S	1931	3,850	586.2	582.5	5,500	588.5	583.5	6,300	589.3	583.8
105	IH 94	2.57	1I	–	3,850	–	–	5,500	–	–	6,300	–	–
110	Chicago, North Shore & Milwaukee Railroad (abandoned)	2.72	1S	–	3,850	–	–	5,500	N/A	N/A	6,300	N/A	–
120	S. 6th Street	2.81	1S	1953	3,050	–	–	4,600	–	–	5,200	–	–
125	S. 7th Street	2.88	1S	1901	3,050	–	–	4,600	–	–	5,200	–	–
130	S. 8th Street	2.95	1S	1907	3,050	–	–	4,600	–	–	5,200	–	–
131	Drop Structure	2.95	1S	N/A	3,050			4,600			5,200		
135	S. 9th Street	3.01	1S	1911	3,050	–	–	4,600	–	–	5,200	–	–
140	S. 9th Place	3.08	1S	1908	3,050	–	–	4,600	–	–	5,200	–	–
145	S. 10th Street	3.14	1S	1911	3,050	–	–	4,600	–	–	5,200	–	–
150	S. 11th Street	3.20	1S	1909	3,050	–	–	4,600	–	–	5,200	–	–
155	S. 12th Street	3.26	1S	1907	3,050	–	–	4,600	–	–	5,200	–	–
160	S. 13th Street	3.32	1S	1912	3,050	–	–	4,600	–	–	5,200	–	–
165	S. 14th Street	3.39	1S	1913	3,050	–	–	4,600	–	–	5,200	–	–
170	S. 15th Street	3.46	1S	1913	3,050	–	–	4,600	–	–	5,200	–	–
175	S. 15th Place	3.52	1S	1920	3,050	–	–	4,600	–	–	5,200	–	–
180	S. 16th Street	3.58	1S	1926	3,050	–	–	4,600	–	–	5,200	–	–
185	Pedestrian Bridge	3.65	1S	–	3,050	612.5	610.2	4,300	614.0	611.7	4,850	616.6	611.9
190	Cleveland Avenue	3.79	1S	1918	3,050	616.7	613.8	4,300	618.6	615.2	4,850	619.2	616.2
200	Chicago & Northwestern Railway	3.94	1S	–	3,050	616.9	616.9	4,300	619.3	618.8	4,850	620.2	619.4
205	Railroad Spur	3.96	1S	–	3,050	618.8	616.9	4,300	621.3	619.3	4,850	622.4	620.2
210	Drop Structure	3.991	1S	–	3,050	618.1	618.8	4,300	620.9	621.3	4,850	622.0	622.4
215	S. 20th Street	4.32	1S	1934	3,050	627.0	624.1	4,300	629.4	625.4	4,850	630.4	625.9
220	Chicago & Northwestern Railway Spur	4.44	1S	–	3,050	627.6	627.0	4,300	630.1	629.4	4,850	631.3	630.4
225	S. 27th Street (U.S.H 41)	4.91	1S	1962	3,050	629.0	628.7	4,300	631.0	630.7	4,850	632.0	631.7
230	S. 29th Street	5.03	1S	1961	3,050	629.8	629.4	4,300	631.5	631.2	4,850	632.5	632.2
232	Drop Structure	5.12	3S	–	3,050	631.5	630.1	4,300	632.7	631.8	4,850	633.2	632.6
235	Kinnickinnic River Parkway	5.14	1S	–	3,050	632.0	631.5	4,300	633.3	632.7	4,850	633.9	633.2
240	Pedestrian Bridge	5.21	1S	–	1,600	632.3	632.1	2,250	633.6	633.4	2,550	634.2	634.0
245	S. 35th Street	5.45	1S	1961	1,600	633.6	633.1	2,250	634.4	634.3	2,550	635.0	634.8
250	W. Forest Home Avenue	5.71	1S	1930	1,350	636.5	634.8	1,850	637.9	635.6	2,050	638.4	636.0
255	Jackson Park Drive	5.87	1S	–	1,350	637.3	636.6	1,850	638.7	638.0	2,050	639.2	638.5
260	Jackson Park Tunnel Outlet Structure	6.01	4S	–	1,350	–	637.4	1,850	–	638.8	2,050	–	639.4
265	Jackson Park Tunnel Inlet Structure	6.14	4S	–	1,350	637.6	–	1,850	639.0	–	2,050	641.4	–
270	Drop Structure	6.271	3S	–	790	644.9	638.6	1,050	644.6	640.0	1,200	644.6	641.9
275	Park Pedestrian Bridge	6.44	1I	–	790	N/A	–	1,050	–	–	1,200	–	–
280	S. 43rd Street	6.51	1S	–	790	649.3	647.5	1,050	649.9	648.0	1,200	650.1	648.2
285	Park Pedestrian Bridge	7.16	1I	–	790	–	–	1,050	–	–	1,200	–	–
290	S. 60th Street Outfall	8.05	4I	–	790	–	–	1,050	–	–	1,200	–	–

NOTE: N/A indicates data not available.

[a] Committed channel modifications along the reach of the Kinnickinnic River from River Mile 2.70 to 3.58 are assumed completed. These modifications are to consist of the following: removal with replacement of four bridges (S. 6th Street, S. 9th Place, S. 13th Street, and S. 16th Street); removal without replacement of the remaining 10 bridges in this reach; channel reconstruction, including removal of the abandoned Chicago, North Shore & Milwaukee Railroad culvert and channel realignment from S. 5th Street extended (River Mile 2.70) to S. 6th Street (River Mile 2.81); removal of channel restrictions in the vicinity of S. 12th Street and S. 8th Street; and dike and floodwall construction as necessary along the channel to provide *two feet of free board.*

[b] Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir; 3—drop structure or natural channel drop; 4—fords, outfalls, or inlet or outlet structures. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.

Source: SEWRPC

Table E-2

HYDROLOGIC-HYDRAULIC SUMMARY—WILSON PARK CREEK EXISTING LAND USE AND COMMITTED CHANNEL CONDITIONS[a]

Structure Identification and Selected Characteristics					10-Year Recurrence Interval Flood			50-Year Recurrence Interval Flood			100-Year Recurrence Interval Flood		
Number	Name	River Mile	Structure Type and Hydraulic Significance[b]	Date of Construction or Major Reconstruction	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)
400	Outlet Control Sill	0.00	2S	N/A	1,800	–	–	2,450	–	–	2,750	–	–
404	W. Oklahoma Avenue Tunnel Outlet	0.05	4S	N/A	1,800	N/A	633.9	2,450	–	634.7	2,750	–	635.0
406	W. Euclid Avenue Tunnel Inlet	0.32	4S	N/A	1,800	638.8	N/A	2,450	639.7	–	2,750	640.0	–
412	W. Lakefield Drive	0.49	1S	1952	1,800	641.0	640.7	2,450	642.8	642.1	2,750	643.6	642.7
416	W. Morgan Avenue Tunnel Outlet	0.68	4S	1954	1,600	–	642.6	2,200	–	644.0	2,450	–	644.6
418	S. 27th Street Tunnel Inlet	0.87	4S	1954	1,600	645.6	–	2,200	647.7	N/A	2,450	648.5	–
420	Howard Avenue	1.30	1S	1956	1,600	646.2	646.2	2,200	648.0	648.0	2,450	648.9	648.8
428	S. 20th Street	1.70	1S	1958	1,600	649.6	648.6	2,200	651.0	649.8	2,450	651.5	650.3
432	Pedestrian Bridge	1.83	1I	–	1,600	–	–	2,200	–	–	2,450	–	–
436	S. 13th Street	2.42	1S	1960	1,250	650.8	650.8	1,700	652.1	652.0	1,900	652.6	652.5
438	IH 94	2.50	1I	N/A	1,250	–	–	1,700	–	–	1,900	–	–
440	Chicago Milwaukee St. Paul & Pacific Railroad	2.57	1S	N/A	1,250	651.5	651.1	1,700	652.6	652.2	1,900	653.0	652.8
444	S. 6th Street	3.03	1S	1960	1,250	656.3	654.6	1,700	657.2	655.3	1,900	657.6	655.6
448	S. 5th Street	3.18	1S	1962	1,250	659.5	658.6	1,700	660.9	659.7	1,900	661.5	660.1
452	Layton Avenue Tunnel Outlet	3.51	4S	N/A	460	–	660.2	550	N/A	661.6	590	–	662.1
454	Howell Avenue Tunnel Inlet	3.65	4S	N/A	460	660.7	–	550	662.0	–	590	662.5	–
455	Airport Tunnel Outlet	3.86	4S	N/A	460	–	660.7	550	N/A	662.0	590	N/A	662.5
456	Airport Tunnel Inlet	4.76	4S	N/A	200	661.2	–	285	662.5	–	320	663.0	–
457	Airport Service Road	4.96	1S	N/A	200	662.9	662.8	285	663.4	663.3	320	663.7	663.6
457A	Drop Structure	5.28	3S	N/A	200	664.6	663.6	285	664.9	664.1	320	665.1	664.0
458	Chicago & Northwestern Railway	5.34	1S	N/A	255	668.4	667.0	360	669.8	667.7	410	670.1	667.9
460	Utility Lane	5.36	1S	N/A	255	669.1	668.4	360	670.4	669.8	410	670.8	670.1
464	Pennsylvania Avenue	5.54	1S	N/A	260	671.6	670.9	365	672.8	671.6	415	673.4	671.8
468	Frontage Road	5.98	1S	N/A	270	677.1	676.8	380	677.6	677.3	420	677.8	677.6
472	Nicholson Avenue	5.99	1S	N/A	270	677.0	677.0	380	677.6	677.6	420	677.8	677.8
476	Whitnall Avenue	6.12	1S	N/A	270	682.2	680.5	380	682.4	680.8	420	682.4	681.0

NOTE: N/A indicates data not available.

[a] *Committee channel modifications along the reach of the Kinnickinnic River from River Mile 2.70 to 3.58 are assumed completed. These modifications are to consist of the following: removal with replacement of four bridges (S. 6th Street, S. 9th Place, S. 13th Street and S. 16th Street); removal without replacement of the remaining 10 bridges in this reach; channel reconstruction, including removal of the Old North-South Railroad culvert and channel realignment from S. 5th Street extended (River Mile 2.70) to S. 6th Street (River Mile 2.81); removal of channel restriction in the vicinity of S. 12th Street and S. 8th Street; and dike and floodwall construction as necessary along the channel to provide two feet of free board.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir; 3—drop structure or natural channel drop; 4—fords, outfalls, or inlet or outlet structures. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.*

Source: SEWRPC.

Table E-3

HYDROLOGIC-HYDRAULIC SUMMARY—LYONS PARK CREEK EXISTING LAND USE AND COMMITTED 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	Structure Type and Hydraulic Significance[a]	Date of Construction or Major Reconstruction	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)
300	Drop Structure	0.04	3S	N/A	670	686.7	686.4	980	687.5	687.4	1,150	687.9	687.8
303	Parking Lot Tunnel Outlet	0.06	4S	N/A	670	—	686.7	980	N/A	687.5	1,150	—	687.9
305	W. Cleveland Avenue Tunnel Inlet	0.12	4S	N/A	670	692.3	—	980	693.1	—	1,150	695.0	—
310	Drop Structure	0.12	3S	N/A	670	692.3	—	980	693.1	—	1,150	695.0	—
315	Pedestrian Bridge	0.20	1I	N/A	670	—	—	980	—	—	1,150	—	—
320	Drop Structure	0.27	3S	N/A	670	696.2	695.8	980	697.2	696.8	1,150	697.6	697.3
325	Drop Structure	0.31	3S	N/A	670	698.7	697.0	980	699.8	697.9	1,150	700.2	698.3
330	W. Stack Drive	0.36	1S	N/A	670	701.9	699.8	980	704.8	700.9	1,150	704.9	701.4
335	Drop Structure	0.37	3S	N/A	670	703.1	701.9	980	703.9	704.8	1,150	704.9	704.9
340	Drop Structure	0.42	3S	N/A	670	705.3	704.0	980	706.2	704.8	1,150	706.6	705.1
345	Drop Structure	0.50	3S	N/A	670	709.2	707.0	980	710.2	707.8	1,150	710.5	708.2
350	W. Bennett Avenue Tunnel Outlet	0.54	4S	N/A	670	—	709.9	980	—	710.8	1,150	—	711.2
—	Oklahoma Avenue	0.61	N/A	N/A	670	—	—	980	—	—	1,150	N/A	—
355	W. Lakefield Drive Extension Tunnel Inlet	0.70	4S	N/A	670	720.5	—	980	721.2	—	1,150	724.3	—
360	Drop Structure	0.70	3S	N/A	670	720.5	—	980	721.2	—	1,150	724.3	—
365	Drop Structure	0.80	3S	N/A	670	722.3	722.4	980	723.1	723.2	1,150	724.4	724.4
370	S. 57th Street Culvert	0.84	1S	N/A	670	725.9	722.9	980	728.1	723.7	1,150	727.5	724.0
375	Pedestrian Bridge	0.89	1I	N/A	670	—	—	980	—	—	1,150	—	—
380	Pedestrian Bridge	0.97	1I	N/A	670	—	—	980	—	—	1,150	—	—
385	Pedestrian Bridge	1.07	1I	N/A	670	—	—	980	—	—	1,150	—	—
390	S. 55th St. Culvert	1.17	1S	N/A	670	738.8	733.8	980	739.0	734.6	1,150	739.1	734.8
395	W. Forest Home Avenue Culvert Outlet	1.31	4I	N/A	475	—	N/A	640	—	—	710	—	—

NOTE: N/A indicates data not available.

[a] Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir; 3—drop structure or natural channel drop; 4—fords, outfalls, or inlet or outlet structures. Hydraulically significant structures are denoted by an S; hydraulically insignificant structures are denoted by an I.

Source: SEWRPC

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Appendix F

HYDROLOGIC-HYDRAULIC SUMMARY FOR YEAR 2000 PLAN LAND USE AND PLANNED CHANNEL CONDITIONS

Table F-1

HYDROLOGIC-HYDRAULIC SUMMARY—KINNICKINNIC RIVER YEAR 2000 PLAN LAND USE AND PLANNED CHANNEL CONDITIONS[a]

Structure Identification and Selected Characteristics							10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile	Structure Type and Hydraulic Significance[b]	Date of Construction or Major Reconstruction	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Backwater[d] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Backwater[d] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Backwater[d] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth at Road at Centerline of Bridge (feet)
60	Chicago & North Western Railway	0.84	1S	N/A	100	Yes	4,550	582.5	582.5	0.0	-6.6	-9.1	6,500	583.5	583.5	0.0	-5.6	-8.1	7,400	583.8	583.8	0.0	-5.3	-7.8
65	Kinnickinnic Avenue (STH 32)	1.28	1S	1907	50	Yes	4,550	582.5	582.5	0.0	-4.5	-10.5	6,500	583.5	583.5	0.0	-3.5	-9.5	7,400	583.8	583.8	0.0	-3.2	-9.2
70	Chicago, Milwaukee, St. Paul & Pacific Railroad	1.31	1S	N/A	100	Yes	4,550	582.5	582.5	0.0	-22.7	-22.7	6,500	583.5	583.5	0.0	-21.7	-21.7	7,400	583.8	583.8	0.0	-21.4	-21.4
75	Chicago & North Western Railway	1.35	1S	N/A	100	Yes	4,550	582.5	582.5	0.0	-19.4	-20.8	6,500	583.5	583.5	0.0	-18.4	-19.8	7,400	583.8	583.8	0.0	-18.1	-19.5
80	S. First Street	1.43	1S	1955	10	Yes	4,350	582.5	582.5	0.0	-3.9	-14.3	6,200	583.5	582.5	0.0	-2.9	-13.3	7,000	583.8	583.8	0.0	-2.6	-13.0
85	Becher Street	1.67	1S	1966	10	Yes	4,350	582.5	582.5	0.0	-3.4	-11.4	6,200	583.5	583.5	0.0	-2.4	-10.4	7,000	583.8	583.8	0.0	-2.1	-10.4
90	Lincoln Avenue	1.96	1S	1928	50	Yes	4,350	582.5	582.5	0.0	-5.5	-11.0	6,200	583.5	583.5	0.0	-4.5	-10.0	7,000	583.8	583.8	0.0	-4.2	-9.7
95	S. First Street	2.01	1S	1952	10	Yes	4,350	582.5	582.5	0.0	-5.5	-11.3	6,200	583.5	583.5	0.0	-4.5	-10.3	7,000	583.8	583.8	0.0	-4.2	-9.0
100	Chase Avenue	2.40	1S	1931	50	No	4,350	587.1	582.5	3.4	-2.1	-3.5	6,200	589.2	584.1	4.8	0.0	-1.5	7,000	589.9	584.9	4.8	+0.2	-1.3
105	IH 94	2.57	1I		100	–	4,350	–	–	–	–	–	6,200	–	–	–	–	–	7,000	–	–	–	–	–
110	Chicago, North Shore & Milwaukee Railroad (abandoned)	2.72	1S	N/A	100	–	3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
120	S. 6th Street	2.81	1S	1953	50		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
125	S. 7th Street	2.88	1S	1901	10	–	3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
130	S. 8th Street	2.95	1S	1907	10		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
131	Drop Structure	2.95	3S	N/A	–		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
135	S. 9th Street	3.01	1S	1911	10		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
140	S. 9th Place	3.08	1S	1908	10		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
145	S. 10th Street	3.14	1S	1911	10		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
150	S. 11th Street	3.20	1S	1909	10		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
155	S. 12th Street	3.26	1S	1907	10		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
160	S. 13th Street	3.32	1S	1912	50		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
165	S. 14th Street	3.39	1S	1913	10		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
170	S. 15th Street	3.46	1S	1913	10		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
175	S. 15th Place	3.52	1S	1920	10		3,750	–	–	–	–	–	5,300	–	–	–	–	–	6,000	–	–	–	–	–
180	S. 16th Street	3.58	1S	1926	50		3,550	–	–	–	–	–	5,000	–	–	–	–	–	5,700	–	–	–	–	–
185	Pedestrian Bridge	3.65	1S	N/A	–	–	3,550	613.1	611.4	0.0	-2.5	-5.8	5,000	616.6	614.4	0.0	-1.8	-5.1	5,700	616.4	616.4	0.0	-0.7	-4.0
190	Cleveland Avenue	3.79	1S	1918	50	Yes	3,550	617.5	614.4	0.0	-19.9	-19.9	5,000	619.4	616.2	0.0	-19.0	-19.0	5,700	620.4	616.6	0.0	-18.1	-18.1
200	Chicago & North Western Railway	3.94	1S	N/A	100	Yes	3,550	617.7	617.7	1.1	-4.0	-4.0	5,000	620.5	619.6	1.3	-2.0	-2.0	5,700	621.7	620.6	1.7	-1.0	-1.0
205	Railroad Spur	3.96	1S	N/A	100	Yes	3,550	619.7	617.7	0.0	-6.7	6.7	5,000	622.7	620.5	0.0	-4.2	-4.2	5,700	624.2	621.7	0.0	-2.5	-2.5
210	Drop Structure	3.995	3S	N/A	–	–	3,550	619.2	619.8	–	–	–	5,000	622.3	622.7	–	–	–	5,700	623.8	624.2	–	–	–
215	S. 20th Street	4.32	1S	1934	10	Yes	3,550	628.0	624.6	2.9	-15.1	-15.1	5,000	630.8	626.0	4.1	-13.3	-13.3	5,700	632.9	626.7	5.2	-11.3	-11.3
220	Chicago & North Western Railway Spur	4.44	1S	N/A	100	Yes	3,550	628.6	628.0	0.6	-6.1	-6.1	5,000	631.7	630.9	0.7	-3.2	-3.2	5,700	633.8	633.1	0.7	-0.9	-0.9
225	S. 27th Street (U.S. H 41)	4.91	1S	1962	50	Yes	3,550	629.8	629.4	0.3	-11.6	-13.2	5,000	632.4	632.1	0.2	-9.0	-10.6	5,700	634.2	633.9	0.1	-7.3	-8.9
230	S. 29th Street	5.03	1S	1961	10	Yes	3,550	630.4	630.1	0.3	-9.6	-10.0	5,000	632.8	632.6	0.1	-7.1	-7.5	5,700	634.49	634.28	0.1	-5.4	-5.8
232	Drop Structure	5.12	3S	N/A	–	–	3,550	630.4	630.7	–	–	–	5,000	632.7	633.0	–	–	–	5,700	634.4	634.6	–	–	–
235	Kinnickinnic River Parkway	5.14	1S	N/A	10	Yes	3,550	632.8	630.4	2.0	-7.2	-7.8	5,000	634.3	632.7	1.2	-5.5	-6.1	5,700	635.5	634.4	0.9	-4.0	-4.6
240	Pedestrian Bridge	5.21	1S	N/A	–	–	1,600	633.0	632.8	0.2	-9.2	-9.2	2,250	634.5	634.4	0.0	-7.8	-7.8	2,550	635.7	635.6	0.0	-6.5	-6.5
245	S. 35th Street	5.45	1S	1961	50	Yes	1,600	633.7	633.5	0.0	-9.8	-9.8	2,250	635.0	634.8	0.0	-8.5	-8.5	2,550	636.0	635.9	0.1	-7.4	-7.4
250	W. Forest Home Avenue	5.71	1S	1930	50	Yes	1,600	636.5	634.8	1.5	-12.8	-12.8	2,250	637.9	635.8	2.0	-10.8	-10.8	2,550	638.4	636.6	1.7	-9.8	-9.8
255	Jackson Park Drive	5.87	1S	N/A	10	Yes	1,600	637.3	636.6	0.7	-5.4	-7.9	2,250	638.7	638.0	0.7	-4.0	-6.4	2,550	639.2	638.5	0.6	-3.4	-5.8
260	Jackson Park Tunnel Outlet Structure	6.01	4S	N/A	–	–	1,600	–	637.4	–	–	–	2,250	–	638.8	–	–	–	2,550	–	639.4	–	–	–
265	Jackson Park Tunnel Inlet Structure	6.14	4S	N/A	–	–	1,600	637.6	–	–	–	–	2,250	639.0	–	–	–	–	2,550	641.4	–	–	–	–
270	Drop Structure	6.271	3S	N/A	–	–	1,600	644.4	638.6	–	–	–	2.250	644.6	640.0	–	–	–	2,550	644.6	641.9	–	–	–
275	Park Pedestrian Bridge	6.44	1I	N/A	–	–	1,600	–	–	–	–	–	2,250	–	–	–	–	–	2,550	–	–	–	–	–
280	S. 43rd Street	6.51	1S	N/A	50	No	790	649.3	647.5	1.6	0.0	-2.8	1,100	649.9	648.0	1.9	0.2	-2.6	1,200	650.1	648.2	1.9	0.3	-2.5
285	Park Pedestrian Bridge	7.16	1I	N/A	–	–	790	–	–	–	–	–	1,100	–	–	–	–	–	1,200	–	–	–	–	–
290	S. 60th Street Outfall	8.05	4I	N/A	–	–	790	–	–	–	–	–	1,100	–	–	–	–	–	1,200	–	–	–	–	–

NOTE: N/A indicates data not available.

[a] *Committed channel modifications along the reach of Wilson Park Creek from W. Euclid Avenue (River Mile 0.32) to S. 6th Street (River Mile 3.03) are assumed completed. These modifications are to consist of lowering the streambed profile from 2.5 to 6 feet, forming trapezoidal section with an average bottom width of about 20 feet, and lining the channel bottom and the bottom portion of the sidewalls with concrete.*

[b] *Structure codes are as follows: 1–bridge or culvert; 2–dam, sill, or weir; 3–drop structure or natural channel drop; 4–fords, outfalls, or inlet or outlet structures. 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 deck is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *Backwater is defined as the maximum increase in stage on the upstream side of a bridge or culvert above that which would occur in the absence of a bridge or culvert. Backwater was determined by extending the flood stage profile on the downstream side of the bridge or culvert upstream through the structure and subtracting the resulting elevation on the upstream side of the structure from the upstream flood stage profile commensurate with the presence of the structure.*

Source: SEWRPC

Table F-2

HYDROLOGIC-HYDRAULIC SUMMARY—WILSON PARK CREEK YEAR 2000 PLAN LAND USE AND PLANNED CHANNEL CONDITIONS[a]

Structure Identification and Selected Characteristics							10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile	Structure Type and Hydraulic Significance[b]	Date of Construction or Major Reconstruction	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Backwater[d] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Backwater[d] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Backwater[d] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth at Road at Centerline of Bridge (feet)
400	Outlet Control Sill	0.00	2S	N/A	–	–	2,200	–	–	–	–	–	2,850	–	–	–	–	–	3,100	–	–	–	–	–
404	W. Oklahoma Avenue Tunnel Outlet	0.05	4S	N/A	–	–	2,200	–	634.2	–	–	–	2,850	–	634.8	–	–	–	3,100	–	–	–	–	–
406	W. Euclid Avenue Tunnel Inlet	0.32	4S	N/A	–	–	2,200	639.1	–	–	–	–	2,850	640.1	–	–	–	–	3,100	640.6	–	–	–	–
412	W. Lakefield Drive	0.49	1S	1952	10	Yes	2,200	642.0	641.6	0.3	-6.8	-7.8	2,850	643.8	642.9	0.8	-5.2	-6.3	3,100	644.9	643.3	1.4	-4.5	-5.5
416	W. Morgan Avenue Tunnel Outlet	0.68	4S	1954	–	–	2,000	–	643.4	–	–	–	2,750	–	644.6	–	–	–	3,100	–	645.3	–	–	–
418	S. 27th Street Tunnel Inlet	0.87	4S	1954	–	–	2,000	647.0	–	–	–	–	2,750	647.6	–	–	–	–	3,100	649.0	–	–	–	–
420	Howard Avenue	1.30	1S	1956	50	Yes	2,000	647.4	647.4	0.1	-7.4	-7.8	2,750	648.6	648.1	0.4	-6.8	-7.2	3,100	650.0	649.3	0.6	-5.3	-5.7
428	S. 20th Street	1.70	1S	1958	10	Yes	2,000	650.5	649.4	0.8	-6.2	-8.0	2,750	651.9	650.6	1.4	-5.3	-7.1	3,100	652.7	651.2	1.4	-4.2	-6.0
432	Pedestrian Bridge	1.83	1I	N/A	–	–	2,000	–	–	–	–	–	2,750	–	–	–	–	–	3,100	–	–	–	–	–
436	S. 13th Street	2.42	1S	1960	50	Yes	1,650	651.7	651.6	0.0	-8.5	-8.5	2,300	653.2	653.0	0.4	-7.5	-7.5	2,600	653.9	653.6	0.2	-6.5	-6.5
438	IH 94	2.50	1I	N/A	100	–	1,650	–	–	–	–	–	2,300	–	–	–	–	–	2,600	–	–	–	–	–
440	Chicago, Milwaukee, St. Paul & Pacific Railroad	2.57	1S		100	Yes	1,650	652.3	651.9	0.4	-17.0	-17.0	2,300	653.6	653.3	0.4	-15.9	-15.9	2,600	654.2	654.0	0.3	-15.0	-15.0
444	S. 6th Street	3.03	1S	1960	10	Yes	1,650	657.2	655.3	1.6	-7.2	-7.8	2,300	658.3	656.2	1.8	-6.4	-7.0	2,600	658.8	656.6	1.8	-5.3	-5.9
448	S. 5th Street	3.18	1S	1962	10	Yes	1,650	660.8	659.8	1.0	-3.1	-3.1	2,300	662.6	660.8	1.5	-2.3	-2.3	2,600	663.6	661.3	2.1	-1.3	-1.3
452	Layton Avenue Tunnel Outlet	3.51	4S	N/A	–	–	580	–	661.4	–	–	–	750	–	663.2	–	–	–	830	–	664.1	–	–	–
454	Howell Avenue Tunnel Inlet	3.65	4S	N/A	–	–	580	661.8	–	–	–	–	750	663.6	–	–	–	–	830	664.6	–	–	–	–
455	Airport Tunnel Outlet	3.86	4S	N/A	–	–	580	–	661.9	–	–	–	750	–	663.8	–	–	–	830	–	664.7	–	–	–
456	Airport Tunnel Inlet	4.76	4S	N/A	–	–	400	662.7	–	–	–	–	550	664.5	–	–	–	-10.0	620	665.3	–	–	–	-9.3
457	Airport Service Road	4.96	1S	N/A	–	–	400	664.0	663.8	0.0	-6.4	-8.6	550	665.0	664.9	0.0	-5.5	-7.7	620	665.7	665.6	0.0	-3.7	-5.9
457A	Drop Structure	5.28	3S	N/A	–	–	400	–	–	–	–	–	550	–	–	–	–	–	620	–	–	–	–	–
458	Chicago & Northwestern Railway	5.34	1S	N/A	100	Yes	400	–	–	–	–	–	550	–	–	–	–	–	620	–	–	0.5	-19.4	-19.4
460	Utility Lane	5.36	1S	N/A	–	–	400	–	–	–	–	–	550	–	–	–	–	–	620	–	–	–	–	–
464	Pennsylvania Avenue	5.54	1S	N/A	50	No	400	–	–	–	–	–	550	–	–	–	–	–	620	–	–	–	–	–
468	Frontage Road	5.98	1S	N/A	–	–	400	–	–	–	–	–	550	–	–	–	–	–	620	–	–	–	–	–
472	Nicholson Avenue	5.99	1S	N/A	10	No	400	–	–	–	–	–	550	–	–	–	–	–	620	–	–	–	–	–
476	Whitnall Avenue	6.12	1S	N/A	50	Yes	400	–	–	–	–	–	550	–	–	–	–	–	620	–	–	–	–	–

NOTE: N/A indicates data not available.

[a] *Committed channel modifications along the reach of Wilson Park Creek from W. Euclid Avenue (River Mile 0.32) to S. 6th Street (River Mile 3.03) are assumed completed. These modifications are to consist of lowering the streambed profile from 2.5 to 6 feet, forming a trapezoidal section with a average bottom width of about 20 feet, and lining the channel bottom and the bottom portion of the sidewalls with concrete. The recommended plan channel would consist of the enclosure of about 0.8 mile of Edgerton Channel from the existing airport channel (River Mile 5.28) through Whitnall Avenue (River Mile 6.12). The channel would be enclosed in a double reinforced concrete box culvert 10 feet wide and 6 feet deep from the airport channel to a point approximately 1,600 feet downstream of Nicholson Avenue (River Mile 5.66). From there a transition would be made to a single 10 by 6 foot box culvert extending upstream through Whitnall Avenue.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir; 3—drop structure or natural channel drop; 4—fords, outfalls, or inlet or outlet structures. 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 deck is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *Backwater is defined as the maximum increase in stage on the upstream side of a bridge or culvert above that which would occur in the absence of a bridge or culvert. Backwater was determined by extending the flood stage profile on the downstream side of the bridge or culvert upstream through the structure and subtracting the resulting elevation on the upstream side of the structure from the upstream flood stage profile commensurate with the presence of the structure.*

Source: SEWRPC

Table F-3

HYDROLOGIC-HYDRAULIC SUMMARY—LYONS PARK CREEK YEAR 2000 PLAN LAND USE AND PLANNED CHANNEL CONDITIONS[a]

Structure Identification and Selected Characteristics							10-Year Recurrence Interval Flood						50-Year Recurrence Interval Flood						100-Year Recurrence Interval Flood					
Number	Name	River Mile	Structure Type and Hydraulic Significance[b]	Date of Construction or Major Reconstruction	Recommended Design Frequency (years)	Adequate Hydraulic Capacity[c]	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Backwater[d] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Backwater[d] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth on Road at Centerline of Bridge (feet)	Instantaneous Peak Discharge (cfs)	Upstream Stage (feet above msl)	Downstream Stage (feet above msl)	Backwater[d] (feet)	Depth at Low Point in Bridge Approach Road (feet)	Depth at Road at Centerline of Bridge (feet)
300	Drop Structure	0.04	3S	N/A	–	–	670	686.7	686.4	0.0	–	–	980	687.5	687.4	0.0	–	–	1,150	687.9	687.8	0.0	–	–
303	Parking Lot Tunnel Outlet	0.06	4S	N/A	–	–	670	–	686.7	–	–	–	980	–	687.5	–	–	–	1,150	–	687.9	–	–	–
305	W. Cleveland Avenue Tunnel Inlet	0.12	4S	N/A	10	Yes	670	692.3	–	–	-5.6	-9.1	980	693.1	–	–	-4.0	-7.5	1,150	695.0	–	–	-4.0	-5.6
310	Drop Structure	0.12	3S	N/A	–	–	670	692.3	–	–	–	–	980	693.1	–	–	–	–	1,150	695.0	–	–	–	–
315	Pedestrian Bridge	0.20	1I	N/A	–	–	670	–	–	–	–	–	980	–	–	–	–	–	1,150	–	–	–	–	–
320	Drop Structure	0.27	3S	N/A	–	–	670	696.2	695.8	–	–	–	980	697.2	696.8	–	–	–	1,150	697.6	697.3	–	–	–
325	Drop Structure	0.31	3S	N/A	–	–	670	698.7	697.0	–	–	–	980	699.8	697.9	–	–	–	1,150	700.2	688.3	–	–	–
330	W. Stack Drive	0.36	1S	N/A	10	Yes	670	701.9	699.8	1.5	-3.1	-5.3	980	704.8	700.9	1.6	-1.6	-3.8	1,150	704.9	701.4	2.7	-1.5	-3.3
335	Drop Structure	0.37	3S	N/A	–	–	670	703.1	701.9	–	–	–	980	703.9	704.8	–	–	–	1,150	704.9	704.9	–	–	–
340	Drop Structure	0.42	3S	N/A	–	–	670	705.3	704.0	–	–	–	980	706.2	704.8	–	–	–	1,150	706.6	705.1	–	–	–
345	Drop Structure	0.50	3S	N/A	–	–	670	709.2	707.0	–	–	–	980	710.2	707.8	–	–	–	1,150	710.5	708.2	–	–	–
350	W. Bennett Avenue Tunnel Outlet	0.54	4S	N/A	10	Yes	670	–	709.9	–	-5.5	-6.1	980	–	710.8	–	-4.6	-5.2	1,150	–	711.2	–	-4.1	-4.7
–	Oklahoma Avenue	0.61	N/A	N/A	–	–	670	–	–	–	–	–	980	–	–	–	–	–	1,150	–	–	–	–	–
355	W. Lakefield Drive Extension Tunnel Inlet	0.70	4S	N/A	–	–	670	720.5	–	–	–	–	980	721.2	–	–	–	–	1,150	724.3	–	–	–	–
360	Drop Structure	0.70	3S	N/A	–	–	670	720.5	–	–	–	–	980	721.2	–	–	–	–	1,150	724.3	–	–	–	–
365	Drop Structure	0.80	3S	N/A	–	–	670	722.3	722.4	–	–	–	980	723.1	723.2	–	–	–	1,150	724.4	724.4	–	–	–
370	S. 57th Street Culvert	0.84	1S	N/A	10	Yes	670	725.9	722.9	0.8	-4.0	-5.2	980	728.1	723.7	1.4	-2.6	-3.8	1,150	727.5	724.0	0.2	-2.1	-3.3
375	Pedestrian Bridge	0.89	1I	N/A	–	–	670	–	–	–	–	–	980	–	–	–	–	–	1,150	–	–	–	–	–
380	Pedestrian Bridge	0.97	1I	N/A	–	–	670	–	–	–	–	–	980	–	–	–	–	–	1,150	–	–	–	–	–
385	Pedestrian Bridge	1.07	1I	N/A	–	–	670	–	–	–	–	–	980	–	–	–	–	–	1,150	–	–	–	–	–
390	S. 55th Street Culvert	1.17	1S	N/A	10	Yes	670	738.8	733.8	0.0	-2.0	-2.0	980	739.0	734.6	0.0	-1.2	-1.2	1,150	739.1	734.8	0.0	-1.0	-1.0
395	W. Forest Home Avenue Culvert Outlet	1.31	4I	N/A	–	–	475	–	N/A	–	–	–	640	–	–	–	–	–	710	–	–	–	–	–

NOTE: N/A indicates data not available.

[a] *Committed channel modifications along the reach of Wilson Park Creek from W. Euclid Avenue (River Mile 0.32) to S. 6th Street (River Mile 3.03) are assumed completed. These modifications are to consist of lowering the streambed profile from 2.5 to 6 feet, forming a trapezoidal section with a average bottom width of about 20 feet, and lining the channel bottom and the bottom portion of the sidewalls with concrete. The recommended plan channel would consist of the enclosure of about 0.8 mile of Edgerton Channel from the existing airport channel (River Mile 5.28) through Whitnall Avenue (River Mile 6.12). The channel would be enclosed in a double reinforced concrete box culvert 10 feet wide and 6 feet deep from the airport channel to a point approximately 1,600 feet downstream of Nicholson Avenue (River Mile 5.66). From there a transition would be made to a single 10 by 6 foot box culvert extending upstream through Whitnall Avenue.*

[b] *Structure codes are as follows: 1—bridge or culvert; 2—dam, sill, or weir; 3—drop structure or natural channel drop; 4—fords, outfalls, or inlet or outlet structures. 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 deck is overtopped by a flood having a recurrence interval equal to or less than the recommended design frequency.*

[d] *Backwater is defined as the maximum increase in stage on the upstream side of a bridge or culvert above that which would occur in the absence of a bridge or culvert. Backwater was determined by extending the flood stage profile on the downstream side of the bridge or culvert upstream through the structure and subtracting the resulting elevation on the upstream side of the structure from the upstream flood stage profile commensurate with the presence of the structure.*

Source: SEWRPC

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Appendix G

MODEL RESOLUTION FOR ADOPTION OF THE COMPREHENSIVE PLAN FOR THE KINNICKINNIC RIVER WATERSHED

WHEREAS, the Southeastern Wisconsin Regional Planning Commission, which was duly created by the Governor of the State of Wisconsin in accordance with Section 66.945(2) of the Wisconsin Statutes on the 8th day of August 1960, upon petition of the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha, has the function and duty of making and adopting a master plan for the physical development of the Region; and

WHEREAS, the Milwaukee County Board in late 1974 approved participation by the County for the development by the Southeastern Wisconsin Regional Planning Commission of a comprehensive plan for the Kinnickinnic River watershed leading to recommendations for the development of water-related community facilities in the watershed, including integrated proposals for water pollution abatement, flood control, land and water use, and park and public openspace reservation, to generally promote the orderly and economical development of the Kinnickinnic River watershed; and

WHEREAS, such plan has been completed and the Southeastern Wisconsin Regional Planning Commission did on the ____ day of ____________, 197__ approve a resolution adopting the comprehensive plan for the Kinnickinnic River watershed and has recommended such plan to the local units of government within the watershed; and

WHEREAS, such plan contains recommendations for land use development and regulation; environmental corridor land preservation; park and outdoor recreation land acquisition and development; channel modification and dike, floodwall, and detention reservoir construction; bridge replacement or modification; floodway and floodplain regulations; flood insurance and other nonstructural floodland management measures; streamflow recordation; pollution abatement facility construction; land management practices; and water quality monitoring and is, therefore, a desirable and workable water control and water-related community facility plan for the Kinnickinnic River watershed; and

WHEREAS, the aforementioned recommendations, including all studies, data, maps, figures, charts, and tables, are set forth in a published report entitled SEWRPC Planning Report No. 32, A Comprehensive Plan for the Kinnickinnic River Watershed, published in ________________ 1978; and ____________.

WHEREAS, the Commission has transmitted certified copies of its resolution adopting such comprehensive plan for the Kinnickinnic River watershed, together with the aforementioned SEWRPC Planning Report No. 32, to the local units of government; and

WHEREAS, the (Name of Local Governing Body) has supported, participated in the financing of, and generally concurred in the watershed and other regional planning programs undertaken by the Southeastern Wisconsin Regional Planning Commission and believes that the comprehensive plan for the Kinnickinnic River watershed prepared by the Commission is a valuable guide, not only to the development of the watershed but to the community, and that the adoption of such plan by the (Name of Local Governing Body) will assure a common understanding by the several governmental levels and agencies concerned and enable these levels and agencies of government to program the necessary areawide and local plan implementation work.

NOW, THEREFORE, BE IT RESOLVED that, pursuant to Section 66.945(12) of the Wisconsin Statutes, the (Name of Local Governing Body) on the ____ day of ____________, 19__, hereby adopts the comprehensive plan for the Kinnickinnic River watershed previously adopted by the Commission as set forth in SEWRPC Planning Report No. 32 as a guide for watershed and community development.

BE IT FURTHER HEREBY RESOLVED that the ________________ clerk transmit a certified copy of this resolution to the Southeastern Wisconsin Regional Planning Commission.

ATTESTATION:

____
(President, Mayor, or Chairman of the Local Governing Body)

____
(Clerk of Local Governing Body)